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DEPARTMENT OF HEALTH
NEW ZEALAND

ENVIRONMENTAL RADIOACTIVITY ANNUAL REPORT

1972

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

APRIL 1973

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), by pathologists, 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:

L.P. Gregory	Officer in Charge, Monitoring Operations, Radiochemistry, Editorial Work.
T. Baltakmens	Professional Officer, Radiochemistry.
J.E. Dobbs	Technical Officer, Gamma Spectroscopy.
M.A. Findlay(Mrs)	Technician.

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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C O N T E N T S

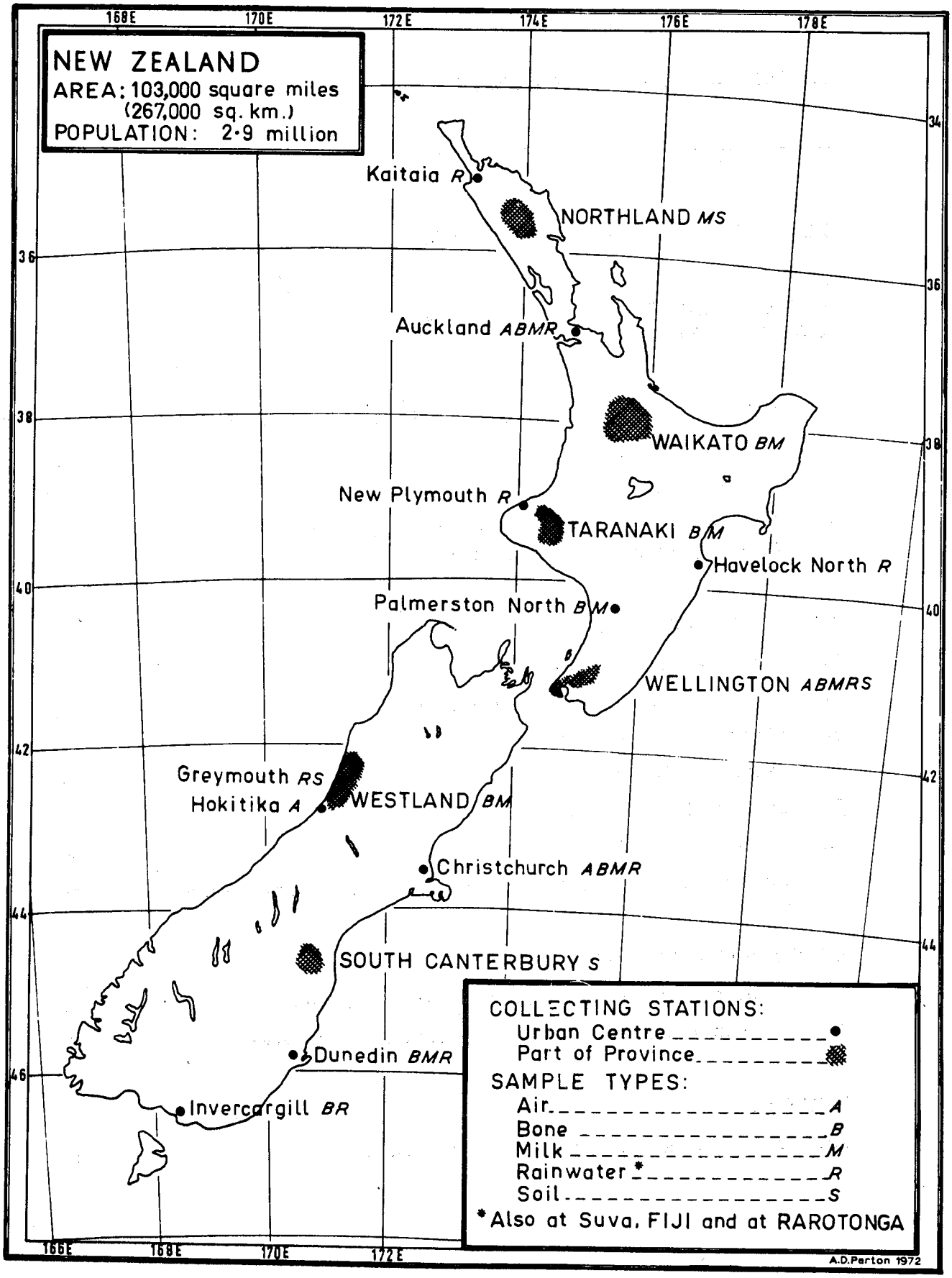

Fig. 1 COLLECTING STATIONS IN NEW ZEALAND

INTRODUCTION

This report continues the re-designed series of annual reports concerned mainly with long-term levels of environmental radioactivity in New Zealand and at Fiji and Rarotonga. The types of samples measured and the collecting stations are shown in Fig. 1. The present report should be read in conjunction with the 1971 annual report - the first of the new style reports - which summarised earlier reports, and discussed global fallout and specific radionuclides of potential health significance (1).

During June and July 1972 France conducted her sixth series of nuclear tests in the South Pacific. The results of the extended programme monitoring short-term levels of fallout from these tests were recently published and compared with levels monitored during earlier French test series (2).

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. Radioactive fallout in rain is expressed as:

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

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

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

2. 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.

   Radium-226 and lead-210 contamination in bone is given as:

   picocuries per gram of ash . . . . . pCi/g ash.

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

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(1) Environmental Radioactivity Annual Report 1971, Report No. NRL-F/48 June 1972.

(2) Fallout From Nuclear Weapons Tests Conducted by France in the South Pacific During June and July 1972, and Comparisons with Previous Test Series, Report No. NRL-F/49, October 1972.

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 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.

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	270 pCi/g Ca
	Caesium-137	7,000 pCi/g K
	Iodine-131*	200 pCi/litre
In Air:	Mixed fission products between 10 and 80 days old.	300 pCi/m^3
In Rainwater:	Mixed fission products between 10 and 80 days old.	6,000 pCi/litre

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 one 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, and would not, in itself, justify the disruptions and possible risks associated with remedial actions.

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

* Not a routine measurement (see NRL-F/49 for results of ^{131}I measurements during the special monitoring programmes).

Comparison of Reference Levels with Natural Radiation Background

It is also necessary to consider the possible hazards from continuing weapons tests. Under these conditions 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.

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.

SUMMARY STATEMENT ON THE LABORATORY'S LONG-TERM MONITORING RESULTS

During 1972 the levels of radioactive contamination were small percentages of the reference levels.

The stratospheric fallout of long-lived bomb test material such as strontium-90 reached a maximum in New Zealand in 1964 as a result of the large scale tests by the U.S.S.R. and U.S.A. in 1961 and 1962. Levels then decreased to a minimum in 1968, but increased slightly during the next three years as a result of the French tests in the South Pacific. During 1972 levels again decreased to the minimum value found in 1968. The average annual deposition over the past four years has been about one-third of the 1964 maximum.

Levels of strontium-90 and caesium-137 in milk reflect these changes. During the last few years these levels have been about one-half of the maximum levels recorded in 1965.

During the extended monitoring programme covering the 1972 French nuclear tests short-term fallout levels were extremely low at all stations comprising our monitoring network, and were barely detectable above normal fluctuations in radioactivity. It is therefore to be expected that any future contribution to long-term levels from the 1972 series will be negligible.

The long-term average levels since measurements commenced are also small percentages of the reference levels. It is therefore considered that the levels reported herein do not constitute a public health hazard.

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 fallout. Hereafter the term "total beta activity" refers only to this residual radioactivity due to fission products.

In the absence of fresh fission products in the atmosphere, the levels of total beta activity in air are usually less than 0.1 picocuries per cubic metre (typically about 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.

In Fig. 2 the 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 1971 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. This delay is apparent in Fig. 2.

During the 1972 French tests fresh fission products in air were occasionally present at extremely low levels, barely detectable above the residual level from previous tests. The results thus confirm unofficial statements by the news media of the very low power of three devices reported to have been detonated.

The monthly average levels shown in Fig. 2 have been averaged for each year since 1966, where possible, and are shown in TABLE 1.

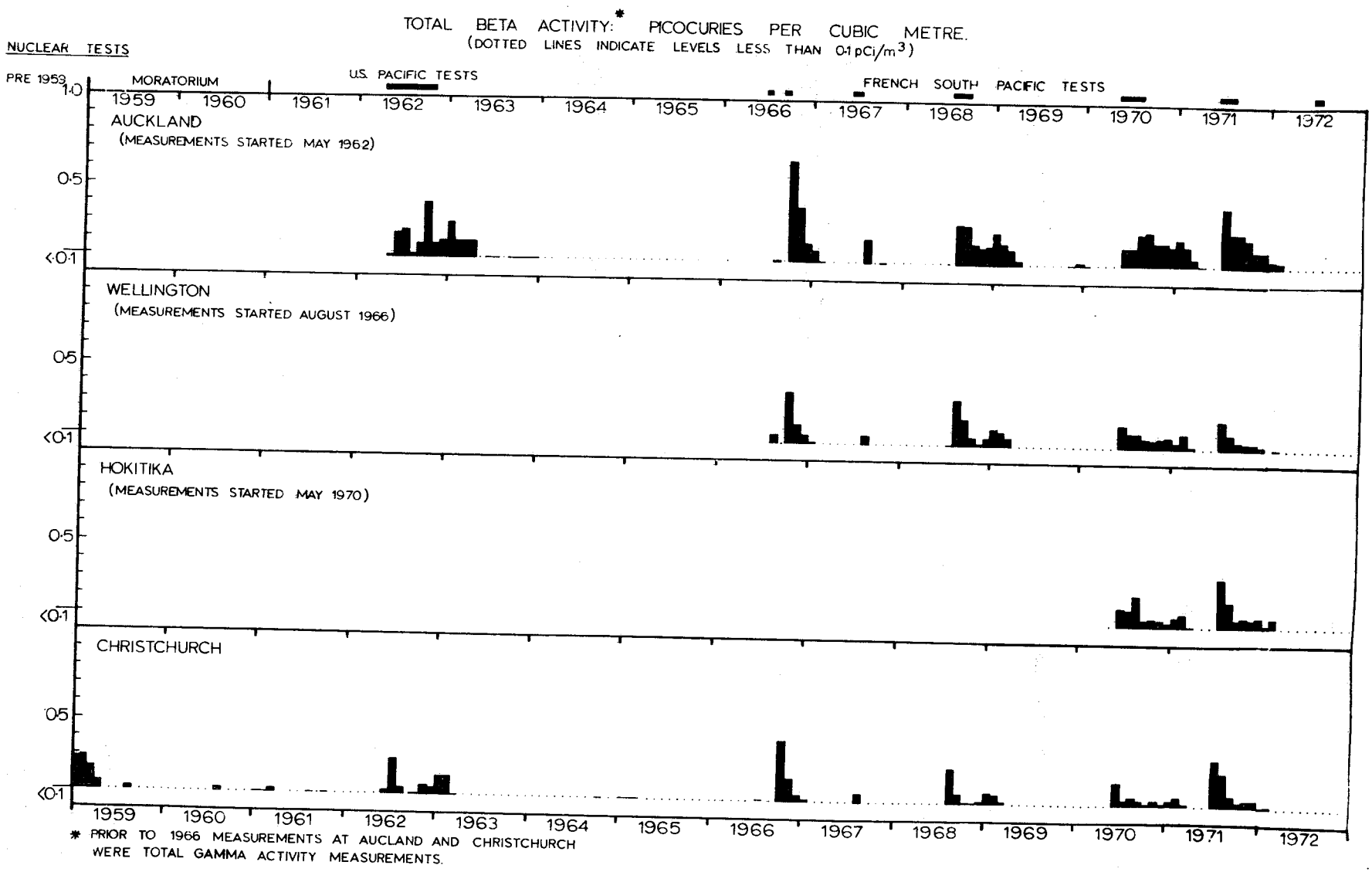
TABLE 1 TOTAL BETA ACTIVITY IN AIR - ANNUAL AVERAGES (pCi/m^3)

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

* Estimate

The results of measurements on individual air filter samples collected during 1972 are given in TABLE 7 APPENDIX. Filters were changed three times each week except during the special monitoring programme from July to September when they were changed daily. For that period the monthly

Fig. 2 FISSION PRODUCTS IN AIR - MONTHLY AVERAGES



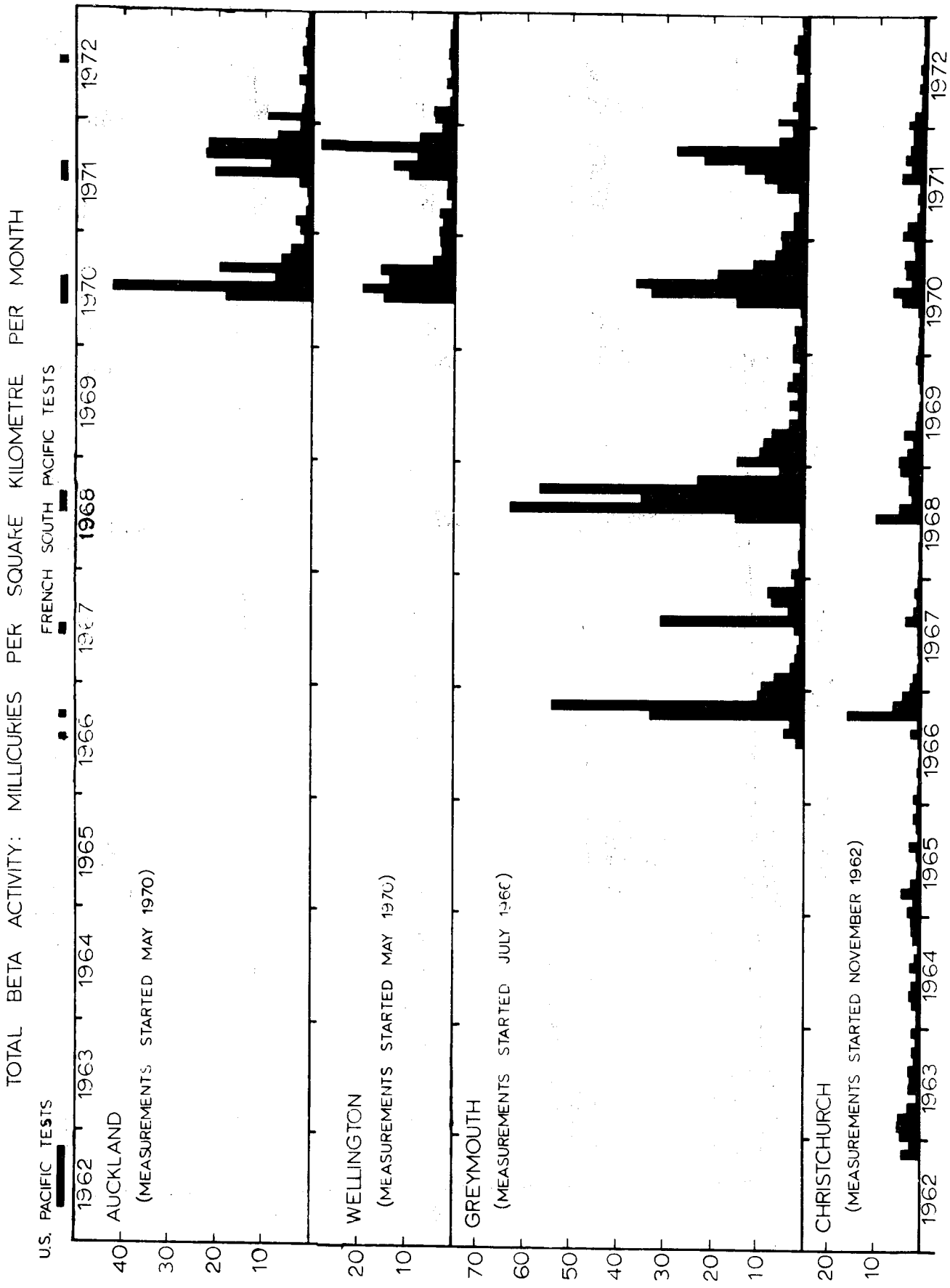


Fig. 3 FISSION PRODUCTS IN RAIN - MONTHLY DEPOSITION

averages only are given in TABLE 7, the individual daily results for the New Zealand stations and also for four Pacific Island stations were given in Report No. NRL-F/49 (2).

2. Fission Products in Rain

Increases in the levels of fission products in weekly rainwater samples have occurred concurrently with increases in air radioactivity. The weekly depositions, totalled for each month, are shown in Fig. 3. 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 results for individual collections during 1972 are given in TABLE 8 APPENDIX. During the special monitoring period, however, monthly totals only are given in the table. For that period the individual results, together with those from nine Pacific Island stations, have already been tabled and assessed for their associated gamma dose in Report No. NRL-F/49 (2).

TABLE 8 also gives the average concentration of fission products in rainwater during 1972. This assessment is useful when rainwater is considered to be the sole source of drinking water, because it allows comparison with the reference level which is based on continuous consumption. The average concentration during 1972 was less than 25 pCi/litre at all New Zealand stations.

3. General Statement on Levels of Total Beta Activity in Air and Rainwater

During 1972 levels of fission products in air and rainwater were the lowest since 1966 (including 1969 when no tests occurred) and were very small fractions of the Reference Levels.

SPECIFIC RADIONUCLIDES

1. Strontium-90 in Rain

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

Monthly strontium-90 deposits at individual stations during 1972 are given in TABLE 9 APPENDIX together with rainfall data and strontium-90 concentration in the rain. In Fig. 8 APPENDIX the monthly deposits are shown for each station since monitoring commenced.

The New Zealand country-wide average deposits are shown in Fig. 4 where they may be compared with average levels of strontium-90 in rain and milk (and caesium-137 in milk).

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 reaching a minimum in 1968.

Since 1966 smaller scale French nuclear tests have been 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 29 nuclear devices are reported to have been exploded in the atmosphere from these tests, most of them being in the low or medium power (kiloton) range. However, megaton explosions are reported to have occurred twice in 1968, and once each in 1970 and 1971. As a result of these South Pacific tests the annual rate of strontium-90 deposit over New Zealand increased during the period 1969 to 1971 and was about 50% higher than the minimum in 1968, although still only about one-third of the peak value in 1964.

During 1972 the annual deposit again fell to the minimum value which was recorded in 1968.

TABLE 2 lists the annual deposits at individual stations and the New Zealand country-wide average for each year since 1960. The annual deposits at Suva and Rarotonga are also shown in this table, and it is of interest to note that during the last six years the values at these islands have been generally similar to the New Zealand country-wide average value. It is also of interest 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 at Suva. This illustrates a significant characteristic of stratospheric fallout, namely that the tropics receive less global fallout than the mid-latitudes.

(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 3.

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(4) "Radioactive Fallout in Air and Rain, Results to the middle of 1972". United Kingdom Atomic Energy Authority, AERE-R 7245.

(5) "Fallout Program, Quarterly Summary Report, 1 April 1973". Health and Safety Laboratory, United States Atomic Energy Commission, HASL-273 APPENDIX.

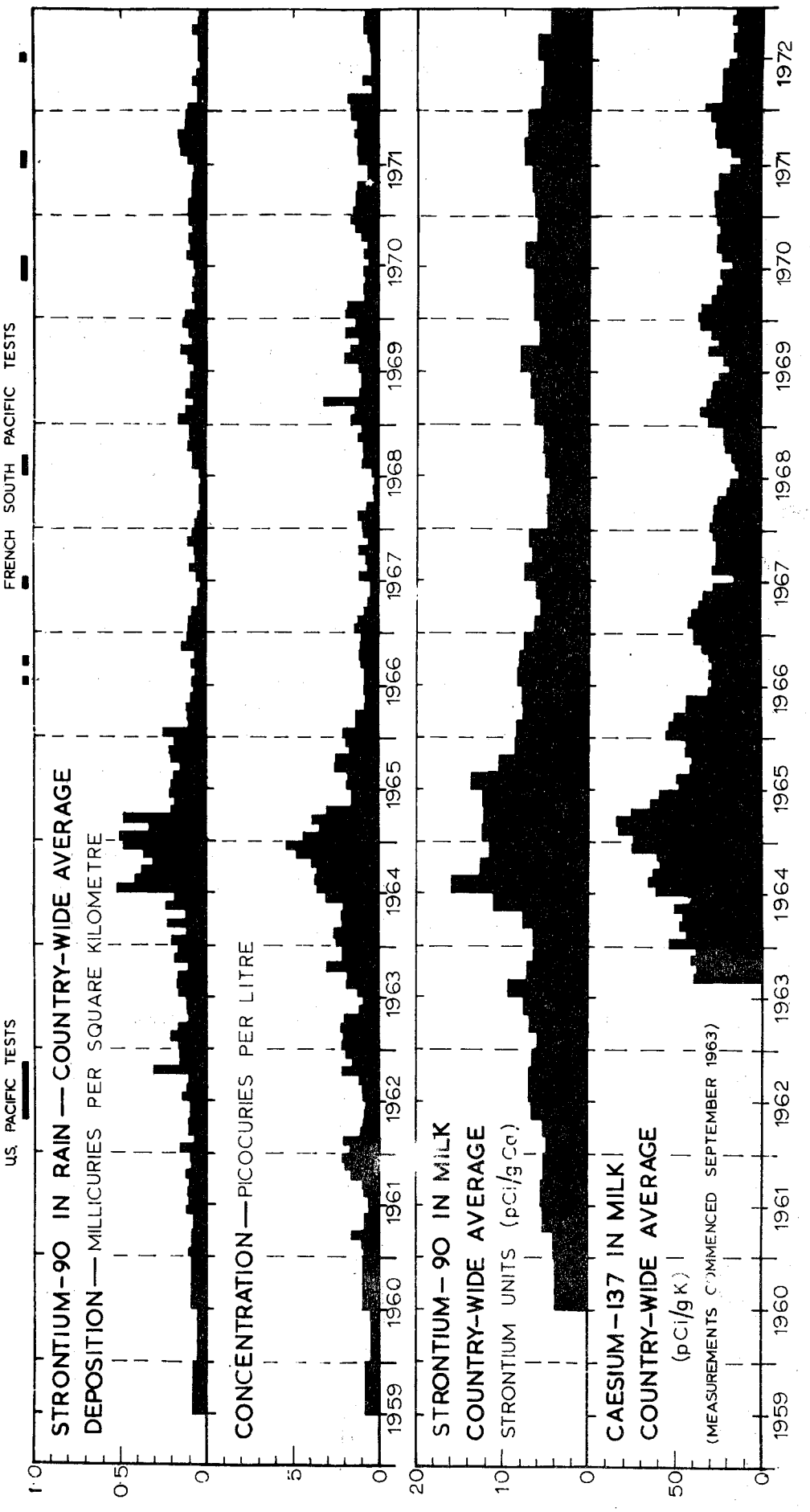

Fig. 4 COUNTRY-WIDE AVERAGE LEVELS OF LONG-LIVED RADIONUCLIDES IN RAIN AND MILK

TABLE 2 ANNUAL DEPOSITION OF STRONTIUM-90 mCi/km^2

Station	Mean Annual Rainfall (cm)	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
NEW ZEALAND														
Kaitaia	141				1.8	4.1	3.1	1.6	1.0	0.9	1.5	1.0	2.0	0.9
Auckland	123	1.2	1.1	1.8	2.0	4.0	2.9	1.3	0.9	0.7	1.3	0.9	1.3	0.7
New Plymouth	151				2.0	5.3	4.2	1.9	1.3	1.0	1.5	1.2	1.9	0.9
Havelock Nth	74	0.7	0.8	1.0	1.0	1.6	1.7	0.8	0.5	0.6	0.7	0.6	1.0	0.5
Wellington	127	0.8	1.1	1.8	2.0	3.4	3.9	1.6	1.0	0.9	1.1	1.2	1.2	0.8
Greymouth	243	1.5	2.2	2.8	3.7	7.8	5.9	2.2	1.7	1.4	2.2	2.1	2.5	1.8
Christchurch	56	0.5	0.7	0.7	1.2	1.3	1.7	0.7	0.4	0.4	0.7	0.5	0.7	0.4
Dunedin	63				1.0	1.8	2.0	0.7	0.6	0.4	0.7	0.5	0.8	0.6
Invercargill	108	0.5	1.2	1.2	1.7	3.0	2.8	1.1	0.9	0.5	1.2	0.7	1.1	0.9
Country-wide Average		0.9	1.2	1.6	1.8	3.6	3.1	1.3	0.9	0.8	1.2	1.0	1.4	0.8
PACIFIC ISLANDS														
Suva, Fiji	294		1.0	1.6	2.4	2.5	2.0	1.2	0.8	1.0	1.3	0.9	1.5*	0.9
Rarotonga	208								0.9*	0.7	0.7	1.0	0.9*	0.8

The mean annual rainfall is for the years 1963 to 1972 inclusive (at Rarotonga: 1967 to 1972 inclusive)

*Estimate

TABLE 3 ANNUAL DEPOSITION OF STRONTIUM-90 mCi/km^2

Year	Northern Hemisphere Stations		New Zealand Average
	Milford Haven	New York City	
1954	2.0 (up 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	(0.4)* to end of June only.	0.7	0.8

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

It will be seen from TABLE 3 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 3 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 levels subsequently fell rapidly and became about the same at all three stations from about 1969. Levels would have fallen below those listed for recent years but for the continuing nuclear weapons tests in the atmosphere, by China in the northern hemisphere, and by France in the southern hemisphere. Such testing has maintained the annual depositions at a relatively steady level during recent years. However, there has been a decrease during 1972.

2. Strontium-90 Cumulative Deposition

The annual depositions listed in TABLE 3 have been totalled, corrected for radioactive decay, and are presented in Fig. 5 as cumulative deposition.

In addition to the New Zealand country-wide average, the cumulative deposition at the highest rainfall station Greymouth, and at the lowest rainfall station Christchurch, are presented in Fig. 5 to show the range within New Zealand. (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.)

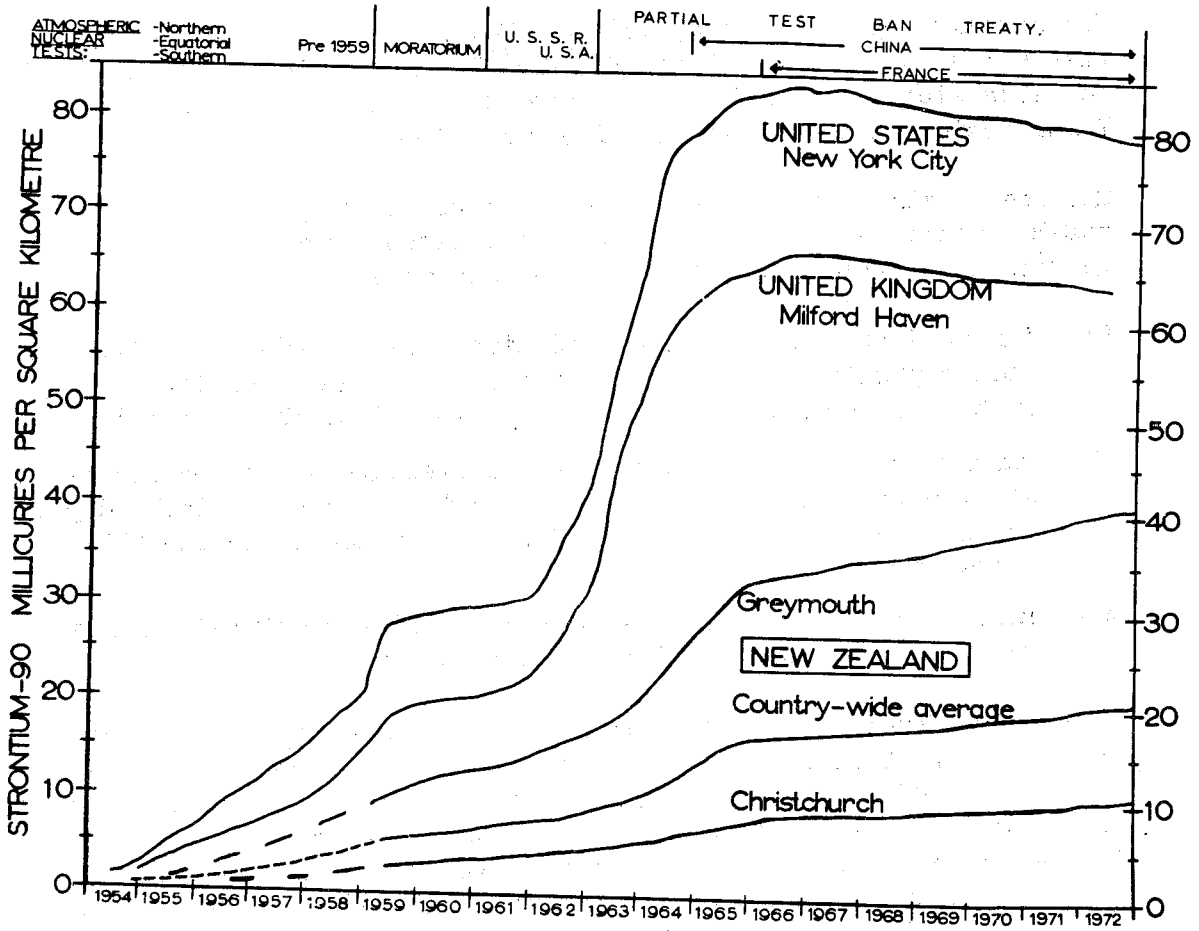

Fig. 5 CUMULATIVE DEPOSITION OF STRONTIUM-90 - COMPARISON

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 shown in Fig. 5.

The cumulative deposition has also been evaluated frequently by measurement of strontium-90 in soil at four selected sites in New Zealand. The results of these measurements on samples collected to October 1970 were given in Report No. NRL-F/48 (1). Soils were also sampled at these sites at the end of 1971 and 1972. Because of the low rate of strontium-90 deposition during recent years the 1971 samples have not been evaluated but are being kept in our sample bank. The 1972 collection is currently being evaluated.

3. Strontium-89 in Rain

The monthly deposits during 1972 of 50 day half-life strontium-89 from the French tests, and the ratios of $^{89}Sr/^{90}Sr$ are listed in TABLE 10 APPENDIX for each station. In Fig. 6 values of the ratio are plotted on a logarithmic scale for each station since 1962.

The use of this type of measurement for estimating what proportion of the total strontium-90 deposit derives from recent nuclear tests was explained in Report No. NRL-F/48 (1). The main conclusions reached were:

(1) During 1966 and 1967 deposited strontium-90 originated from delayed stratospheric fallout from the early 1961 and 1962 tests, together with a proportion of fresh strontium-90 from the French tests.

(2) During 1968 to 1970 the southern hemisphere stratospheric reservoir of strontium-90 from the earlier tests was substantially depleted and most of the strontium-90 fallout originated in the 1968 and 1970 French tests.

(3) During 1971 the deposit was a mixture of strontium-90 from the 1971 tests and the earlier 1968 and 1970 tests.

During the first half of 1972 the ratio continued to decrease at the expected rate following the 1971 tests, and had reached low values of about 2 when the 1972 tests commenced in late June. The ratio at most stations then tended to level off at this low value or increase slightly due to traces of fresh strontium-89 from the 1972 low yield tests. By the end of 1972 the ratio had fallen to less than one at all stations. This indicates that only small amounts of strontium-90 were produced by the 1972 tests and that the measured deposition of strontium-90 during the year derived mainly from the earlier French test series.

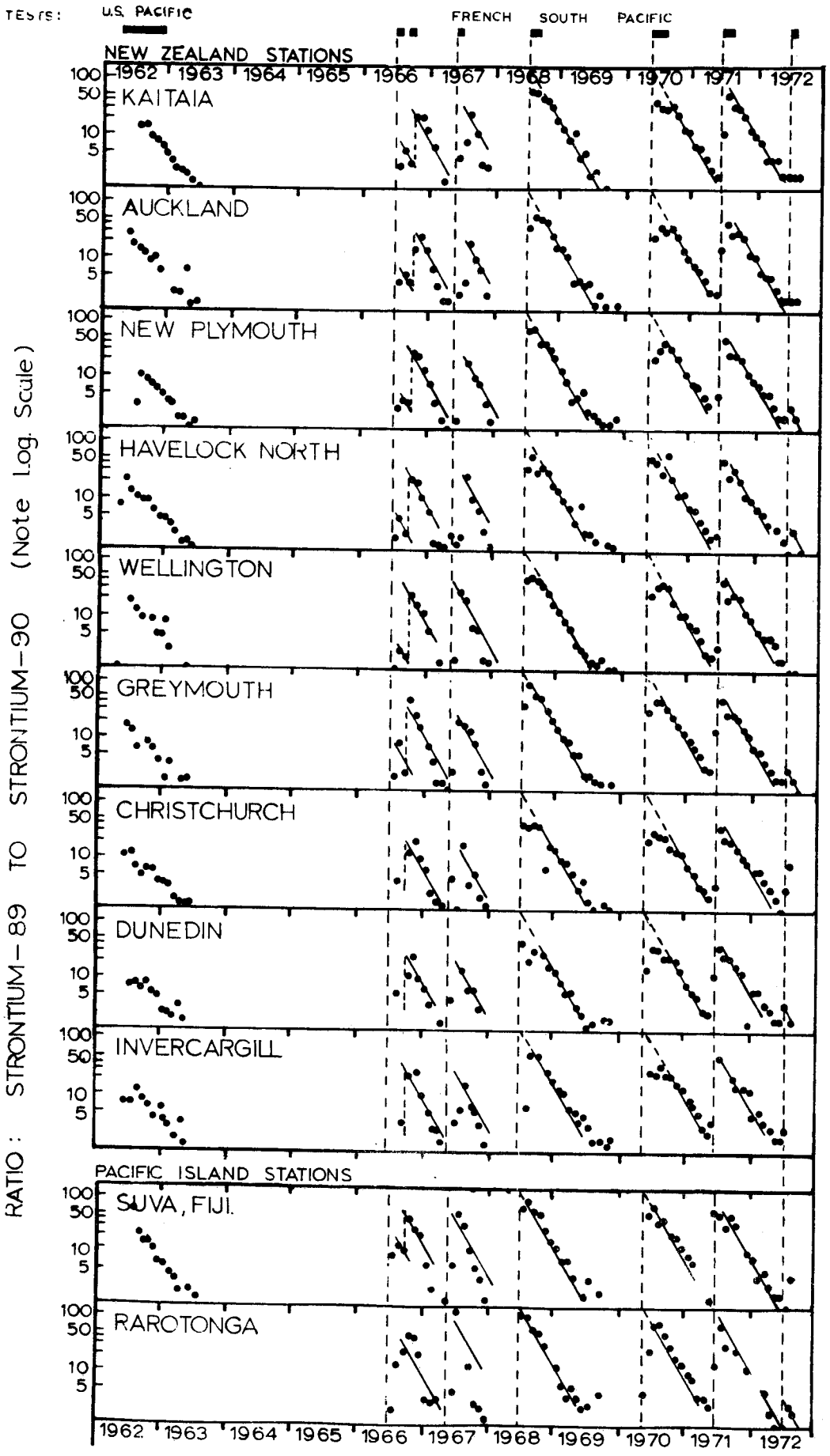

Fig. 6 STRONTIUM-89/STRONTIUM-90 RATIO IN RAINWATER

4. Strontium-90 in Milk

(a) At Nine New Zealand Stations

The average levels of strontium-90 in milk for each quarter during 1972 are listed in TABLE 11 APPENDIX for each collecting station. Individual station levels since about 1960 are also shown graphically in Fig. 9 APPENDIX.

The country-wide average values since measurements started in New Zealand are shown graphically in Fig. 4 (page 11) together with country-wide average levels of caesium-137 in milk and strontium-90 in rain. This comparison graph clearly indicates the changing levels of these long-lived fallout products in the environment resulting from atmospheric nuclear tests during the last 12 to 13 years.

Levels in New Zealand milk reached their maximum values during 1964 and 1965 when the rate of strontium-90 deposition was also a maximum. Milk levels then fell steadily reaching a minimum value in 1968 which was less than half the 1965 maximum. This indicates that the level in milk is mainly dependent on current fallout rates rather than on the cumulative deposit in the soil. However, the decrease in milk levels during the period 1965 to 1968 was at a slower rate than the decrease in annual strontium-90 deposit during this period, because of some uptake from soil to grass.

Due to the French tests milk levels stopped falling in 1968 and showed a slight increase during the next three years. However, following the decline in deposition of strontium-90 in rain, the milk level for 1972 fell to the lowest value since 1968.

TABLE 4 lists the average levels at each station, and the country-wide average for each year since 1962.

TABLE 4 AVERAGE LEVELS OF STRONTIUM-90 IN MILK - STRONTIUM UNITS

STATIONS	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	Av.*
Northland	4.5	6.3	7.5	11.2	10.6	6.5	5.1	4.1	6.3	5.2	7.3	4.8	6.8
Auckland		5.5	5.3	9.1	9.4	6.1	5.2	3.8	6.0	5.1	5.8	4.6	6.0
Waikato	4.1	4.9	5.6	9.5	9.8	6.3	5.0	4.1	5.4	5.2	6.0	4.4	6.0
Taranaki	7.1	9.4	9.9	17.1	16.7	12.5	10.4	8.0	9.4	9.7	10.2	8.2	11.0
Palmerston Nth		4.3	4.9	7.1	8.4	4.8	3.9	3.6	5.8	3.6	5.0	5.0	5.1
Wellington					8.8	6.1	5.4	4.8	5.1	4.7	4.8	4.1	5.5
Westland	12.7	13.5	17.2	26.0	28.8	22.7	17.8	14.0	17.9	21.0	18.3	14.7	19.3
Christchurch	1.6	2.1	2.7	2.6	4.3	2.4	1.9	1.6	1.7	2.2	2.0	1.9	2.3
Dunedin		3.0	3.7	4.1	7.4	4.0	3.1	2.4	3.0	2.5	3.0	3.1	3.6
Country-wide Average		6.1	7.1	10.8	11.6	7.9	6.4	5.2	6.7	6.6	6.9	5.6	7.3

* Average 1962 - 1972 (for Wellington 1965 - 1972)

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 about three times the country-wide average.

(b) Comparison with two Northern Hemisphere Stations

In Fig. 7 the country-wide average levels of strontium-90 in New Zealand milk are compared with levels in Canadian (6) and New York City (5) milk.

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. Figure 7 indicates that 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 strontium-90 deposition in the two hemispheres, the milk levels have been about the same.

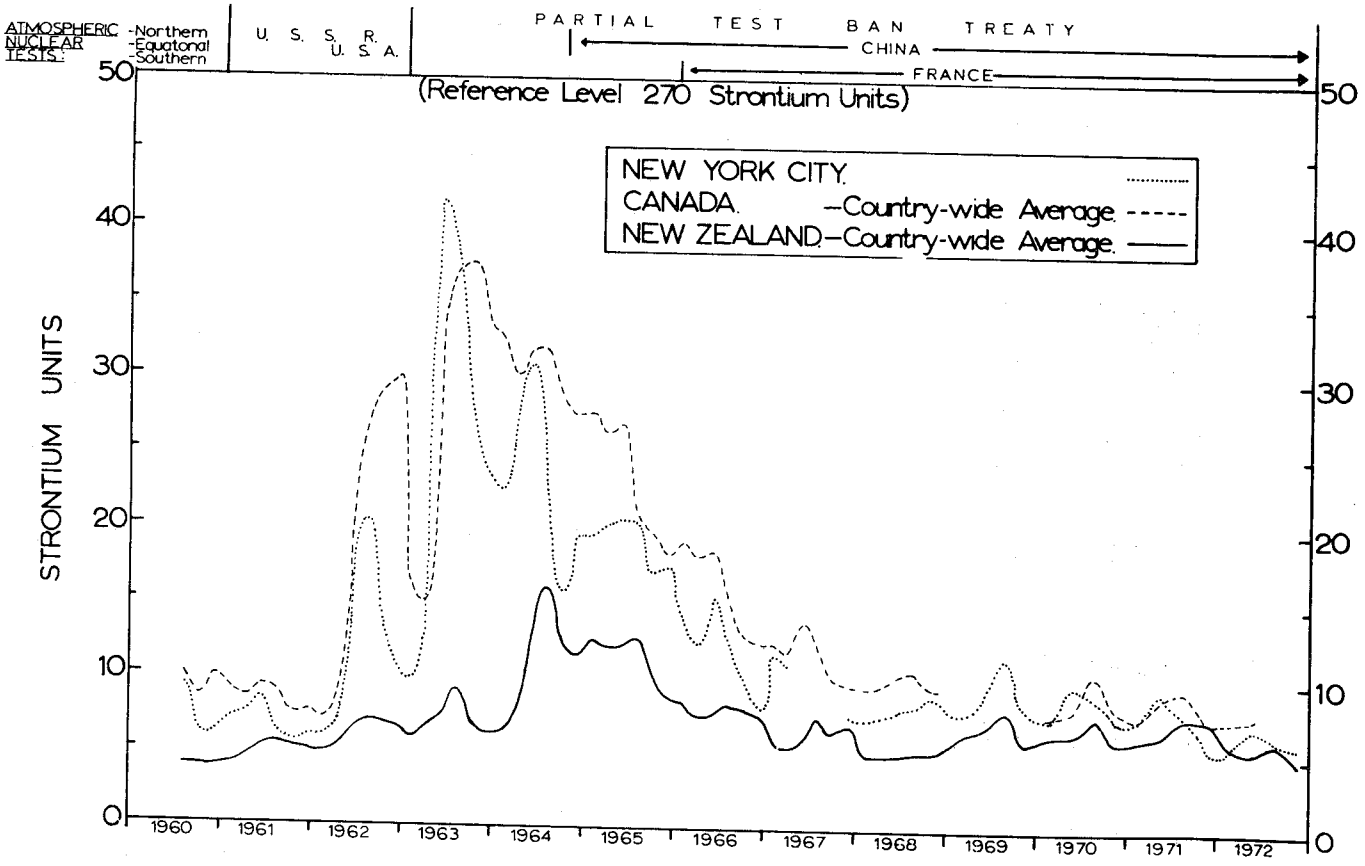

Fig. 7 STRONTIUM-90 LEVELS IN MILK - COMPARISON

(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

(6) "Data From Radiation Protection Programs"; "Radiation Surveillance in Canada", RPD Report Series of the Radiation Protection Division, Department of National Health and Welfare, Canada.

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.

It is appropriate to attempt a hazard assessment as follows:

Assume that the average level in New Zealand milk during the period 1962 to 1972 inclusive was maintained indefinitely in the average New Zealand diet as a whole. Furthermore consider the discrimination against strontium in its passage from diet to bone (the observed ratio of Strontium Units in bone to Strontium Units in diet is 1 to 4). Under these hypothetical equilibrium conditions the bone levels of New Zealanders would not exceed the levels listed in TABLE 5.

TABLE 5 STRONTIUM-90 HAZARD ASSESSMENT (1962 - 1972)

Station	Strontium Units		% of Reference Level
	Milk	Bone	
Lowest Level (Christchurch)	2.3	0.6	0.9%
Highest Level (Westland)	19.3	4.8	7.1%
Country-wide Average	7.3	1.8	2.7%

Results of strontium-90 measurements in human bone samples are given in TABLE 13 APPENDIX.

5. Caesium-137 in Milk

(a) At Nine New Zealand Stations

The levels of caesium-137 in milk for each month during 1972 are listed in TABLE 12 APPENDIX for each collecting station. Individual station levels since mid-1963 are also shown graphically in Fig. 10 APPENDIX.

TABLE 6 gives the annual average levels at each station and also the country-wide averages since 1964. The higher levels at Taranaki due to the "soil effect" have been discussed in the previous annual report NRL-F/48 (1). The country-wide averages are also compared graphically with strontium-90 levels in rain and milk in Fig. 4 (page 11).

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.

TABLE 6 AVERAGE LEVELS OF CAESIUM-137 IN MILK - pCi/g K										
	1964	1965	1966	1967	1968	1969	1970	1971	1972	AVERAGE
Northland	49	54	37	26	15	27	22	23	21	30
Auckland	51	53	33	26	18	26	18	18	15	29
Waikato	69	84	60	48	36	41	35	36	28	49
Taranaki	168	185	141	123	102	101	89	80	72	118
Palmerston Nth	19	26	11	7	3	5	6	7	2	10
Wellington	25*	29	18	13	7	9	11	9	7	14
Westland	76	77	43	33	21	38	39	30	22	42
Christchurch	7	11	4	3	1	2	4	3	2	4
Dunedin	11	18	9	5	3	4	5	5	4	7
Country-wide Average	53	60	39	31	23	28	25	23	19	34
* Estimate										

(b) Comparison of Measured Levels with the Reference Level

During the period 1964 to 1972 inclusive the country-wide average level was 34 pCi/g K which is about 0.5% of the reference level. At the highest level station, Taranaki, the average level over the same period was 118 pCi/g K, about 1.7% of the reference level, whereas at Christchurch, the lowest level station, the average was 4 pCi/g K, about 0.06% of the reference level.

6. Lead-210 in Rain

The measurement of naturally-occurring lead-210 deposition in rain was continued during 1972. The evaluation was made in samples from the stations routinely supplying rainwater collections for strontium-90 determination.

Lead-210 is produced in the atmosphere by decay of radon which has diffused from land surfaces. The subsequent deposition 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. 11 APPENDIX. Earlier results, including higher results during 1965 at four stations and references to levels in milk, were discussed in the previous annual report NRL-F/48 (1).

During 1972 the New Zealand country-wide average deposition was about 1.7 mCi/km^2 compared to 1.1 mCi/km^2 in 1971. During the last five years the annual deposition has averaged about 1.4 mCi/km^2 for the New Zealand stations. During the same period the annual deposition of strontium-90 from weapons tests has averaged about 1.0 mCi/km^2.

7. Strontium-90, Radium-226, and Lead-210 in Human Bone

TABLE 13 APPENDIX lists the levels of artificially produced strontium-90, and naturally-occurring radium-226 and lead-210, in New Zealand human bone

samples. These three radionuclides are major bone seekers of potential health hazard, and the levels listed are those present at the time of death. TABLE 13 is subdivided into panels in chronological order. Within each panel the results are listed in order of rainfall area, and within each area in order of age at death.

The strontium-90 concentrations range from less than 0.1 to 3.2 Strontium Units (pCi/g Ca). The levels in bone tend to be higher in high rainfall districts where strontium-90 deposition and milk levels are higher. The levels also tend to be higher in young bone formed during the last decade of higher global fallout. It is of interest to see that in no case does the concentration in bone reach the equilibrium levels calculated from the dietary level for the area as listed in TABLE 5 (STRONTIUM-90 HAZARD ASSESSMENT 1962 - 1972).

The radium-226 levels, however, do not depend on the average rainfall, nor on the age of the subject. With the exception of occupational exposure or accidental ingestion, the levels are expected to reflect the radium content of the local soil and water supplies.

Lead-210 is one of the radioactive daughters of radium-226 naturally present in the earth's crust. However, environmental fractionation leading to natural fallout of lead-210 in rain results in higher concentrations of lead-210 in foliage and in surface soil layers. The levels are therefore generally higher than radium-226 levels in food chains and in human bone.

MISCELLANEOUS INFORMATION

1. International Intercomparison of Measurements

During 1972 this Laboratory again participated in international intercomparisons of environmental radioactivity measurements. The programmes were organised by The International Atomic Energy Agency; The International Reference Centre for Radioactivity, W.H.O.; and The U.S. Environmental Protection Agency.

The types of environmental samples measured for radionuclide content were: milk, mixed diet, human bone ash, soil, marine sediment, and seaweed. Radionuclides and elements measured were: strontium-89, strontium-90, caesium-134, caesium-137, barium-140, cerium-144, zirconium-95/niobium-95, cobalt-60, ruthenium-106, potassium, and calcium.

2. 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 previous annual report NRL-F/48 (1).

The procedures for radiostrontium in various media are detailed in a technical report (7) which is available from this Laboratory on request.

The procedures for strontium-90, radium-226, and lead-210 in human bone were published recently in outline (8) and are currently being detailed in a technical report which will be available on request in the very near future.

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(7) "The Determination of Radiostrontium in Rainwater, Soil, Milk, and Bone". L.P. Gregory, National Radiation Laboratory, Report No. NRL-RM/3, 1970.

(8) "A Simplified Separation of Strontium, Radium, and Lead from Environmental Media by Precipitation Followed by Fractional Elution". L.P. Gregory, ANALYTICAL CHEMISTRY, Vol.44, page 2113, October 1972.

APPENDIX

List of Tables and Figures in the Appendix

TABLE 7 TOTAL BETA ACTIVITY OF AIR FILTER SAMPLES : 1972

Picocuries per Cubic Metre (at measurement time - four days after collection)

Collection: From 9.00 a.m. on the date shown to 9.00 a.m. on the following date (filters changed routinely three times each week*)

N.S. No Sample Received.

Auckland Date	pCi/m^3	Wellington Date	pCi/m^3	Hokitika Date	pCi/m^3	Christchurch Date	pCi/m^3
Dec. 31	N.S.	Dec. 31	0.08	Dec. 31	0.17	Jan. 2	0.22
Jan. 3	0.17	Jan. 3	0.09	Jan. 3	0.11	" 5	0.08
" 5	0.18	" 5	0.12	" 5	0.08	" 7	0.07
" 7	0.14	" 7	0.06	" 7	N.S.	" 10	0.10
" 10	0.15	" 10	0.12	" 10	0.16	" 12	0.11
" 12	0.10	" 12	0.11	" 12	0.17	" 14	0.08
" 14	0.14	" 14	0.09	" 14	0.08	" 17	0.11
" 17	0.15	" 17	0.08	" 17	0.08	" 19	0.10
" 19	0.16	" 19	0.11	" 19	0.13	" 21	0.11
" 21	0.11	" 21	0.07	" 21	0.13	" 24	0.10
" 24	0.11	" 24	0.08	" 24	0.11	" 26	0.10
" 26	0.12	" 26	0.08	" 26	0.17	" 28	0.07
" 28	0.14	" 28	0.06	" 28	0.09		
Jan. Av.	0.14	Jan. Av.	0.09	Jan. Av.	0.12	Jan. Av.	0.10
Jan. 31	0.12	Jan. 31	0.08	Jan. 31	0.09	Jan. 31	0.06
Feb. 2	0.11	Feb. 2	0.07	Feb. 2	0.16	Feb. 3	0.09
" 4	0.18	" 4	0.09	" 4	0.17	" 4	0.08
" 7	0.19	" 7	0.12	" 7	0.18	" 7	0.12
" 9	0.09	" 9	0.05	" 9	0.11	" 9	0.08
" 11	0.11	" 11	0.10	" 11	0.11	" 11	0.11
" 14	0.09	" 14	0.19	" 14	0.12	" 14	0.13
" 16	0.16	" 16	0.13	" 16	0.16	" 16	0.11
" 18	0.10	" 18	0.17	" 18	0.25	" 18	0.17
" 23	0.10	" 21	0.09	" 21	0.14	" 21	0.14
" 25	0.10	" 23	0.07	" 23	0.08	" 24	0.11
" 28	0.15	" 25	0.10	" 25	0.12	" 28	0.14
		" 28	0.21	" 28	0.20		
Feb. Av.	0.13	Feb. Av.	0.11	Feb. Av.	0.15	Feb. Av.	0.11
March 1	0.17	March 1	0.15	March 1	0.18	March 1	0.13
" 3	0.09	" 3	0.08	" 3	0.05	" 3	0.07
" 6	0.01	" 6	0.09	" 6	0.08	" 6	0.08
" 8	0.01	" 8	0.05	" 8	0.12	" 8	0.06
" 10	0.11	" 10	0.06	" 10	0.07	" 10	N.S.
" 13	0.13	" 13	0.08	" 13	0.07	" 13	0.05
" 15	0.07	" 15	0.14	" 15	0.10	" 15	0.07
" 17	0.10	" 17	0.07	" 17	0.05	" 17	0.05
" 20	0.15	" 20	0.07	" 20	0.08	" 20	0.03
" 22	0.13	" 22	0.11	" 22	0.09	" 22	0.05
" 24	0.06	" 24	0.05	" 24	0.07	" 24	0.03
" 27	0.07	" 27	0.03	" 27	0.11	" 27	0.02
" 29	0.04	" 29	0.05	" 29	0.03	" 29	0.06
March Av.	0.09	March Av.	0.08	March Av.	0.08	March Av.	0.06

(continued)

Auckland Date	pCi/m^3	Wellington Date	pCi/m^3	Hokitika Date	pCi/m^3	Christchurch Date	pCi/m^3
March 31	0.05	March 31	0.06	March 31	0.04	April 4	0.02
April 3	0.05	April 3	0.02	April 3	0.03	" 5	0.02
" 5	0.06	" 5	0.04	" 5	0.02	" 7	0.07
" 7	0.04	" 7	0.06	" 7	0.04	" 10	0.10
" 10	0.07	" 10	0.14	" 10	0.11	" 12	0.05
" 12	0.04	" 12	0.05	" 12	0.08	" 14	0.03
" 14	0.05	" 14	0.02	" 14	0.06	" 17	0.05
" 17	0.08	" 17	0.04	" 17	0.09	" 19	0.04
" 19	0.07	" 19	0.04	" 19	0.06	" 21	0.05
" 21	0.05	" 21	0.06	" 21	0.07	" 24	0.05
" 24	0.07	" 24	0.08	" 24	0.09	" 26	0.03
" 26	0.05	" 26	0.04	" 26	0.06	" 28	0.03
" 28	0.06	" 28	0.04	" 28	0.05		
April Av.	0.06	April Av.	0.05	April Av.	0.06	April Av.	0.05
May 1	0.14	May 1	0.04	May 1	0.05	May 1	0.04
" 3	0.06	" 3	0.04	" 3	0.12	" 3	0.06
" 8	0.09	" 5	0.06	" 5	0.05	" 5	0.08
" 10	0.11	" 8	0.07	" 8	0.10	" 8	0.06
" 12	0.07	" 10	0.06	" 10	0.08	" 10	0.14
" 15	0.05	" 12	0.05	" 12	0.03	" 12	0.05
" 17	0.04	" 15	0.03	" 15	0.03	" 15	0.04
" 19	0.05	" 17	0.02	" 17	0.01	" 17	0.02
" 22	0.05	" 19	0.04	" 19	0.03	" 19	0.03
" 24	0.05	" 22	0.04	" 22	0.05	" 22	0.03
" 26	0.03	" 24	0.04	" 24	0.04	" 24	0.02
" 29	0.04	" 26	0.03	" 26	0.03	" 29	0.04
		" 29	0.04	" 29	0.05		
May Av.	0.07	May Av.	0.04	May Av.	0.05	May Av.	0.05
May 31	0.03	May 31	0.02	May 31	0.02	May 31	0.02
June 2	0.03	June 2	0.03	June 2	0.03	June 2	0.03
" 5	0.03	" 5	0.03	" 5	0.04	" 6	0.02
" 7	0.03	" 7	0.03	" 7	0.04	" 7	0.02
" 9	0.04	" 9	0.02	" 9	0.05	" 9	0.03
" 12	0.04	" 12	0.04	" 12	0.01	" 12	0.01
" 14	0.03	" 14	0.02	" 14	0.01	" 14	0.02
" 16	0.03	" 16	0.02	" 16	0.02	" 16	0.04
" 19	0.04	" 19	0.03	" 19	0.03	" 19	0.04
" 21	0.04	" 21	0.05	" 21	0.03	" 21	0.02
" 23	0.02	" 23	0.07	" 23	0.05	" 23	0.03
" 26	0.02	" 26	0.03	" 26	0.03	" 26	0.03
" 28	0.03	" 28	0.03	" 28	0.02	" 28	0.03
" 30	0.03	" 30	0.05	" 30	0.01	" 30	0.02
June Av.	0.03	June Av.	0.03	June Av.	0.03	June Av.	0.03

Monthly Averages During the Special Monitoring Programme*

July Av.	0.04	July Av.	0.03	July Av.	0.03	July Av.	0.02
Aug. Av.	0.06	Aug. Av.	0.04	Aug. Av.	0.04	Aug. Av.	0.04
Sept. Av.	0.04	Sept. Av.	0.03	Sept. Av.	0.03	Sept. Av.	0.03

(continued)

Auckland Date		pCi/m^3	Wellington Date		pCi/m^3	Hokitika Date		pCi/m^3	Christchurch Date		pCi/m^3
Oct.	1	0.04	Oct.	1	0.04	Oct.	1	0.02	Oct.	1	0.03
"	2	0.04	"	3	0.07	"	4	0.03	"	3	0.02
"	6	0.03	"	6	0.02	"	6	0.01	"	6	<0.01
"	9	0.02	"	9	0.02	"	9	0.03	"	9	0.01
"	11	0.05	"	11	0.02	"	11	0.03	"	11	0.03
"	13	0.02	"	13	0.02	"	13	0.01	"	13	0.01
"	16	0.02	"	16	0.01	"	16	<0.01	"	16	0.02
"	18	0.02	"	18	0.02	"	18	0.02	"	18	0.03
"	20	0.03	"	20	0.03	"	20	0.03	"	24	0.03
"	23	0.04	"	23	0.03	"	23	0.02	"	25	0.03
"	25	0.04	"	25	0.02	"	25	0.01	"	27	0.03
"	27	0.02	"	27	0.02	"	27	0.02	"	30	0.03
"	30	0.04	"	30	0.04	"	30	0.04			
Oct.	Av.	0.03	Oct.	Av.	0.03	Oct.	Av.	0.02	Oct.	Av.	0.02
Nov.	1	0.02	Nov.	1	0.03	Nov.	1	0.01	Nov.	1	0.03
"	3	0.03	"	3	0.01	"	3	<0.01	"	3	0.02
"	6	0.04	"	6	0.02	"	6	<0.01	"	6	0.02
"	8	0.03	"	8	0.02	"	8	0.02	"	8	0.03
"	10	0.02	"	10	0.02	"	10	0.02	"	10	0.03
"	13	0.03	"	13	0.03	"	13	0.02	"	13	0.03
"	16	0.03	"	15	0.02	"	15	<0.01	"	15	0.02
"	17	0.02	"	17	0.02	"	17	0.02	"	17	0.02
"	20	0.02	"	20	0.01	"	20	0.03	"	20	0.02
"	22	0.02	"	22	N.S.	"	22	0.02	"	24	0.02
"	24	0.03	"	24	0.02	"	24	0.02	"	27	0.02
"	27	0.03	"	27	0.03	"	27	<0.01	"	29	0.01
"	29	0.02	"	29	<0.01	"	29	<0.01			
Nov.	Av.	0.03	Nov.	Av.	0.02	Nov.	Av.	0.01	Nov.	Av.	0.02
Dec.	1	0.02	Dec.	1	0.03	Dec.	1	0.03	Dec.	1	0.03
"	4	0.03	"	4	0.04	"	4	0.02	"	4	0.03
"	6	<0.01	"	6	0.03	"	6	0.01	"	6	0.02
"	8	0.02	"	8	0.03	"	8	0.01	"	8	0.03
"	11	0.02	"	11	0.01	"	11	0.03	"	11	0.02
"	13	0.02	"	13	0.02	"	13	0.01	"	13	0.01
"	15	0.03	"	15	0.03	"	15	0.02	"	15	0.02
"	18	0.01	"	18	0.01	"	18	0.01	"	18	0.01
"	20	0.01	"	20	0.04	"	20	0.02	"	20	0.02
"	22	0.05	"	22	0.01	"	22	0.02	"	22	0.02
"	25	0.02	"	25	0.03	"	25	0.04	"	26	0.02
"	27	0.02	"	27	0.03	"	27	0.01	"	29	0.04
"	29	0.02	"	29	0.01	"	29	0.02			
Dec.	Av.	0.02	Dec.	Av.	0.03	Dec.	Av.	0.02	Dec.	Av.	0.02
1972	Av.	0.06	1972	Av.	0.05	1972	Av.	0.05	1972	Av.	0.05

* During the special monitoring programme, from July to September inclusive, air filter samples were changed daily. Individual results, including those from four Pacific Island stations, were given in the report on monitoring fallout from the French nuclear tests during 1972 (NRL-F/49, October 1972, Table 2).

TABLE 8 TOTAL BETA ACTIVITY OF WEEKLY RAINWATER SAMPLES : 1972

Deposition: mCi/km^2 (at time of measurement - about four days after collection)

Collection: From date shown to start of next collection.

Rainfall: cm

N.S. No Sample Received.

Collection	Auckland		Wellington		Greymouth*		Christchurch	
	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2
Dec. 31	6.7	4.0	1.9	1.8	2.8	2.9	3.9	1.0
Jan. 7	0.4	1.1	0.8	0.5	3.7	0.7	0.5	0.2
" 14	0.3	0.9	0.1	0.3	0.1	0.3	<0.1	0.6
" 21	trace	0.9	0.2	0.6	4.2	1.6	<0.1	0.6
" 28	0.5	2.5	5.1	1.2	1.9	0.8	2.0	1.5
January	7.9	9.4	8.1	4.4	12.7	6.3	6.4	3.9
Feb. 4	0.6	0.8	2.1	3.1	0.9	0.8	2.2	1.0
" 11	0.3	0.5	nil	0.4	nil	0.1	<0.1	1.4
" 18	1.7	0.7	1.9	0.8	1.9	0.8	0.1	0.3
" 25	nil	0.1	trace	0.2	0.4	0.5	nil	N.S.
February	2.6	2.1	4.0	4.5	3.2	2.2	2.4	2.7
Mar. 3	14.9	0.8	3.3	0.7	9.2	0.7	1.5	0.5
" 10	1.4	0.2	3.3	0.1	6.2	1.8	0.1	0.2
" 17	0.5	0.3	trace	<0.1	0.8	0.5	0.1	0.1
" 24	2.7	0.4	3.6	0.5	9.6	0.7	0.7	0.4
March	19.5	1.7	10.2	1.4	25.8	3.7	2.4	1.2
Mar. 31	0.9	0.1	0.8	0.3	11.2	0.8	2.8	0.4
April 7	4.4	0.5	2.9	0.2	<0.1	<0.1	0.2	0.1
" 14	1.9	0.5	0.7	0.2	4.6	0.4	1.1	0.4
" 21	1.0	0.4	0.6	0.2	11.1	1.4	0.5	0.1
April	8.2	1.5	5.0	0.9	26.9	2.7	4.6	1.0
April 28	1.1	0.4	1.5	0.4	1.0	0.4	<0.1	0.3
May 5	0.1	0.2	trace	<0.1	3.0	0.7	trace	<0.1
" 12	12.5	1.1	9.5	1.1	6.0	0.5	7.7	0.7
" 19	0.7	0.2	0.4	0.2	4.4	0.3	0.3	0.3
" 26	1.7	0.5	3.4	0.3	6.5	0.6	1.6	0.5
May	16.1	2.4	14.8	2.0	20.9	2.5	9.6	1.8
June 2	0.7	0.3	1.1	0.1	nil	<0.1	1.3	0.4
" 9	1.7	0.1	7.6	0.7	1.9	0.3	1.1	0.2
" 16	2.6	0.4	0.1	<0.1	2.7	0.4	1.5	0.2
" 23	5.1	0.3	0.4	0.2	7.5	0.2	<0.1	<0.1
June	10.1	1.1	9.2	1.0	12.1	0.9	3.9	0.8

(continued)

Collection	Auckland		Wellington		Greymouth*		Christchurch	
	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2
Monthly Totals During the Special Monitoring Programme**								
July	12.6	1.8	14.0	1.4	23.9	2.8	7.7	1.2
August	11.0	1.9	14.6	1.7	15.9	2.4	2.8	0.7
September	4.7	1.0	2.9	1.5	23.0	3.4	1.3	0.4
Sept. 29	<0.1	<0.1	<0.1	0.1	7.5	0.9	0.1	<0.1
Oct. 6	2.7	0.7	7.2	0.3	27.3	0.7	5.8	0.2
" 13	1.1	0.2	1.2	0.3	2.2	0.3	0.9	0.2
" 20	0.5	0.1	3.5	0.4	1.8	0.2	0.7	0.2
" 27	<0.1	<0.1	0.2	0.4	5.4	0.4	nil	<0.1
October	4.4	1.2	12.2	1.5	44.2	2.5	7.5	0.6
Nov. 3	0.3	0.3	2.7	0.3	13.6	0.6	2.2	0.2
" 10	0.4	<0.1	<0.1	<0.1	1.6	0.4	0.7	<0.1
" 17	1.2	0.2	0.3	0.3	0.4	0.1	8.5	0.3
" 24	1.4	0.2	1.0	0.2	5.5	0.4	14.3	<0.1
November	3.3	0.7	4.1	0.8	21.1	1.5	25.7	0.5
Dec. 1	<0.1	<0.1	0.3	<0.1	4.0	0.2	1.6	0.1
" 8	3.2	0.3	2.9	0.3	4.5	0.9	1.6	0.2
" 15	0.2	<0.1	0.2	0.1	3.9	0.3	0.7	0.2
" 22	0.9	<0.1	0.7	0.1	2.2	0.4	0.3	<0.1
December	4.3	0.5	4.1	0.6	14.6	1.8	4.2	0.5
1972 total	104.7	25.3	103.2	21.7	244.3	32.7	78.5	15.3

Average Concentration (pCi/litre)

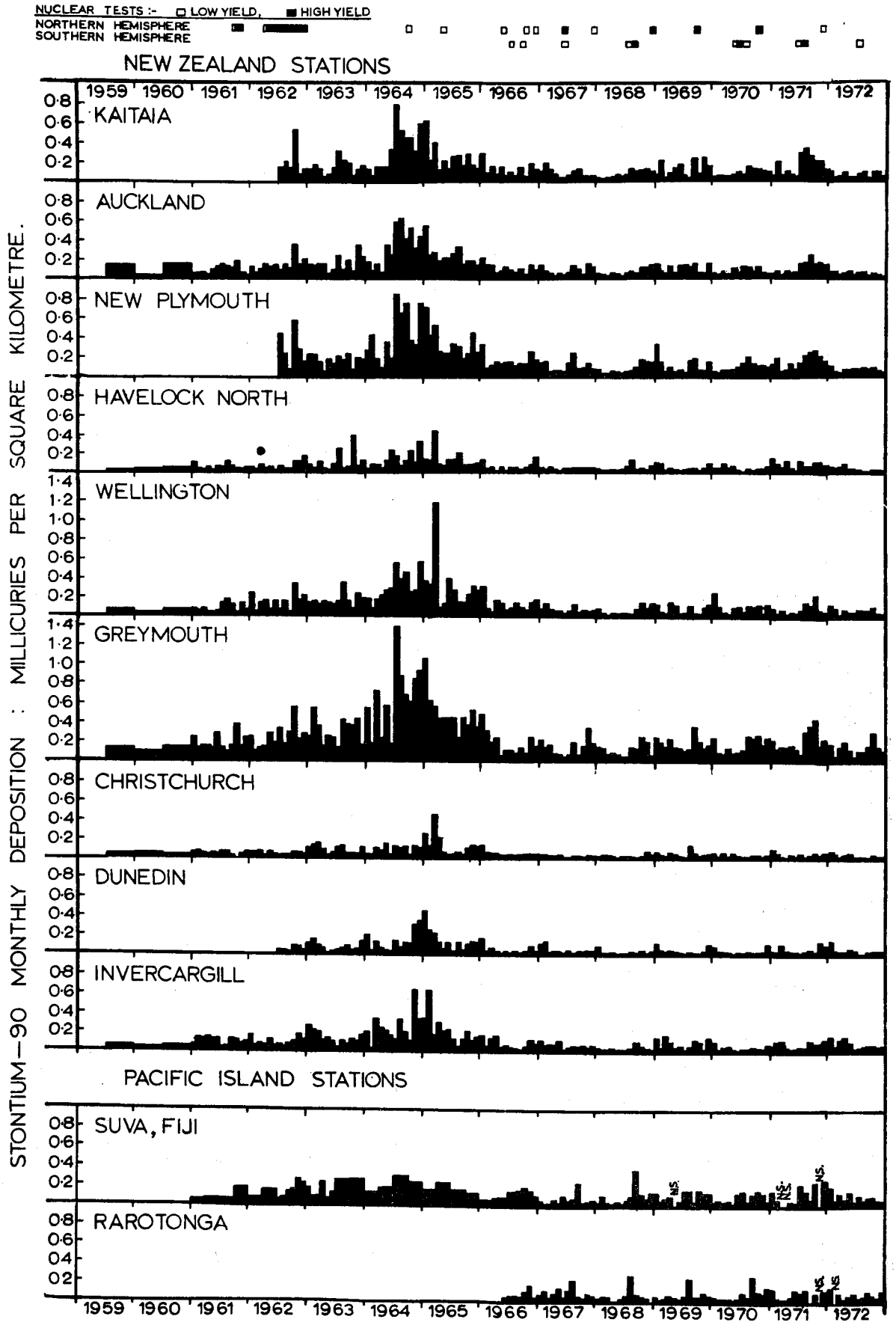
During 1972	24	21	13	19
During special monitoring period	17	15	14	19

* Collections at Greymouth start one day later than the date listed.

** The monthly totals in this panel are summed from the results of four or five separate weekly collections which, like the other collection periods listed in this tabls, do not necessarily coincide exactly with each calendar month. The individual results were listed in the separate report on the monitoring of fallout from the French nuclear tests during 1972 (NRL-F/49, October 1972, Table 4).

TABLE 9	STRONTIUM-90 IN RAIN : 1972														
Station			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Monthly Average
Kaitaia	Rainfall	cm	4.1	3.3	16.7	10.9	9.0	8.4	13.5	11.7	4.0	12.9	13.0	10.4	118	
	Deposition	mCi $^{90}Sr/km^2$	0.11	0.05	0.06	0.10	0.05	0.05	0.08	0.10	0.04	0.10	0.10	0.06	0.90	
	Concentration	pCi ^{90}Sr/litre	2.7	1.5	0.4	0.9	0.6	0.6	0.6	0.8	1.0	0.8	0.7	0.6		0.9
Auckland	Rainfall	cm	3.8	2.6	19.4	8.9	15.2	10.4	12.4	10.8	4.7	4.4	3.2	4.4	100	
	Deposition	mCi $^{90}Sr/km^2$	0.08	0.08	0.04	0.06	0.08	0.05	0.07	0.08	0.04	0.06	0.05	0.03	0.72	
	Concentration	pCi ^{90}Sr/litre	2.2	3.1	0.2	0.7	0.5	0.5	0.6	0.8	0.8	1.4	1.6	0.8		1.1
New Plymouth	Rainfall	cm	8.5	7.5	16.4	7.5	15.8	8.5	13.7	14.5	10.9	8.1	6.6	7.4	125	
	Deposition	mCi $^{90}Sr/km^2$	0.10	0.05	0.04	0.07	0.07	0.08	0.08	0.09	0.08	0.09	0.06	0.05	0.86	
	Concentration	pCi ^{90}Sr/litre	1.2	0.6	0.2	1.0	0.5	0.9	0.6	0.6	0.7	1.2	1.0	0.6		0.8
Havelock North	Rainfall	cm	2.9	2.9	12.9	4.1	9.8	8.5	4.7	2.5	2.7	2.7	3.9	2.2	60	
	Deposition	mCi $^{90}Sr/km^2$	0.07	0.06	0.07	0.09	0.04	0.04	0.03	0.01	0.01	0.03	0.02	0.02	0.49	
	Concentration	pCi ^{90}Sr/litre	2.5	2.0	0.5	2.1	0.4	0.5	0.6	0.5	0.5	1.2	0.6	0.9		1.0
Wellington	Rainfall	cm	10.0	5.9	12.2	6.6	14.2	10.3	16.1	10.0	6.8	8.6	3.1	7.4	111	
	Deposition	mCi $^{90}Sr/km^2$	0.12	0.08	0.03	0.07	0.06	0.06	0.08	0.07	0.07	0.10	0.04	0.04	0.82	
	Concentration	pCi ^{90}Sr/litre	1.2	1.4	0.3	1.0	0.4	0.5	0.5	0.7	1.0	1.1	1.2	0.6		0.8
Greymouth	Rainfall	cm	12.8	3.2	26.3	27.8	19.7	7.5	23.8	15.9	22.9	42.8	23.5	18.1	244	
	Deposition	mCi $^{90}Sr/km^2$	0.18	0.06	0.16	0.20	0.12	0.05	0.11	0.11	0.17	0.31	0.16*	0.12	1.75	
	Concentration	pCi ^{90}Sr/litre	1.4	1.9	0.6	0.7	0.6	0.7	0.5	0.7	0.7	0.7	0.7 *	0.7		0.8
Christchurch	Rainfall	cm	6.2	2.6	2.5	4.6	9.6	3.8	7.7	2.8	1.2	7.4	2.6	3.1	54	
	Deposition	mCi $^{90}Sr/km^2$	0.09	0.06	0.02	0.05	0.06	0.02	0.02	0.01	0.01	0.03	0.02	0.03	0.42	
	Concentration	pCi ^{90}Sr/litre	1.4	2.2	0.9	1.1	0.6	0.5	0.3	0.5	0.8	0.4	0.7	1.0		0.9
Dunedin	Rainfall	cm	6.7	2.4	6.4	4.9	9.9	16.8	4.6	4.4	12.3	4.0	4.4	4.3	81	
	Deposition	mCi $^{90}Sr/km^2$	0.14	0.05	0.04	0.04	0.06	0.05	0.02	0.02	0.03	0.04	0.04	0.04	0.57	
	Concentration	pCi ^{90}Sr/litre	2.1	2.1	0.6	0.8	0.6	0.3	0.4	0.4	0.3	1.1	0.8	0.9		0.9
Invercargill	Rainfall	cm	18.3	2.8	19.9	18.2	13.9	12.4	5.9	7.7	17.1	12.0	6.0	9.4	144	
	Deposition	mCi $^{90}Sr/km^2$	0.16	0.05	0.12	0.14	0.09	0.02	0.03	0.04	0.06	0.06	0.04	0.06	0.87	
	Concentration	pCi ^{90}Sr/litre	0.9	1.7	0.6	0.8	0.6	0.2	0.5	0.6	0.4	0.5	0.6	0.7		0.7
New Zealand Country-wide Average	Rainfall	cm	8.1	3.7	14.7	10.4	13.0	9.6	11.4	8.9	9.2	11.4	7.4	7.4	115	
	Deposition	mCi $^{90}Sr/km^2$	0.12	0.06	0.06	0.09	0.07	0.05	0.06	0.06	0.06	0.09	0.06	0.05	0.83	
	Concentration	pCi ^{90}Sr/litre	1.7	1.8	0.5	1.0	0.5	0.5	0.5	0.6	0.7	0.9	0.9	0.8		0.9
Suva, Fiji	Rainfall	cm	35.6	43.4	34.7	40.5	38.4	11.4	13.8	13.8	21.7	53.5	41.7	46.1	395	
	Deposition	mCi $^{90}Sr/km^2$	0.18	0.04	0.11	0.06	0.13	0.04	0.09	0.05	0.07	0.08	0.05	0.04	0.94	
	Concentration	pCi ^{90}Sr/litre	0.5	0.1	0.3	0.2	0.3	0.3	0.7	0.3	0.3	0.1	0.1	0.1		0.3
Rarotonga	Rainfall	cm	22.0	14.5	24.9	3.6	26.9	8.4	2.8	11.8	8.3	4.5	7.5	4.7	140	
	Deposition	mCi $^{90}Sr/km^2$	0.13	0.04*	0.08	0.02	0.06	0.08	0.03	0.04	0.09	0.06	0.04	0.09	0.76	
	Concentration	pCi ^{90}Sr/litre	0.6	0.3 *	0.3	0.6	0.2	0.9	0.9	0.4	1.1	1.3	0.5	1.9		0.8

* No result available. The value given is an estimate.



COLLECTIONS STARTED AT INDIVIDUAL STATIONS
FROM JULY 1959 TO JUNE 1966, AS SHOWN.

N.S. No Sample

Fig. 8 STRONTIUM-90 IN RAIN - INDIVIDUAL STATIONS

TABLE 10 STRONTIUM-89 DEPOSITION AND THE RATIO STRONTIUM-89 TO STRONTIUM-90 IN RAIN : 1972

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia	Deposition mCi $^{89}Sr/km^2$	0.9	0.2	0.3	0.4	0.1	<0.1	0.2	0.2	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	8	4	4	4	2	2	2	2	<1	<1	<1	
Auckland	Deposition mCi $^{89}Sr/km^2$	0.5	0.4	0.2	0.2	0.2	0.1	0.2	0.2	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	6	5	5	3	2	2	2	2	<1	<1	<1	
New Plymouth	Deposition mCi $^{89}Sr/km^2$	0.7	0.2	0.2	0.3	0.2	0.1	0.2	0.2	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	7	5	5	3	2	2	3	2	1	<1	<1	
Havelock North	Deposition mCi $^{89}Sr/km^2$	0.5	0.3	0.3	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	7	6	4	<1	3	2	1	3	1	<1	<1	
Wellington	Deposition mCi $^{89}Sr/km^2$	0.7	0.4	0.2	0.2	0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	6	5	5	4	2	2	1	1	<1	<1	<1	
Greymouth	Deposition mCi $^{89}Sr/km^2$	1.2	0.4	0.7	0.5	0.3	<0.1	0.3	0.2	0.2	<0.1	*	-
	Ratio $^{89}Sr/^{90}Sr$	7	6	4	3	2	2	3	2	1	<1		
Christchurch	Deposition mCi $^{89}Sr/km^2$	0.5	0.3	<0.1	0.2	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	6	6	4	3	2	1	3	8	<1	<1	<1	
Dunedin	Deposition mCi $^{89}Sr/km^2$	0.9	0.3	0.2	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	6	6	4	3	2	2	4	2	<1	<1	<1	
Invercargill	Deposition mCi $^{89}Sr/km^2$	0.8	0.3	0.5	0.4	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	5	6	4	3	2	2	3	<1	<1	<1	<1	
New Zealand Country-wide Average	Deposition mCi $^{89}Sr/km^2$	0.7	0.3	0.3	0.3	0.2	<0.1	0.1	0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	6	5	4	3	2	2	2	3	<1	<1	<1	
Suva, Fiji	Deposition mCi $^{89}Sr/km^2$	1.5	0.2	0.5	0.2	0.3	<0.1	0.1	0.2	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	8	4	5	3	2	2	1	4	<1	<1	<1	
Rarotonga	Deposition mCi $^{89}Sr/km^2$	0.1	*	0.4	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
	Ratio $^{89}Sr/^{90}Sr$	<1	*	5	2	1	1	3	2	<1	<1	<1	

* No result available.
\- Measurements discontinued.

TABLE 11	STRONTIUM-90 IN MILK : 1972				
Stations	"Strontium Units" pCi/g Ca				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
Northland	5.6	3.5	6.3	3.9	4.8
Auckland	5.0	4.2	5.7	3.5	4.6
Waikato	4.3	4.3	5.4	3.6	4.4
Taranaki	8.1	8.7	9.6	6.2	8.2
Palmerston North	3.3	6.4	7.6	2.6	5.0
Wellington	4.2	4.0	4.4	3.7	4.1
Westland	17.9	13.6	12.0	15.2	14.7
Christchurch	2.0	2.0	1.8	1.7	1.9
Dunedin	3.0	4.0	2.8	2.5	3.1
Country-wide Average	5.9	5.6	6.2	4.8	5.6

TABLE 12	CAESIUM-137 IN MILK : 1972												
Stations	pCi/g K												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Northland	31	26	23	19	23	21*	19	14	18	14*	10	29	21
Auckland	21	20	19	12	13	14	13	15	13	14	13	13	15
Waikato	39	37	31	34	29	25*	21	21	23	25	29	26	28
Taranaki	134	62	78	91	91	61	48	64	65	48	78	42	72
Palmerston North	4	2	1	1	3	7	1	4	2	<1	<1	2	2
Wellington	12	12	7	5	5	7	6	7	5	6	5	7	7
Westland	37	26	29	28	27	19	17	12	14	19	16	14	22
Christchurch	4	4	1	2	2	3	2	2	2	1	1	1	2
Dunedin	5	5	6	4	5	6	3	2	2	1	2	2	4
Country-wide Average	32	22	22	22	22	18	14	16	16	14	17	15	19

* Estimate

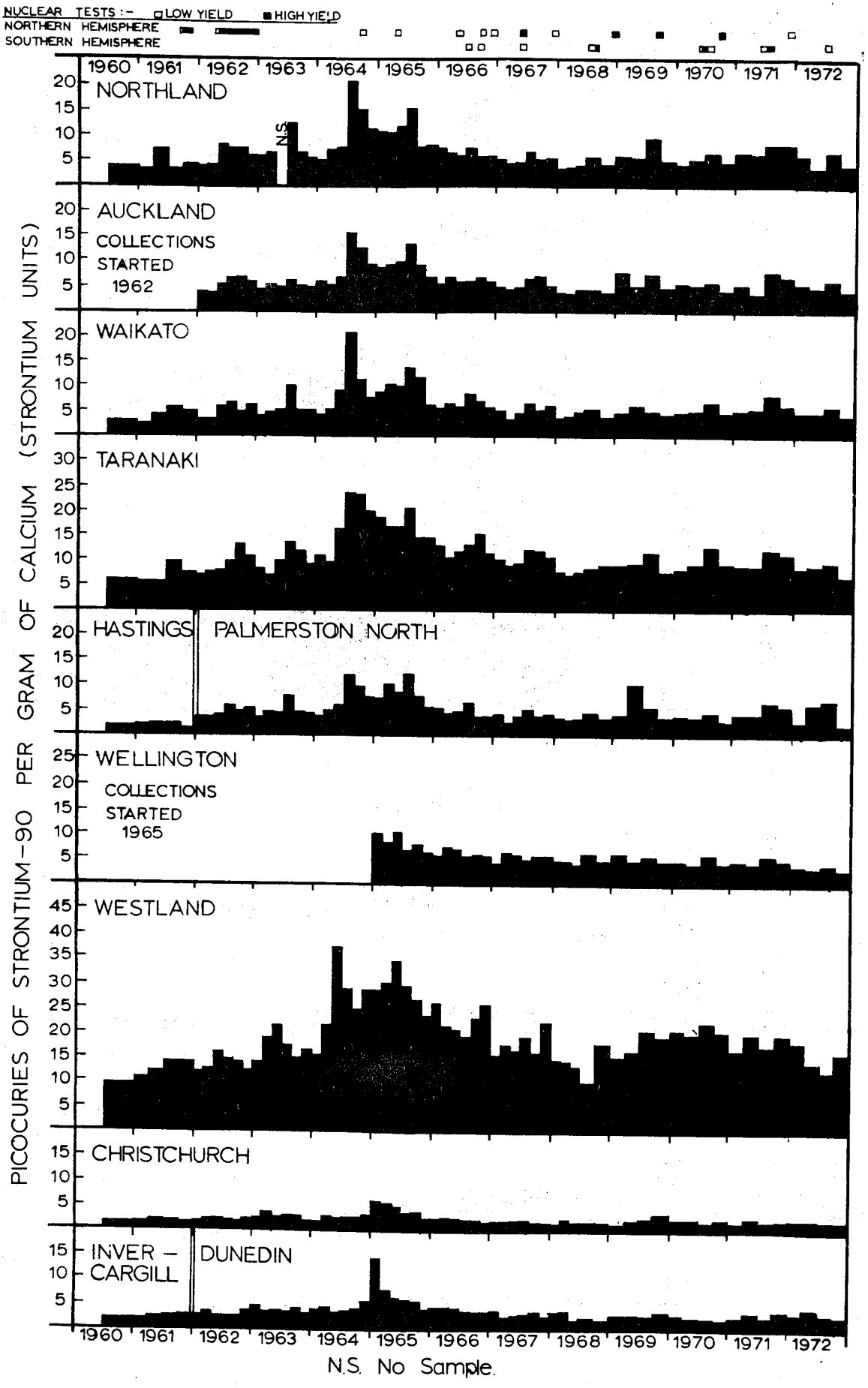


Fig. 9 STRONTIUM-90 IN MILK - INDIVIDUAL STATIONS

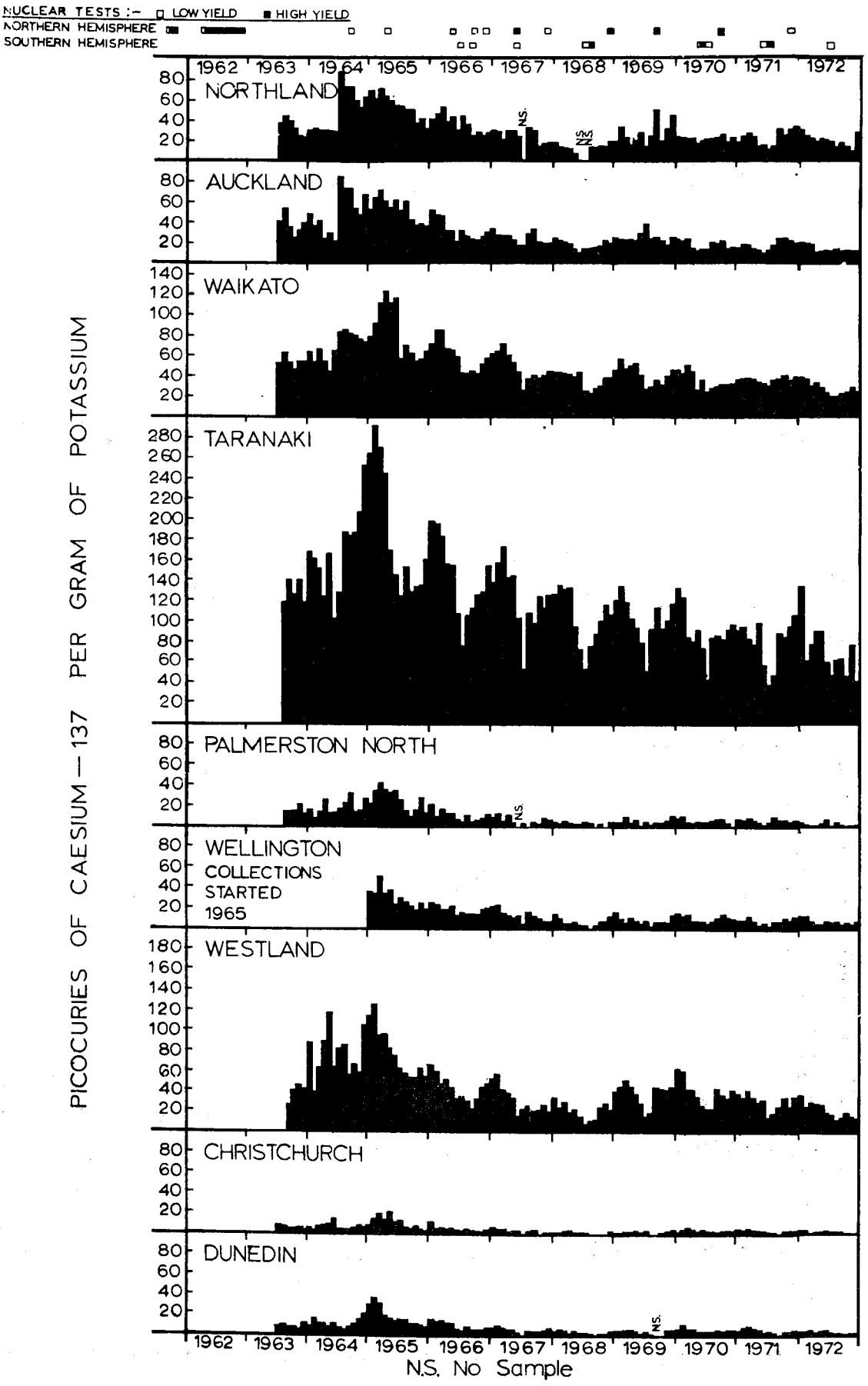
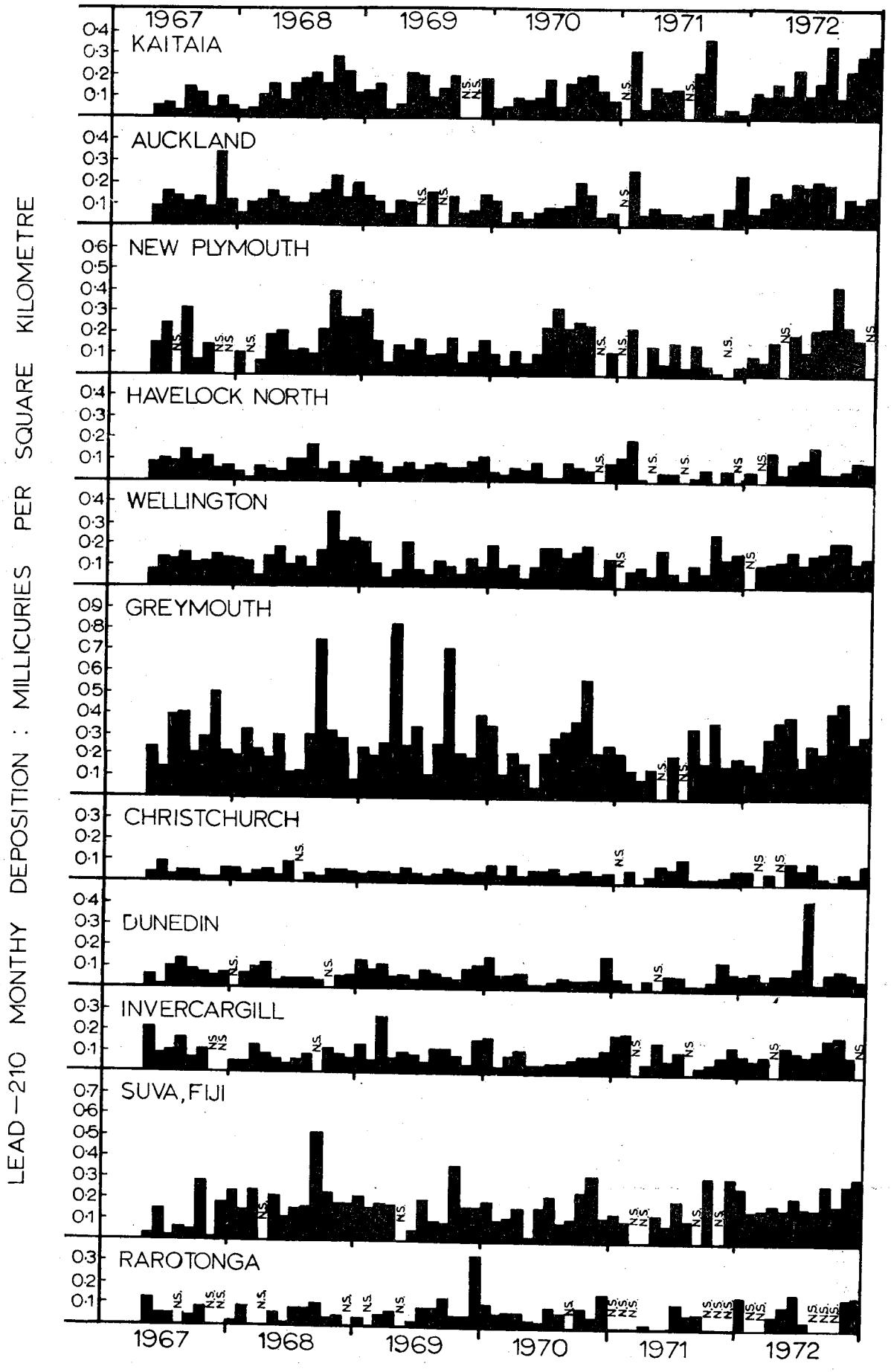


Fig. 10 CAESIUM-137 IN MILK - INDIVIDUAL STATIONS



N.S. No Sample or No Results Available.

Fig. 11 LEAD-210 IN RAIN - INDIVIDUAL STATIONS

TABLE 13 RADIONUCLIDES IN HUMAN BONE

Rainfall Area: The areas within New Zealand from which samples have been obtained are classified according to mean annual rainfall:

Low: up to 100cm per year
Medium: 100 to 150cm per year
High: over 150cm per year

Age at Death: y year, m month, SB stillborn.

Bone Type: F femur, H humerus, L longbones, V vertebrae, R rib, S Skull.

Sample Data					Radionuclide Levels***		
					Artificial	Naturally-Occurring	
Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
3	Low	7/61	5m	F,V,R	0.9	0.016	0.047
4	"	7/61	9y	F,V	0.6	0.011	0.053
7*	"	9/61	23y	F,V	0.7	0.214	0.355
1	"	6/61	53y	F	<0.1	0.026	0.101
2	"	7/61	60y	F	<0.1	0.011	0.099
33	"	9/61	78y	H	0.2	0.012	0.054
34	"	9/61	79y	H	0.1	0.013	0.040
29	"	2/61	83y	H	0.1	0.017	0.050
5	High	9/61	68y	F	0.2	0.012	0.080
31	"	11/61	68y	H	0.3	0.010	0.074
8	"	10/61	80y	F	<0.1	0.040	0.106
6	"	9/61	85y	F	<0.1	0.010	0.111
10	Low	5/62	7y	F	0.5	0.020	0.094
36	"	1/62	56y	H	0.3	0.009	0.118
32	Medium	2/62	53y	H	0.3	0.046	0.193
30	"	2/62	67y	H	0.2	-	-
19	High	12/62	9m	F	3.2	0.036	0.079
11	"	11/62	1y	F	2.1	-	-
12	"	11/62	2y 6m	F	1.2	0.020	0.060
23	"	12/62	8y	F	1.6	0.026	0.078
9	"	5/62	16y	F	1.4	0.017	0.150
15	"	11/62	16y	F	0.6	0.013	0.057
14	"	11/62	19y	V,R	0.9	0.013	0.190
13	"	11/62	72y	V	0.9	0.021	0.173
16	Low	11/63	4y	F	2.3)	0.009	0.094
16				V	2.5)		
35	Medium	6/63	84y	H	0.3	0.041	0.077
17	High	8/63	1y 3m	F	2.1	0.026	0.096
27	"	12/63	3y 9m	L	2.2	0.012	0.085
18	"	8/63	5y	F	1.3	0.010	0.076
22	"	7/63	5y 6m	F	1.4	0.008	0.050
21	"	1/63	7y	F	0.9	0.026	0.151
20	"	2/63	19y	F	1.4	0.023	0.072
25	Low	4/64	SB	L	1.0	-	-
25				R	1.0	-	-
25				V	0.9	-	-
26	Low	4/64	SB	L	0.6	-	-
26				R	0.9	-	-
26				V	0.8	-	-
26				S	0.7	-	-
24	Low	4/64	6y	F	1.2)	0.021	0.069
24				V	1.0)		
28	High	2/64	6y	L	1.4	0.008	0.058
74	Low	11/66	3y	F	3.0	0.014	0.139
46	"	7/66	7y	F	1.9	0.009	0.036
42	"	6/66	16y 6m	F	1.0	0.074	0.098

(continued)

Sample Data					Radionuclide Levels		
					Artificial	Naturally-Occurring	
Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
43	"	6/66	19y	F	0.5	0.010	0.057
49**	-	9/66	18y	F	0.5	0.023	0.085
58	Low	7/66	20y	F	0.9	0.017	0.090
71	"	11/66	21y	F	0.5	0.037	**0.114**
68	Low	8/66	23y	F	0.4	0.010	0.109
79	Medium	12/66	2y 6m	F	1.5	0.011	**0.107**
52	"	8/66	3y	F	2.1	0.036	0.046
72	"	11/66	3y	F	1.5	0.013	**0.121**
86	"	12/66	3y	F	2.4	0.030	
41	"	6/66	3y 6m	F	2.4	0.020	0.069
83	"	11/66	5y	F	1.5	0.016	**0.112**
44	"	6/66	7y	F	2.0	0.006	0.048
47	"	7/66	7y	F	2.3	0.013	0.037
56	"	8/66	7y	F	1.5	0.010	0.076
80	"	12/66	7y 9m	F	2.1	0.021	**0.155**
62	"	8/66	8y	F	1.4	0.016	-
81	"	11/66	8y 8m	F	1.4	0.030	**0.155**
61	"	8/66	9y	F	1.4	0.014	0.100
53	"	8/66	9y	F	1.3	0.022	0.054
65	"	9/66	9y	F	1.3	0.142	0.292
76	"	11/66	9y	F	1.0	0.020	**0.129**
84	"	12/66	10y 7m	F	1.2	0.029	**0.146**
73	"	11/66	12y	F	1.2	0.016	**0.126**
59	"	9/66	13y	F	1.2	0.017	0.119
60	"	8/66	14y	F,V	1.2	0.013	0.087
51	"	8/66	14y	F	1.1	0.024	0.038
87	"	12/66	14y 7m	F	1.0	0.012	0.043
63	"	8/66	15y	F	1.1	0.010	0.075
78	"	12/66	15y	F	1.8	0.031	0.042
55	"	8/66	16y	F	1.7	0.016	0.063
50	"	10/66	16y	F	0.9	0.030	0.067
75	"	11/66	16y	F	0.9	0.014	**0.115**
77	"	12/66	16y	F	1.0	0.010	**0.102**
38	"	6/66	17y	F	1.0	0.021	0.047
82	"	11/66	17y	F	1.1	0.033	**0.198**
70	"	10/66	18y	F	1.0	0.038	**0.167**
64	"	7/66	19y	F	0.9	0.018	0.102
45	"	6/66	20y	F	0.9	0.010	0.046
57	"	7/66	22y	F	0.6	0.011	0.071
48	"	8/66	22y	F	0.6	0.010	0.042
69	"	10/66	22y	F	0.8	0.013	0.097
40	"	6/66	24y	F	0.5	0.012	0.073
54	"	8/66	25y	F	0.4	0.019	0.042
85	"	12/66	27y	F	0.2	0.012	
39	"	6/66	31y	F	0.5	0.016	0.093
67	High	8/66	14y	F	2.4	0.017	0.115
37	"	5/66	17y	F	1.0	0.014	0.058
66	"	8/66	17y	F	1.4	0.016	0.092
89	Low	1/67	18y	F	1.0	0.023	
91	High	7/67	3y	F	2.6	0.008	
92	"	12/67	15y	F	1.4	0.014	
90	"	6/67	18y	F	1.9	0.026	
93	High	4/68	5y	F	1.7	0.022	0.031
94	"	8/68	15y 6m	F	1.6	0.026	
96	Medium	4/71	15y 10m	V	1.1	0.011	
97	"	4/71	18y	-	1.0	0.041	
95	"	4/71	76y	V	1.1	0.024	

* Occupationally exposed to luminizing materials.
** Resident in New Zealand a very short time - most of life spent in Australia.
*** To convert approximately pCi/g Ca into pCi/g ash multiply by 0.39.