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PRELIMINARY REPORT

RONGELAP REASSESSMENT PROJECT

APRIL 15, 1988

Rongelap Reassessment Project
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1. INTRODUCTION

1.1 Task

Rongelap Atoll was accidentally contaminated with radioactive fallout in 1954 as a result of the Bravo thermonuclear test-shot at Bikini, 130 miles away. In 1978, to inform the Rongelap people of the extent of residual contamination 24 years later and of its potential effects upon their health, DOE (Department of Energy) surveyed the region and subsequently issued a specially prepared book report in Marshallese.

The book was entitled, The Meaning of Radiation for Those Atolls in the Northern Part of the Marshall Islands that were Surveyed in 1978, and was published in 1982. (We shall refer to it as DOE-1982.) The first part dealt in general with radiation and fallout, and how they might affect plants, animals and man. The situation at Rongelap was dealt with specifically on pages 38 - 39. (Note 1)

DOE's assessment of Rongelap Island was not accepted by the Rongelap people, so much so that in 1985 the residents abandoned their homes and moved to Majieto in Kwajalein Atoll.

The U. S. Congress, therefore, provided for an independent assessment of DOE's conclusions for Rongelap Island in the Compact of Free Association Act of 1985 (U.S. Public Law 99-239, section 103(i); see Note 2). The functions of the present report are therefore as follows:

"[The referee shall] review the data collected by the Department of Energy relating to the radiation levels and other conditions on Rongelap Island resulting from the thermonuclear test...The purpose...shall be to establish whether the data cited in support of the conclusions as to habitability of Rongelap Island as set forth in the [book] ...are adequate and whether such conclusions are supported by the data....If...the data are inadequate to support...habitabilty...the government of the Marshall islands shall contract...[for]...a complete survey...[and for recommendations of]...the steps needed to restore habitability..."

1.2 Procedure

The DOE-1982 book now under review was discussed with its senior author, Dr. William Bair (Pacific Northwest Laboratories, Richland, Washington 99352), and Dr. Bair has read the parts of this Report referring to it. Dr. William Robison (Environmental Sciences Division, Lawrence Livermore Laboratory, Livermore CA 94550), who supplied the field data was also interviewed.

Relevant Rongelap studies that were supported by DOE at Brookhaven National Laboratory (Upton, New York 11973), were discussed with Dr. William H. Adams, (Medical Department) and Mr. E. Lessard (Safety & Environmental Protection Division). The citation of their work in this Report has been checked by them.

Additional information from DOE-supported laboratories that became available after DOE-1982 had been written was made available to us by Adams, Lessard and Robison. Also, we have taken a number of samples in the field and have had them analyzed independently.

Other sources of information in the international literature have been used and are cited in the text.

We have also discussed from time to time various matters relating to the Report, or the progress made in developing it, with the Rongelap people or their representatives, including Senator Jeton Anjain, P.O. Box 1006, Majuro, Republic of the Marshall Islands, 96960.

We have also consulted Mr. Peter Oliver, Special Assistant for Compact Affairs, Republic of the Marshall Islands, P.O. Box 15, Majuro, 96960.

The Reassessment Report (the present document) was written by Henry I. Kohn in his capacity as Referee under contract with RepMar. The opinions and statements made are therefore his responsibility. The task, however, was greatly facilitated by employing an international panel of experts, selected so as to represent a variety of overlapping specialties that would cover the problems under examination.

If they chose to do so, the consultants who were still in disagreement with the final draft of the Report (having discussed earlier versions with Dr. Kohn), were asked to write brief notes on their own views to be mentioned in the text and to be included as footnotes or among the "Notes to the Text".

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Others have informally helped in the production of this report.

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Republic, lists the population of the atoll as totalling 235. Previously, it was 165 in 1973, 189 in 1967, 264 in 1958. In 1954 at the time of the Bravo incident, 84 persons were evacuated. (These fluctuations reflect the need to work elsewhere?.) Earlier records for Japanese and German periods of control are: 99 in 1945, 98 in 1935, 110 in 1920, 100 in 1906, 120 in 1860.

However, Mr. Peter Oliver, the Republic's Special Assistant for Compact Affairs, has informed me that the Rongelap Distribution Authority now makes per capita payments from its Nuclear Claims Fund to 1,578 individuals. Currently, these amount to $1480 per year to those exposed to fallout in 1954, and $480 to others. The Council has also determined that 2,277 individuals qualify for the benefits of the Section 177 Health Care Program as a result of their ties to Rongelap.

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It had been planned that the "cloud" would be blown to the west and north (Fig. 2.1 #1). Unexpectedly for whatever reason (Note 3), it was blown to the east so that at about 5 hours after detonation fallout began at Rongelap Atoll, and during the ensuing 7 hours fell in such quantities as to suggest to Rongelapese, who had never seen snow, that it was snowing (Sharp & Chapman, 1957). Rather than avoiding contact, children played in the powdery, finely granular fallout, and no particular effort was made to separate it from food or clothing. No warning was or had been issued by the military.

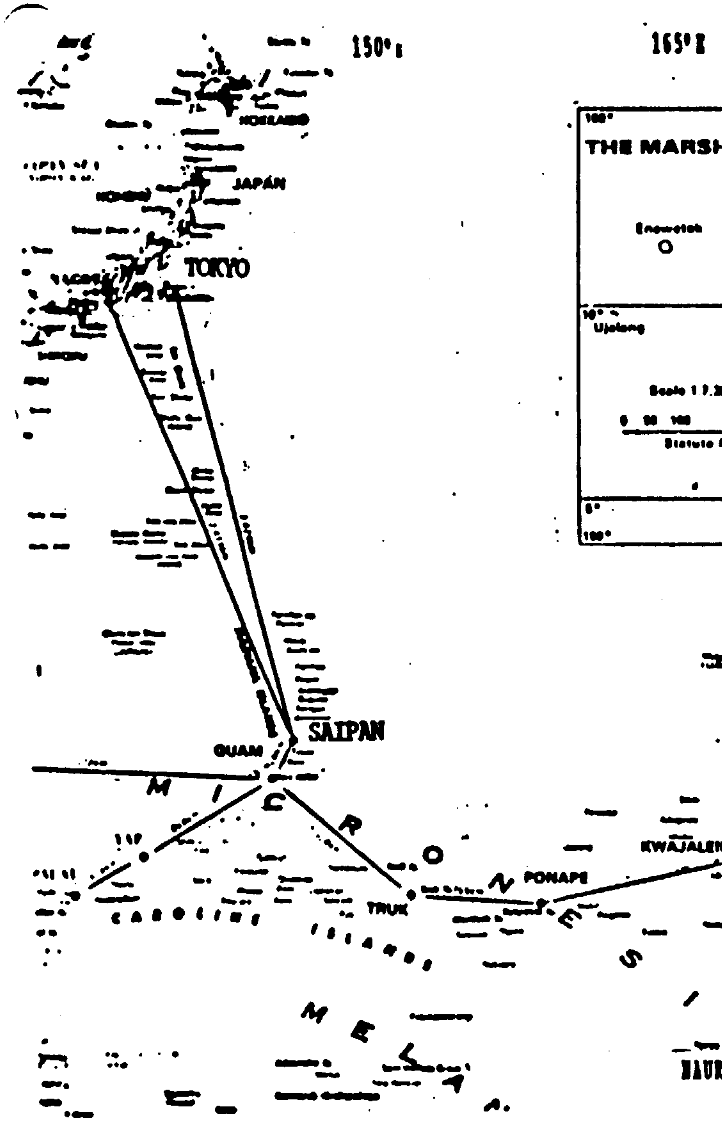

Fig. 2.1 #1 LOCATI

About 50 hours after the "shot", the Navy removed the 64 Rongelap residents from the Atoll to the medical base at Kwajalein (Sharp & Chapman, 1957; Cronkite et al, 1956) Also, eighteen visiting Rongelapese were removed from Sifo Island, Ailingnae Atoll, and 157 Utirik people from Utirik Atoll. It was immediately recognized that the surveillance and care of these people required far more professional staff than the base could supply, and a special medical team hurriedly organized for this purpose in the United States, utilizing naval and AEC personnel, reached the base 8 days after the detonation.

Consistent with a whole-body dose of 190 rem (over two days), two-thirds of the Rongelap group experienced nausea, 10% with vomiting and diarrhea, which cleared within three days or so, and all showed depressed white-blood-cell counts (Cronkite et al, 1956). As a result of the skin dose from physical contact with fallout, about 70% developed skin lesions of widely varying severity after a latency period of two to three weeks. Most of these were to heal successfully but a few developed significant scarring.

The most "significant" part of the initial exposure produced no immediate signs or symptoms. A half-dozen thyroid-seeking radionuclides entered the body through fallout-contamination of food and water. Over the course of the following weeks these iodine and tellurium radionuclides delivered doses that eventually caused thyroid hypofunction and the appearance of thyroid tumors.

The Bravo test posed new dosimetry problems, only vaguely sensed before. Owing to the gigantic energy-yield at ground level, great quantities of coralloid radioactive material were generated (Hiroshima and Nagasaki had involved high air-bursts): 142 radionuclides were involved whose radiations and rates of decay varied greatly, and whose eventual effects depended on the weather conditions and the living habits of the exposed population.

At the time of evacuation, the exposure rate in Rongelap village was 1.2 - 2.3 R/hour. The whole-body dose of "175 R in air" reported in 1956 was approximately correct. The dose estimate for the thyroid gland, however, was much too low because only iodine-131 had been considered in the calculation. As a result, the appearance of thyroid disease later on was quite unexpected.

An upwards revision of thyroid dose was reported in 1964 when iodine-133 and iodine-135 were included. (James, 1964). The revisions of 1984 (Lessard et al, 1985; Lessard, 1984a), based on a comprehensively planned attack on the problem (Bond et al, 1978), put the mean adult whole-body dose at 190 rem. The revised total dose to the thyroid gland, including contributions from all seven important radionuclides was greatly increased and varied significantly with age at exposure in 1954 -- from 5,200 rem for a one-year old to 1,600 rem at age 14, and 1,200 rem for the adult male. It was estimated that 95% of the thyroid dose was received during the first three post-exposure weeks, and 100% within three months (Note 4).

2.2 Return to Rongelap - 1957

The AEC (Atomic Energy Commission)[1] decision that Rongelap had become safe was based on field data by the Radiation Ecology Laboratory, University of Washington College of Fisheries, and dose calculations by AEC staff. For 1957 the annual external gamma dose at Rongelap Island was estimated to be less than 0.5 roentgen, the maximum permissible for the general population, and it was expected to decline owing to physical decay. However, the AEC assessment was inadequate with respect to internal dosage resulting from contaminated food (Note 5).

In 1957, therefore, the Rongelap people returned to Rongelap Island. In March 1958 there were 81 persons there who had been exposed on Rongelap or Ailingnae, and approximately 100 others who had not.

To anticipate any late effects that might follow the acute exposures of 1954, the AEC commissioned Brookhaven's Medical Division to establish the Marshall Islands Medical Program, whose staff has visited the Rongelap people once or twice a year since 1957. Since Rongelap soil still contained low levels of radionuclides which might enter the body through the food chain, the program included equipment to measure radionuclides within the human body (whole-body counting). Since 1978 the counting program has been operated by Brookhaven's Safety & Environmental Protection Division.

2.3 Rongelap: 1957-1987

The medical findings were summarized or updated by R. A. Conard, who led the whole program for many years (Conard et al. 1958; 1975; 1980) and more recently by Adams et al (1984). The status of the dosimetry, originally included in the Conard reports, has been more recently reported on by Lessard et al (1984; 1985). In brief, the following sequence of health-related events occurred over the past 30 years.

1957-63. General health was improved compared to that prior to the Bravo shot, owing to the medical attention received. Among the usual problems in the Marshall Islands were parasitism, chronic skin disease, diabetes adult-onset type II, and bad teeth in adults, and infant diarrhea. The vast majority of skin reactions to radiation had disappeared without sequelae, except for scarring in the most heavily irradiated cases. No skin cancers were observed. Two possible examples of radiation effects occurred. First, it was reported that about twice as many abnormally terminated pregnancies occurred among the exposed parents as would be expected normally. Second, two boys showed markedly stunted growth, suggesting thyroid deficiency.

1964-75. Unquestionable damage to the thyroid gland, especially to those exposed below the age of 10, made its appearance. A reexamination of earlier estimates of dose to the thyroid gland led to their elevation by a factor of about 2 for adults, and 5 or more for children. The administration of thyroid hormone (interrupted on occasion) to the entire exposed population was begun in 1965 as a prophylactic measure against thyroid neoplasia (nodules, cancer), and also to correct for possible losses in thyroid function.

By the end of 1974 (Fig 2.3 # 1), the thyroid tumor record was as follows:

Age below 10 in 1954: 17 tumors in 19 persons examined, including 1 cancer.

Age 10-18 years in 1954: 2 tumors in 12 persons examined.

Age above 18 years in 1954 : 3 tumors in 33 persons examined, including 2 cancers.

Almost all persons with thyroid nodules were sent for surgical treatment to the Cleveland Metropolitan Hospital, Cleveland, Ohio. Each one was compensated at the rate of $25,000 per surgery.

The occurrence of thyroid disease as well as a case of acute leukemia worried the Rongelap people. The medical team was accused of having deceived the Rongelap people and of using them as guinea pigs. The Brookhaven medical services were boycotted during 1972, but they were accepted later in the year after a favorable report on the matter by an international committee.

EG&G and some terrestrial work by Lawrence Livermore National Laboratory (Robison et al, 1980; Robison et al, 1982b; Tipton & Meibaum,1981).

<u>1980-84</u>. DOE summarized its survey results in 1982 with a report in Marshallese, embellished with colored illustrations. (This is the DOE-1982 book under review in the present report. See Note 1.) The conclusion, that Rongelap Island was safe, was not accepted by all of the people. The Rongelap people requested the Government to transfer them to another atoll. Significant parts of the anti-nuclear documentary film, <u>Half-Life</u>, were filmed at Rongelap. The film suggested that the people had been used as "guinea pigs".

1985. The Rongelap people abandoned Rongelap and sailed for Majieto Island in Kwajalein Atoll. The U. S. Congress passed the Compact of Free Association Act of 1985 (Public Law 99-239) of which Section 103(i) is the basis for the present inquiry (Note 2).

1987 The following points are of major interest for the present report.

(a) A clear distinction should be made between the late effects of the large acute exposure in 1954 (190 rem whole-body) and the possible (but as yet undetermined) effects of the much smaller chronic dose since resettlement in 1957 (3.5 rem or less to 1978).

(b) The original dose estimates for the 1954 exposure were much too low, especially for the thyroid gland. The necessity for major correction later on weakened or destroyed Rongelap confidence in DOE. The residual radiation doses during the first years of resettlement may also have been underestimated, but the corrections would be much smaller.

(c) The occurrence of thyroid tumors (~ 30%) 10 years or later after returning to Rongelap (Fig. 2.3 #1; Note 4B) has been a confusing experience for the Rongelap people. In addition, eight cases of hypothyroidism have been observed (Adams 1988).

(d) No significant increase in tumors outside of the thyroid gland has been seen (Adams et al, 1984), except for 1 basal cell epithelioma in 1987 (Adams 1988). The finding, however, is limited by the small number of persons at risk (81 exposed).

Figure 2.3 #1. Latency period for appearance of thyroid nodules related to thyroid dose received in 1954 at Rongelap & Ailingnae, and Utirik. Details on thyroid dosage are given in Table N.4 #2.

(Figure courtesy of W. H. Adams, Brookhaven National Laboratory)

(e) No obvious gross difference in survivorship between 1954-exposed and 1954-unexposed groups has occurred (Fig. 2.3 #2). Although statistically significant decreases in some blood-cell types have been noted (Adams et al, 1982), none has been clinically significant.

(f) Based on four parameters (longevity, thyroid nodules, carcinoma, blood counts), there is no evidence of effects from the chronic low-level exposure associated with residence on Rongelap since 1957 (Note 4(b)). These studies are admittedly exploratory and cover only a small part of the health spectrum. However, the average dose over the period 1957-78 is quite small (3.5 rem or less), and will be accumulated at lower rates in the future.

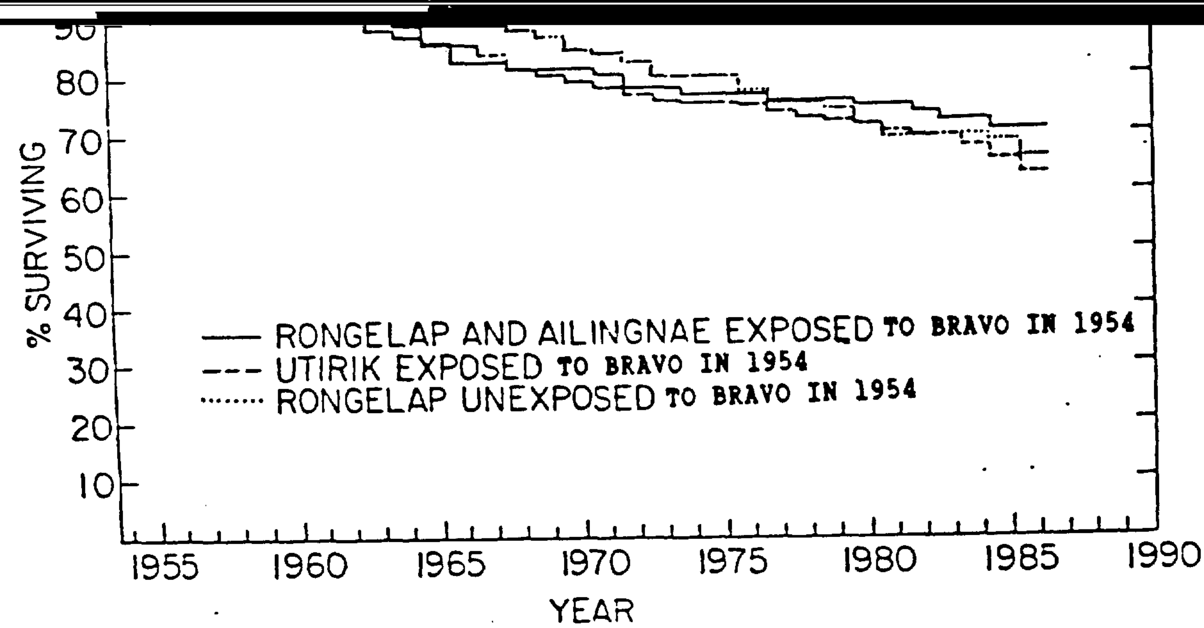

FIGURE 2.3 #2   Survival as a function of time after 1954.

The numbers exposed and whole-body doses were: Rongelap, 67 persons, 190 rem; Ailingnae, 19 persons, 110 rem; Utirik, 167 persons, 11 rem. The unexposed group of 86 Rongelapese was matched (age, sex) in 1957 to the Rongelap-Ailingnae group and has been followed for survival annually.

(Figure courtesy of W. H. Adams, Brookhaven National Laboratory.)

3. REASSESSMENT

With the foregoing as background, let us now attempt to answer the questions which the Congress has asked: Were the doses calculated by DOE for 1978 correct? Does it follow that Rongelap is habitable? If not, what should be done?

It should be noted that the technical position has changed since 1982. More data have been published so that the original meager sampling has become more robust. In addition, we shall consider the findings of the Brookhaven National Laboratory, using an important method which DOE-1982 failed to consider, and also our own findings.*

The data base employed by DOE-1982 comprised the results of the Northern Marshall Islands Survey of 1978 (September-November) which had been planned as an aerial reconnaissance to map external gamma-ray exposure rates (normalized to 1 meter above ground level) (Tipton & Meibaum,1981). Two helicopters were employed, operating from a major support vessel, the U.S.N.S. Wheeling.

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* B. Franke states that the enabling legislation calls for study of only the original findings and report. A second committee should consider subsequent findings, and a third group should execute its recommendations.

Subsequently the Livermore Laboratory program was added to obtain soil, water, vegetation and fish samples at each atoll "as time and facilities might permit" (Robison et al, 1982, Part 1). The time spent at Rongelap Atoll permitted 7 days for 9 islands, of which the major one was Rongelap. Operating from a large ship that had to cruise at a considerable distance offshore, and whose primary function was aerial reconnaissance, restricted the terrestrial work significantly.

The radionuclides dealt with were four: cesium-137, which is distributed throughout the body; strontium-90, a bone seeker; plutonium-239.-240 and americium-241, which have very long half-lives and which are tightly bound by bone, liver and testes (Table 3 #1).

The Livermore group took soil samples from some 20 scattered locations on Rongelap Island whose averages (picocuries/gram) for 0-10 cm depth were: cesium-137, 12; strontium-90, 7.1; plutonium-239,-240, 2.6; americium-241, 0.9 (Table 3 #2).

This soil contamination provided the basis for human exposure in two ways. Radiations emanated from the ground or standing vegetation leading to external dose. Radiations that emanated from food and water after entering the human body were responsible for internal dose.

[redacted]

c/ Quality factor, 1

d/ X and gamma rays are omitted whose total contribution to dose would be less than 10%.

e/ Derived from ICRP Publications 30 and 48. The ICRP limit on intake for workers was divided by 30 (*) to bring the annual committed effective dose-equivalent to 170 mrem, or by 50 (**) for 100 mrem. The ICRP limit includes a factor of 2 to prevent any one tissue receiving more than 50 rem. That factor is unnecessary in the present low-dosage case. The numbers in parentheses give the applicable guide without such correction.*

f/ ICRP Publication 30. Supplement to Part 1. (Annals, Vol. 3), and ICRP Publication 48 for transuranics.

*John Dunster adds: The intake limits apply to adults. For children, the strontium limit should be divided by a factor of about 3, and those for plutonium and americium by about 2. (National Radiation Protection Board G 87, Aug 87.)

TABLE 3 #2

RONGELAP ISLAND: RADIONUCLIDE SOIL PROFILES[a/b/]

Depth (cm)		Average specific activity for dry soil (pCi/g)							
		Cesium-137		Strontium -90		Plutonium -239,-240		Americium -241	
1978	1987	1978	1987	1978	1987	1978	1987	1978	1987
0-5	0-10	15	10.1(7)	6.9		3.2		1.0	1.7(3)
5-10		9		7.7		2.0		.78	
10-15	10-20	5.4	1.2(1)	6.7		1.1		.41	
15-25		2.6		4.5		.35		.18	
25-40		1.8		2.1		.07		.08	
0-40		5.0		4.6		.89		.35	
Number of profiles		27		20		18		17	

a/ The 1978 profiles are from Robison et al, 1982, Part 4, Appendix B.

b/ The 1987 values are from Boikat and Paretzke (Note 8). The number of samples is given in parentheses. They are corrected back to 1978.

The total dose received was the sum of the external and internal doses. The external whole-body dose was estimated by measuring the exposure in air (e.g., at 1 meter above ground) and applying a factor based ultimately on measurements with phantoms to the meter reading. The internal dose was estimated by the Livermore group on the basis of an assumed diet and the analysis of the radionuclide contents of Rongelap food products in it.

The lagoon and its fish were found to be a trivial source of dose. Ground water (well water) was an unimportant source, since its activity was very low and, in any case, the people relied heavily on catchment of rain rather than wells (Noshkin et al 1981).

Before considering the data, the nonprofessional reader may wish to consult Note 6 which explains the radiological usage of such terms as exposure and dose, and the definition of their units. It may also be noted here that my use of the term whole-body dose (internal) usually signifies the committed effective dose equivalent; the tissue dose (internal) is usually the committed dose equivalent. The Livermore Laboratory calculated its doses as integral doses, i.e., for a stated period of time, the annual dose for each year was summed.

[illegible]

et al, 1982b, Table 14). I take this to be the "tissue dose" and it is approximately equal to the committed dose equivalent.

(3) The highest dose to any one person was set at 0.4 rem, this being three times the average dose.

For orientation, it may be said immediately that DOE's whole-body and bone-marrow doses are for all practical purposes confirmed by recalculations employing the original data and assumptions, and by those employing subsequent findings on additional field samplings.

The independent assessment by the Brookhaven National Laboratory, based on whole-body counting for cesium and urinary analysis for strontium, lowers the whole-body dose significantly. This estimate, in my opinion, is the definitive one.

Brookhaven's estimate of the transuranic dose (plutonium, americium) has raised the question of the size of its contribution to dose--a matter which is under discussion--but in any case, not great enough to prevent a decision from being made.

The question of infant dosage, neglected previously, has been dealt with specifically (or will be).

[redacted]

µR/h).

The external dose (whole-body), was calculated from exposure by my assuming 1 roentgen = 0.7 rem (Kerr, 1980). For Rongelap Island the annual dose was .028 rem, well below the EPA guide of .170 rem/year; 8 other major islands were also below the guide (Table 4.1 #1).

There is also a shallow dose to be considered, that due to beta rays which travel for short distances into those parts of the body that are near or in close contact with the soil and that are unshielded. Their contribution is considered to be negligible (Note 9).

TABLE 4.1 #1 AVERAGE EXTERNAL EXPOSURE AND EXTERNAL DOSE RATES (gamma ray) FOR ISLANDS AFFECTED BY BRAVO FALLOUT

Atoll and Reference	Island	Year	Exposure (gamma) a/	Dose (whole-body) b/
			microroentgens/hour	rem/year
Bikini Atoll				
Tipton & Meibaum (1981)	Eneu	1978	2.7	.017
	Bikini		35.0	.215
Shingleton et al (1987)	Eneu	1986	--	.018
	Bikini		--	.160
Rongelap Atoll				
Tipton & Meibaum (1981)	Rongelap	1978	4.5	.028
	Arbar		4.1	.025
	Busch, Tufa, Borukka, Gabelle		5-9	.031-.055
	Eniaetok, Kabelle, Gogan		10-27	.061-.166
	Lukuen, Naen, Yugui, Lomuilal		28-43	.172-.264
Paretzke (Note 8)	Rongelap	1987	4.1 (7)c d/	.025
Greenhouse & Miltenberger (1977)	Rongelap	1977	3.6-4.5	.022-.028
Ailingnae Atoll				
Tipton & Meibaum(1981)	Sifo	1978	1.4	.009
Paretzke (Note 8)	Mogiri	1987d/	1.3 (1)	.008
	Enibuk		2.2 (1)	.013
Utirik Atoll				
Tipton & Meibaum(1981)	Utirik	1978	0.8	.005

a/
Measured at 1 meter above ground level, corrected for cosmic rays.

b/
Annual, whole-body dose (millirem/year) calculated as equal to 6.13 x μR/hour. For the epidermal dose, see Note 9.

c/
The average of 7 locations ranging from 2.2 to 4.6 μR/hour.

d/
Corrected for decay back to 1978.

RONGELAP ATOLL

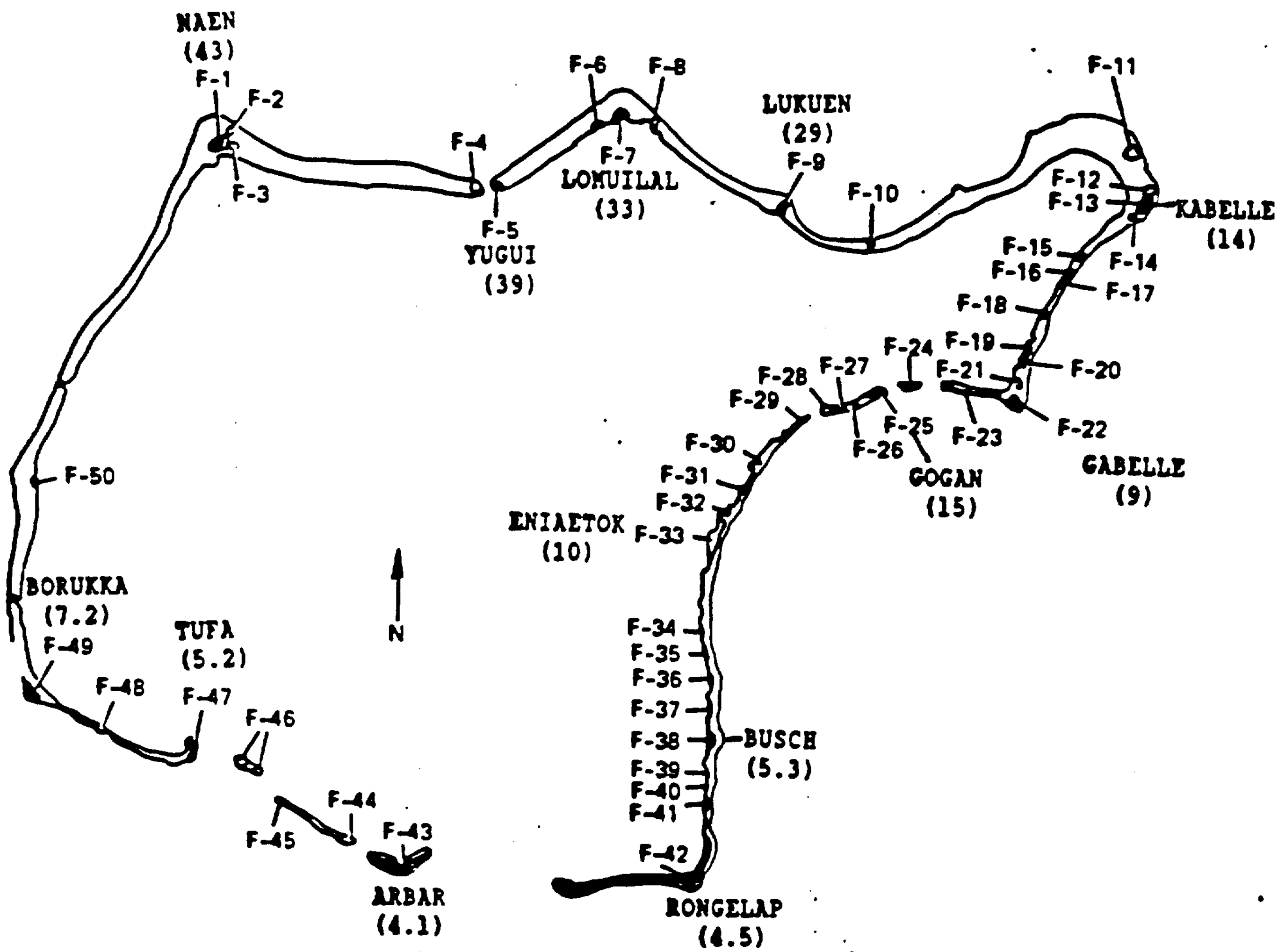


Figure 4 #1 PRINCIPAL ISLANDS OF RONGELAP ATOLL

The numbers in parentheses are the external whole-body exposure-rates in microroentgens/hour, corrected for cosmic radiation, as determined in 1978 by aerial survey (Tipton & Meibaum, 1981).

[illegible]

would decrease it by 25% or more. The 30-year whole-body dose would be .590 rem allowing for spontaneous decay, but not shielding. Environmental decay such as leaching of radionuclides from the soil would reduce this estimate still more, but was not allowed for.

4.2 Internal Dose - Lawrence Livermore National Laboratory

Lawrence Livermore attacked the problem by determining what went into the body by ingestion and inhalation (picocuries per day), and then applying appropriate factors to such input (exposure) to obtain the dose in rem. The particular ones I have used are given in Table 4.2 #1.

Ingestion. The major uncertainty lies in the diet--no one knows precisely what it is, although several attempts have been made to define it. To be on the safe side, DOE-1982 chose the BNL community B diet, i.e., one involving a greater amount of food and also a greater input of contaminated food (Note 11). Naidu et al (1980) who originally described it commented that the diet represented prepared, not eaten food, and that in fact it was more than a person could eat. This results in overestimation of dose. The Lawrence Livermore group that used it for dose calculations concurred.

The 1978 specific activities measured by the Livermore team were made on 21 samples of coconut, 5 of Pandanus, 1 of breadfruit, 1 chicken, 2 pigs and 98 fish, on the whole a barely adequate number (Robison et al, 1981a, 1982b). In 1986, however, the Laboratory took additional samples (Robison 1988), and in 1987 this project also collected some which were analyzed independently. The results, summarized in Table 4.2 #2, show remarkable agreement for the Livermore cesium data on the foods contributing the major part of exposure and reasonably good agreement for the smaller independent confirmation. (?) (Expand this when more data available?)

TABLE 4.2 #1A

INGESTION

FACTORS TO CONVERT "INITIAL DAILY INTAKE (pCi/d)" TO

"WHOLE BODY" OR "TISSUE" DOSE (rem) FOR DIFFERENT PERIODS OF DAILY INTAKE [a]

Radionuclide & period	C.E.D.E.[b]	Red marrow	Lungs	Bone surfaces	Liver
CESIUM-137					
initial year	1.7 E-5[c]	1.8 E-5	Like C.E.D.E		
0-30 year	3.7 E-4	3.8 E-5			
30-70 year	2.2 E-4	2.4 E-5			
STRONTIUM-90					
initial year	4.7 E-5	2.4 E-4	1.8 E-6	5.3 E-4	1.8 E-6
0-30 year	9.2 E-4	5.0 E-3	3.6 E-5	1.1 E-2	3.6 E-5
30-70 year	5.6 E-4	3.0 E-3	2.2 E-5	6.6 E-3	2.2 E-5
PLUTONIUM-239.-240					
initial year	1.3 E-3	1.9 E-3	1.0 E-8	2.4 E-2	4.2 E-3
0-30 year	3.9 E-2	5.7 E-2	3.1 E-7	7.3 E-1	1.3 E-1
30-70 year	5.1 E-2	7.4 E-2	4.1 E-7	9.6 E-1	1.7 E-1
AMERICIUM-241					
initial year	1.3 E-3	Like plutonium			
0-30 year	3.9 E-2	5.7 E-2	1.6 E-6	7.3 E-1	1.3 E-1
30-70 year		Like plutonium			

[a] It is assumed that the daily diet remains constant, but that the radionuclides in it decay spontaneously. The table provides dose factors in rem/picocuries/day. It is based on NRPB (1987) which provides factors in Sv/Bq (= 3.8 x rem/picocurie), and is consistent with ICRP recommendations (ICRP 1986, 1987). These factors allow for the fraction of radionuclide ABSORBED FROM the gut, its distribution and residence time in the body, the absorption and effectiveness of its radiation in the body, and its rate of physical decay.

[b] Committed effective dose equivalent (whole-body dose). Other doses are committed dose equivalents (tissue dose). The C.E.D.E. is the sum of the dose equivalents to 11 tissues of the body of a standard man, each weighted by the risk resulting from a unit dose to that tissue as compared to the risk from a unit dose to the whole body.

[c] E-5 signifies: $\times 10^{-5}$.

TABLE 4.2 #1B

INHALATION

FACTORS TO CONVERT "INITIAL DAILY INTAKE (pCi/d)" TO

"WHOLE BODY" OR "TISSUE" DOSE (rem) FOR DIFFERENT PERIODS OF DAILY INTAKE a/

Radionuclide & period	C.E.D.E.b/	Red marrow	Lungs	Bone surfaces	Liver
CESIUM-137					
initial year	1.0 E-5c/	9.9 E-6	1.1 E-5	9.4 E-6	1.0 E-5
0-30 year	2.2 E-4	2.0 E-5	2.2 E-4	2.0 E-4	2.2 E-4
30-70 year					
STRONTIUM-90					
initial year	7.7 E-5	4.2 E-4	4.6 E-6	9.2 E-4	3.1 E-6
0-30 year	1.6 E-3	8.7 E-3	9.5 E-5	1.9 E-2	6.4 E-5
30-70 year					
PLUTONIUM-239.-240 & AMERICIUM-241					
initial year	1.5 E-1	2.3 E-1	2.3 E-2	2.8 E-0	5. E-1
0-30 year	4.5 E-0	6.9 E-0	6.9 E-1	8.4 E-1	1.5 E-1
30-70 year	6.0 E-0	9.2 E-0	9.2 E-1	1.12 E-2	2.0 E-1

a/ It is assumed that the daily diet remains constant, but that the radionuclides in it decay spontaneously. The table provides dose factors in rem/picocuries/day. It is based on NRPB (1987) which provides factors in Sv/Bq (= 3.8 x rem/picocurie), and is consistent with ICRP recommendations (ICRP 1986, 1987). These factors allow for the fraction of radionuclide absorbed from the gut, its distribution and residence time in the body, the absorption and effectiveness of its radiation in the body, and its rate of physical decay.

b/ Committed effective dose equivalent (whole-body dose). Other doses are committed dose equivalents (tissue dose). The C.E.D.E. is the sum of the dose equivalents to 11 tissues of the body of a standard man, each weighted by the risk resulting from a unit dose to that tissue as compared to the risk from a unit dose to the whole body.

c/ E-5 signifies: x 10^{-5}.

Table 4.2 #2 COMPARISON OF ACTIVITY MEASUREMENTS (Referred to 1978)
CESIUM-137 and STRONTIUM-90

		a/b/ Livermore (collected in 1978)			b/ Livermore (collected in 1986)			b/c/ This Report (collected in 1987)	
a/ Item	grams/ day eaten	# samples	pCi/ gram (fresh)	pCi/ day	# samples	pCi/ gram (fresh)	pCi/ day		pCi/ gram (fresh)
				CESIUM-137					
Copra nut products	293	(18)	6	1758	(4)	6.2	1817		
Drinking nut:									
Meat	100	(3)	2.6	260	(86)	2.3	230	(6)	4.4
Juice	514	(3)	1.4	720	(85)	1.3	668	(7)	1.5
Pandanus juice	96	(2)	11.1	1066	(26)	10.9	1046	(1)	31.4
Breadfruit	36	(1)	2.7	97	(13)	3.4	122	(1)	5.3
Pork	1.4	(2)	8.5	12		—			
Chicken	3	(1)	2.5	8		—			
Fish	194	(98)	.025	5		—			
Arrow root	0		0	0		—		(1)	25.
Coconut crab	1			?					
Limes								(1)	2.3
TOTALS				3926			3883		
				STRONTIUM-90					
Copra nut:									
Meat	168	(8)	.022	4			To be done		
Juice	125	(10)	.004	0.5					
Drinking nut:									
Meat	100								
Juice	514	(3)	.0014	0.7					
Pandanus juice	96	(3)	.181[d/]	17.4					
Breadfruit	36	(1)	.095	3.4					
Pork	1.4	(2)	.005*	0.1					
Chicken	3	(1)	.009*	0.1					
Fish	194	(98)	.01*	1.9					
Arrow root	0								
Coconut crab	1								
TOTALS				28.2					

a/ The activities with an asterisk are from Robison et al (1982b), the original report. The other specific activities are a personal communication from Dr. Robison and involve a revision of the original data.

b/ Number of samples in parentheses. A sample comprised 5-6 coconuts, 3-5 breadfruit, and 1-2 Pandanus fruits.

c/ See Note 8 for details. Well water: cesium-137, .03 pCi/liter; strontium-90, .03 pCi/liter; plutonium-239, .0024 pCi/liter.

d/ The fibrous part of the fruit has a 10-fold greater strontium content, but is not eaten. Cesium is the same in both parts.

[redacted]

and the present doses are about 50% higher. The entries in the table above are based only on chemical determinations (number of samples in parentheses). They are responsible for about 25% of the total dose which Livermore now attributes to plutonium-239,-240 (.37 pCi/day) and americium-241 (.13 pCi/day). The rest of the dose was estimated by a ratio method of extrapolation: it was assumed that the Rongelap ratio, specific activity of food to that of soil (chemically determined) would equal the Bikini ratio (based on chemical determinations for both soil and food).

[redacted]

committed ones.

<u>Inhalation</u>. It is the transuranics that are of consequence. The original estimates of dust intake were very much too high (Shinn et al 1980) and they have been reduced to make them more realistic (Robison 1988). The daily intake for adults is estimated now at .0037 picocuries for plutonium-239,-240, and .0012 for americium-241. Their contribution to the effective whole-body dose would be about .023 rem in 30 years, and about 0.35 rem to the bone marrow, .075 rem to liver, and .42 rem to bone surface. The matter is discussed in Note 10.

<u>Summary</u>. Using the input method, the calculations of dose are in practical agreement with those of DOE-1982. It should be noted that these are for adults. It should also be noted that the estimates depend directly on the assumed diets. The following tabulation is a summary:

	30-year Dose (type B diet)	
Source	Whole-body dose (rem)	Red marrow dose (rem)
Inhalation	.023	.035
Internal doses:		
-cesium-137	1.63	1.67
-strontium-90	.032	.175
-transuranics	.02	.029
External dose	.590	.590
Totals	2.295	2.499
DOE-1982	2.500	3.300

For comparison, this project sampled three sites at Ailininae Atoll, which is not inhabited except for visits to gather food (Note 8). Landings were made on Mogiri, Gerea-Knox, and Enibuk Islands. The cesium-137 averages for the three sites for drinking-coconut meat and juice, and for the first 10 cm of soil, were less than 15% of the corresponding Rongelap averages. Two coconut crabs averaged 1.15 pCi/gram. The plutonium-239,-240 content was less than .006 pCi/gram.

[redacted]

to whole-body counting. The most likely source of the discrepancy would be the diet--the use of the type B diet. Robison (1983) has reported evidence that this could be so. If the MLSC diet (imports available) were employed (Note 11, Table 1), the cesium body content calculated from the input data (.19 microcuries) would be in approximate agreement for

[redacted]

Lessard and Robison agree to this statement?)

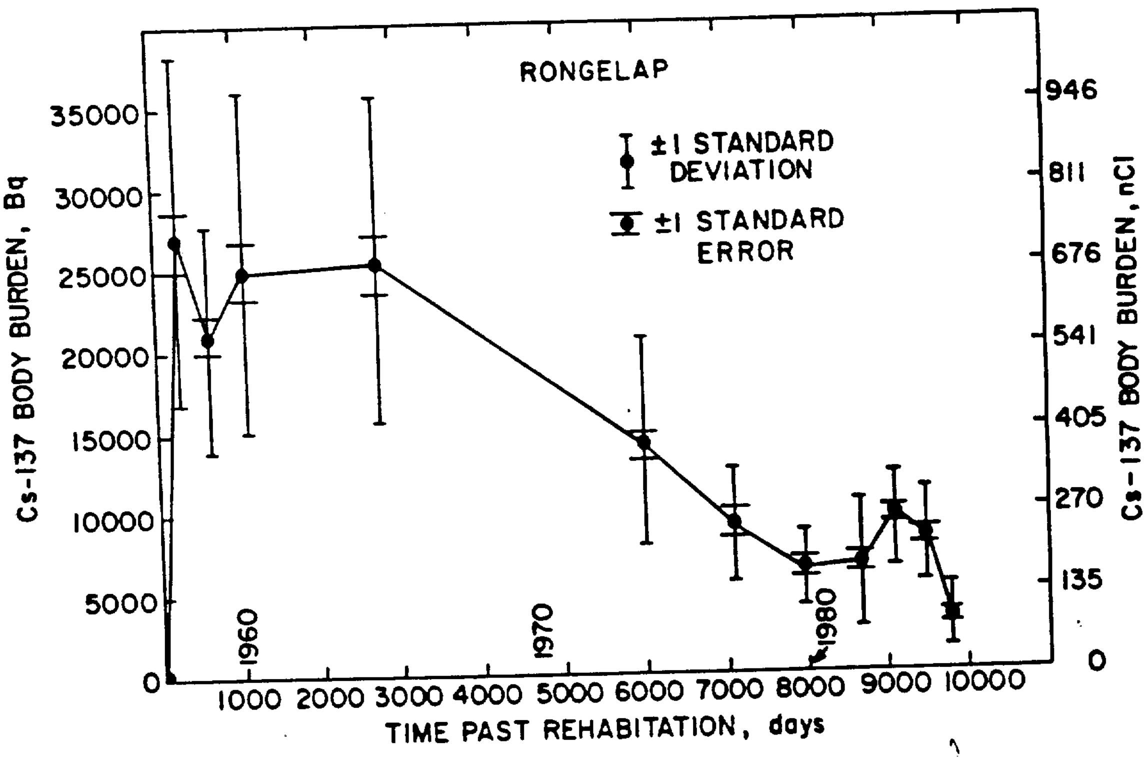


Figure 4.3 #1. Adult cesium-137 body burden as a function of time since resettlement of Rongelap Island in 1957.

The maintenance of the body burden depends on the radionuclide intake from the diet. The physical half-life is 30 years; the physiological half-life is 110 days in men, 80 days in women, and less in youths and children. (1 Bequerel = 27 picocuries; 1 nanocurie = 1,000 picocuries)

(Figure courtesy of E. T. Lessard, Brookhaven National Laboratory.)

We do not have an independent field check on the accuracy of the whole-body field measurements. The point may be made, however, that it was this team that discovered the precipitous rise in body-burden of the Bikini settlers in 1977-78 and who therefore called for their removal from Bikini Atoll (Miltenberger, 1980).

In the case of strontium, we shall take the 1980 findings at face value. The annual whole-body dose, based on urine analysis, was about .001 rem, from which I calculate a 30-year dose of .021 rem. The corresponding tissue doses are: red marrow .11 rem; bone surfaces, .25 rem.

In the case of the transuranics, the background of the problem is worth mention. The quantity of plutonium-239 in the urine is minute, being something like .1 to 1 x 10^{-3} picocuries/liter. It has only been during the past several years that the Brookhaven group has felt able to do accurate determinations using the new fission track method. More than 250 Rongelap samples have been analyzed, but none of these has been reviewed with repect to the history of the donor, i.e., age, period of residence on island, occupation, etc., owing to the fact that DOE cut down support for the project which has now been closed.

[redacted]

rem; bone surfaces, .153 rem; liver, .027 rem. The addition to these of the doses for plutonium-240 and of americium-241, which were not measured, would increase them, by perhaps a factor of two.

[redacted]

residence time is long, an appreciable difference can occur. However, because the transuranic contribution to the adult dose is so small, even if it be increased very appreciably in the infant, it will not necessarily be quantitatively important.

Balancing these variables against one another leads to the following committed dose factors (rem per picocurie daily intake) for whole-body exposure:

Radionuclide	Factor at specified age (rem/pCi/day)			
	0-1 yr	5 yr	10 yr	0-10 yr
Cesium-137				
Strontium-90				
Transuranics				

4.5 Dose Summary

DOE-1982 stated the whole-body dose (integral) to be 2.5 rem for the period 1978-2008, of which 1.63 rem stems from cesium-137. That dose, based on the type B community diet, is about 1 rem too high for the following reasons.

Whole-body counting is the superior method for the determination of the cesium-137 whole-body dose. Based on 1978 conditions at Rongelap Island, the cesium dose by that method for 1978-2008 would be .62 rem (committed effective dose equivalent).

For strontium-90, the urine-derived dose of .021 rem is 60% of that calculated from the diet (.035 rem). The difference is in the same direction as that for cesium, and is small enough in absolute terms so that it will not materially affect the outcome one way or the other.

For plutonium-239, the estimates based on urine (median value) and diet are close enough for practical purposes (.005 rem and .009 rem, respectively; total transuranic, .016 and .020 rem respectively). However, as noted above, the wide spread of the urine data do call for further investigation.

TABLE 4.5 #1

PROJECTED ADULT COMMITTED DOSES (1978-2008)
FOR RESIDENCE ON RONGELAP ISLAND

Radionuclide	Whole-body[a]	Red marrow[b]	Bone surfaces [b]	Liver[b]
	rem	rem	rem	rem
Internal:				
Cesium-137	.62	.62	.62	.62
Strontium-90	.021	.110	.250	< .001
Transuranics[b]	.016	.024	.300	.054
External:	.59	.59	.59	.59
Totals	1.25	1.34	1.76	1.26

a/ Committed effective dose equivalent (standard man) = whole-body dose. The current guide in the U. S. is 5 rem in 30 years. The type B diet is assumed.

b/ I would employ a guide of not more than 30 rem to any one tissue over 30 years, but due allowance must be made for the doses received by other tissues (ICRP No. 30).

c/ Plutonium-239, -240 and americium-241.

I therefore conclude that the doses in Table D.4 # 1 fall well within the present EPA guide for the general population of the U.S.A. (5 rem for 30 years, committed effective dose equivalent, standard man; I also take 30 rem in any one tissue except lens). They also satisfy the ICRP and NCRP guides (3 rem).

Whether or not these estimated doses guarantee that no one in any one year will exceed the individual guide of 0.5 rem, I cannot say. By and large that should be so. But if someone were determined that his intake should exceed the guide, I suppose that he could make it do so by changing his diet, or by eating a great deal of foods grown on highly contaminated islands (e.g., Naen).

The increase in cancer mortality resulting from the dosages of Table 4.5 #1 can be calculated as follows. Suppose that 500 persons were to live continuously on Rongelap Island for the period 1978-2008. On the average each would accumulate a committed dose (whole-body) of 1.25 rem over that 30-year period. For simplicity, I will assume that each receives the dose all at once. Then, taking an overall cancer mortality factor of 5×10^{-4} per rem (Shimizu et al, 1987; Preston and Pierce, 1987), I find the increment to be:

$$500 \times 1.25 \times 5 \times 10^{-4} = .31 \text{ extra cases.}$$

The factor for first generation genetic defects is smaller than that for cancer mortality (National Academy of Sciences, 1972; NCRP, 1987a), being approximately 1 x 10^{-4}.

The foregoing comments apply to the future. But what about the past? The Rongelap residents exposed to the Bravo shot received an acute dose of 190 rem in 1954 and during 1957-1978 they received a chronic dose of 1-3 rem. My opinion is that the addition to these past doses of something like 1.25 rem during the next 30 years will not appreciably increase detectable health and genetic risks in a way that should preclude return to Rongelap Island.

5. DISCUSSION AND RECOMMENDATIONS

The conclusions reached and the issues raised by the body of this report are quite straightforward. The dose received is due to radiations from (a) soil and vegetation externally, and (b) from the food eaten. The review has shown that DOE-1982 overestimated the 1978 adult dose. The whole-body dose reported now (1.25 rem, 30-year) is one-half of theirs; for the red marrow it is 40% (1.34 rem). Both sets of values (DOE-1982 and ours) are well below the current U.S. whole-body guide of 5 rem. I conclude that a return to residence on Rongelap Island is permissible.

(The doses in this report are for 1978. The current dose, 10 years later, would be about 20% less.)

5.1 Assumptions

Within the simple statement on return are several tacit assumptions. Living conditions on return should be equivalent to those prior to leaving in 1985. In particular, the diet should be equivalent to the former one and thus should meet the following conditions.

(a) The food consumed was in part raised locally, but was also purchased when the supply ship visited at regular intervals. I assume that as much money would be available now as was available then.

(b) In addition, the families received foods distributed by the USDA Special Food Assistance Program, but which has only one more year to go.

In the final year, the allotment will be one-quarter of what it has been. I understand that a request for a 3 or 5 year extension is being asked for. The extent to which this program, or an equivalent one, could continue into the future will require discussion.

(c) I have been told that it was only in 1982 that the people became aware of the restriction on food gathering in the more northern islands (e.g., Naen). That restriction should remain in force.

(d) Looking at the map in Fig. 4 #1, one can see how the external exposure rate (i.e., that from soil and vegetation) increases on both sides of the lagoon as one goes from the southernmost islands of Rongelap and Arbar toward the north. For the time being I would consider as forbidden territory all islands to the north of Borukka and Eniaetok. All to the south are suitable for food gathering and residence.

(e) There are no restrictions on fishing, anywhere. Clams, lobsters and terrestrial crabs are restricted like other foods.

(f) There are no restrictions that apply to Ailingnae Atoll.

(g) I would also add to these restrictions that no arrow root be consumed. None was consumed during the 10-15 years prior to leaving thin 1985 because, as I understand it, there was none on Rongelap Island. Since then the plant has returned. The plant is troublesome to prepare, and I would suppose that as long as supplies of flour and rice are available, it will not be used.

[redacted]
from subject to subject.

The problem should be approached from the perspective provided by the data in Table 4.5 #1. The transuranics (plutonium-239,-240 and americium-241) contributed less than 1.5% to the total whole-body dose. Suppose that they had been underestimated by a factor of 100. Their contribution would thus rise to 1.6 rem; added to the 1.25 rem from other sources would give a total whole-body dose of 2.85 rem. This dose is still within the guide.

As noted in Section 4.3, the great variations among the individual plutonium determinations do merit investigation and I urge DOE's support. I suggest that they are not entirely methodological, but stem from physiological variations due to age or other factors. It would be especially important to study the people before they return to Rongelap to determine how rapidly the body content is excreted, as well as after their return for purposes of monitoring.

Once the variation in the urine determinations is understood, their agreement or lack of agreement with the calculated output from an assumed diet could be attacked.

I understand that DOE is now considering the matter.

5.4 Monitoring and Health Programs

I recommend that the whole-body counting program to determine cesium-137 should be resumed as soon as practical. (It was discontinued in 1985.) It should be supplemented at the same time by studies on the strontium and plutonium content of the urine. These studies are essential for the control of the population's exposure to the radionuclides that contaminate the atoll.

Carried out properly, such studies are also of prime interest to scientists throughout the world who are interested in preserving the health of people who have been exposed to nuclear radiations. I know that the Rongelap people do not want themselves to be "guinea pigs" to satisfy the curiosity of research workers. But that is not the case here. The work done would help the Rongelap people themselves, and its results at the same time would also help others.

I expect the Rongelap people to receive routine medical care. But I would also expect certain groups of them to be part of surveys for the appearance of cancer, to undergo blood tests that their physicians may consider to be important, and to help in providing accurate records of vital statistics. All of this cannot be done unless their physicians are allowed to examine them at regular intervals whether or not they feel ill.

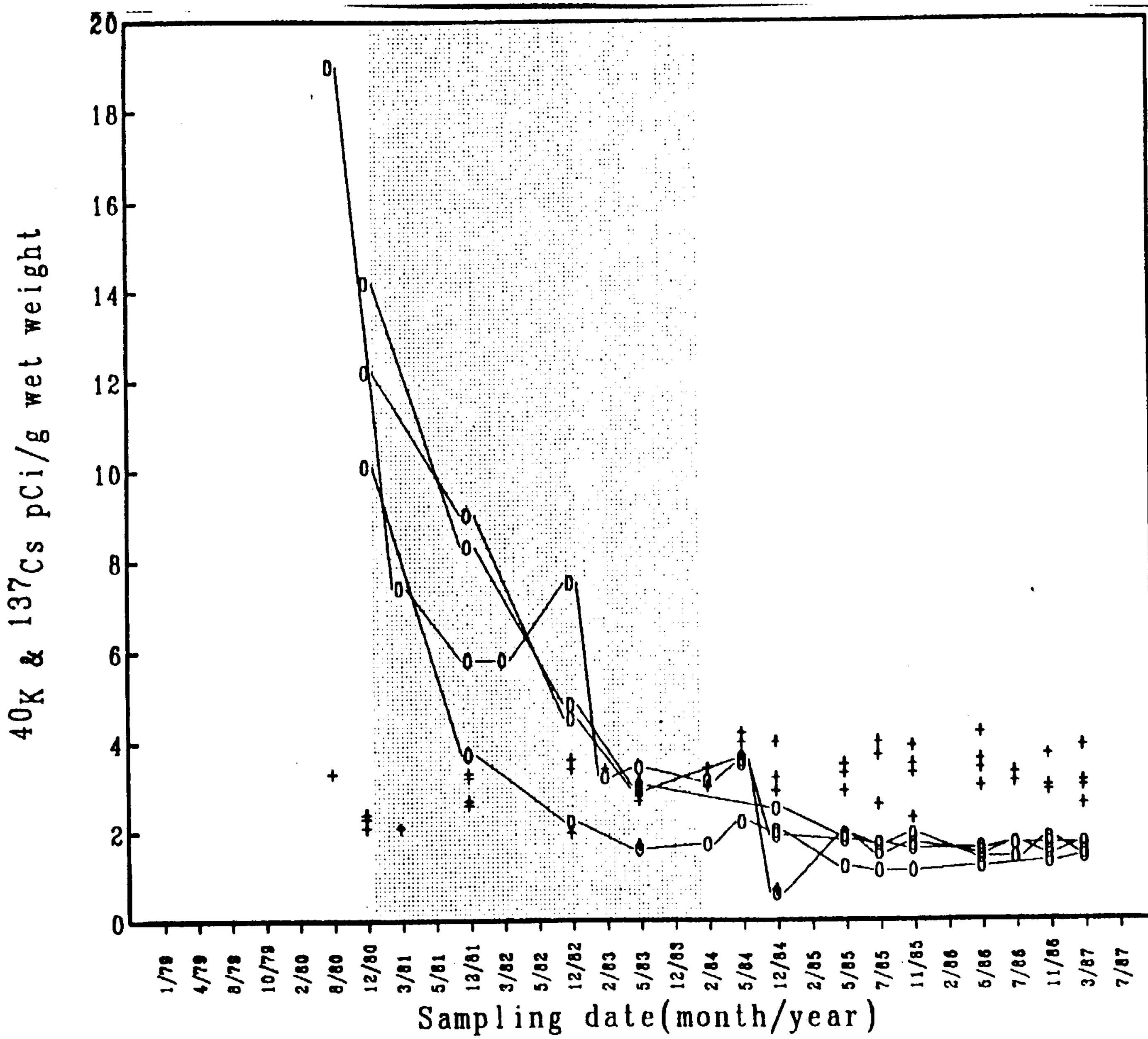
5.5 Rehabilitation of Soil

After the Rongelap people have settled on Rongelap Island, a reexamination should be made of the levels of contamination at the other principal islands of the atoll, for the reasons given in Note 12. At present, the best estimate of their relative degrees of contamination is obtained from a comparison of the external exposure rates determined by aerial reconnaissance (Table 4.1 #1). Based on the results of the resurvey of the atoll and a consideration of the field trials at Bikini, a long-term plan should be drawn up.

The methods now available to combat the radionuclide contamination of soil are essentially two -- remove the upper layer of soil in which the contaminants concentrate, or treat the soil with potassium salts which block its uptake by plants. A variant of the latter is to wash the soil with sea water. A long-term plan might employ all three.

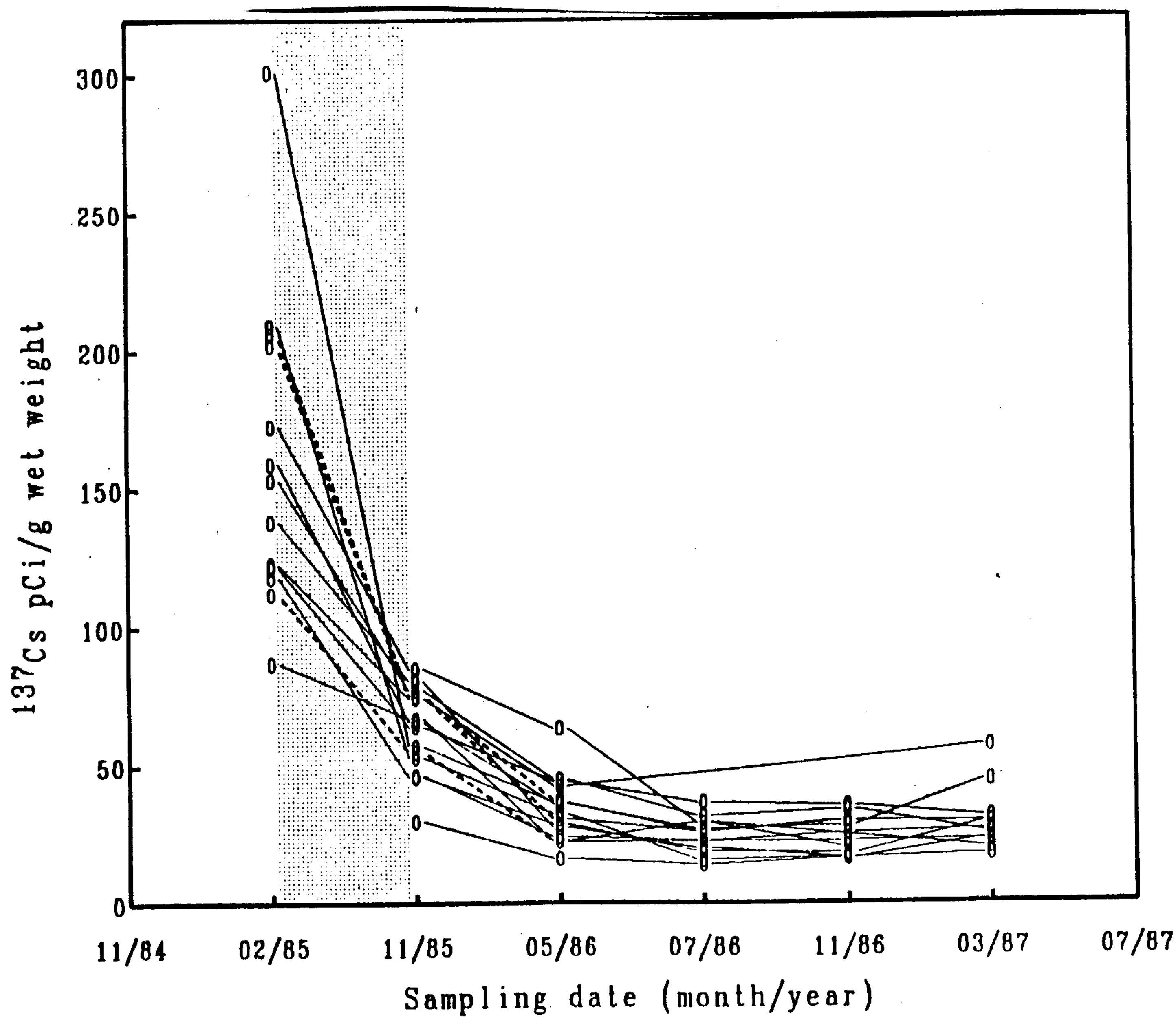
These methods have been under investigation at Bikini Atoll for some years (BARC 1987). Fig. 5.4 #1 illustrates for 4 coconut trees on Eneu Island (Bikini Atoll) how the application of potassium chloride to the soil decreased the contamination of the coconuts. Fig. 5.4 #2 illustrates the results for Bikini Island where the contamination is about ten times as great. Such treatment could be administered to islands of an intermediate level contamination in order to make them habitable. Their complete effectiveness against the highest levels, such as at Naen, is still under investigation, but a report on the matter should become available by next year.

Figure 5.5 #1



The ^{137}Cs concentration in drinking coconut meat from 4 trees on Eneu Island (Experiment #2). The shaded area represents the time during which a total of 1800 lbs. of K per acre was applied. The "+" symbol represents the ^{40}K concentration in the coconut meat. **(This graph was supplied by Dr. W. L. Robison of the Lawrence Livermore National Laboratory.)**

Figure 5.5 #2



The ^{137}Cs concentration in drinking coconut meat from trees treated with 1000 lbs. of K per acre in 4 equal applications in 3 month intervals. The shaded area represents the time in which the K was applied. (This graph was supplied by Dr. W. L. Robison of the Lawrence Livermore National Laboratory.)

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NOTES CITED IN THE TEXT

N.1

The following is quoted from "The Meaning of Radiation for Those Atolls in the Northern Part of the Marshall Islands That Were Surveyed in 1978", U. S. Department of Energy, Washington, D.C., November 1982, page 39:

Information That Has Been Obtained from the Measurements Made in 1978

If 233 people live on Rongelap Island and eat local food only from Rongelap Island

Scientists estimate that the largest amount of radiation a person might receive in one year from radioactive atoms that came from the U S bomb tests is 400 millirem But usually the largest amount a person might receive would be less than this This amount of radiation decreases every year, however, it decreases very slowly

The highest average amount of radiation people might receive in the coming 30 years is 2500 millirem in any part of the body and 3300 millirem in just the bone marrow

In the coming 30 years, scientists estimate that 10 people may die from cancers caused by things other than radiation from the atomic bomb tests In addition to this, from 0 1 to 0 6 people may die in the future from cancers caused by radiation received in the coming 30 years from the atomic bomb tests

In the coming 30 years, scientists estimate that 60 children could be born with health defects caused by things other than radiation from the atomic bomb tests In addition to this, 0 007 to 0 1 children may eventually be born with health defects caused by radiation their parents receive in the coming 30 years from the atomic bomb tests

If people live on Eneaetok and not on Rongelap Island, and eat local food only from Eneaetok, the amount of radiation they receive would be about the same

If people go to Naen from Rongelap Island, and eat food from Naen, they might receive about five times more radiation while they are there

If people go to Namen or Melu from Rongelap Island, and eat food from those two islands, they could receive about two times more radiation while they are there

COMPACT OF FREE ASSOCIATION ACT OF 1985

department or agency of the United States or by contract with a United States firm) shall continue to provide special medical care and logistical support thereto for the remaining 174 members of the population of Rongelap and Utrik who were exposed to radiation resulting from the 1954 United States thermonuclear "Bravo" test, pursuant to Public Laws 95-134 and 96-205. Such medical care and its accompanying logistical support shall total $22,500,000 over the first 11 years of the Compact. 91 Stat. 1159. 94 Stat. 84.

(2) AGRICULTURAL AND FOOD PROGRAMS.—Notwithstanding any other provision of law, upon the request of the Government of the Marshall Islands, for the first five years after the effective date of the Compact, the President (either through an appropriate department or agency of the United States or by contract with a United States firm) shall provide technical and other assistance— President of U.S.

(A) without reimbursement, to continue the planting and agricultural maintenance program on Enewetak;

(B) without reimbursement, to continue the food programs of the Bikini and Enewetak people described in section 1(d) of Article II of the Subsidiary Agreement for the Implementation of Section 177 of the Compact and for continued waterborne transportation of agricultural products to Enewetak including operations and maintenance of the vessel used for such purposes. *Post*, p. 1812.

(3) PAYMENTS.—Payments under this subsection shall be provided to such extent or in such amounts as are necessary for services and other assistance provided pursuant to this subsection. It is the sense of Congress that after the periods of time specified in paragraphs (1) and (2) of this subsection, consideration will be given to such additional funding for these programs as may be necessary.

(i) RONGELAP.—(1) Because Rongelap was directly affected by fallout from a 1954 United States thermonuclear test and because the Rongelap people remain unconvinced that it is safe to continue to live on Rongelap Island, it is the intent of Congress to take such steps (if any) as may be necessary to overcome the effects of such fallout on the habitability of Rongelap Island, and to restore Rongelap Island, if necessary, so that it can be safely inhabited. Accordingly, it is the expectation of the Congress that the Government of the Marshall Islands shall use such portion of the funds specified in Article II, section 1(e) of the subsidiary agreement for the implementation of section 177 of the Compact as are necessary for the purpose of contracting with a qualified scientist or group of scientists to review the data collected by the Department of Energy relating to radiation levels and other conditions on Rongelap Island resulting from the thermonuclear test. It is the expectation of the Congress that the Government of the Marshall Islands, after consultation with the people of Rongelap, shall select the party to review such data, and shall contract for such review and for submission of a report to the President of the United States and the Congress as to the results thereof. Hazardous materials. Contracts. *Post*, p. 1812. Report.

(2) The purpose of the review referred to in paragraph (1) of this subsection shall be to establish whether the data cited in support of the conclusions as to the habitability of Rongelap Island, as set forth in the Department of Energy report entitled: "The Meaning of Radiation for Those Atolls in the Northern Part of the Marshall Islands That Were Surveyed in 1978", dated November 1982, are Report.

United States nuclear testing program, pursuant to the program described in Public Law 95-134 and Public Law 96-205 and their descendants (and any other persons identified as having been so affected if such identification occurs in the manner described in such public laws). Nothing in this subsection shall be construed as prejudicial to the views or policies of the Government of the Marshall Islands as to the persons affected by the consequences of the United States nuclear testing program.

91 Stat. 1159.
94 Stat. 84.

(2) At the end of the first year after the effective date of the Compact and at the end of each year thereafter, the providing agency or agencies shall return to the Government of the Marshall Islands any unexpended funds to be returned to the Fund Manager (as described in Article I of the Section 177 Agreement) to be covered into the Fund to be available for future use.

(3) The Fund Manager shall retain the funds returned by the Government of the Marshall Islands pursuant to paragraph (2) of this subsection, shall invest and manage such funds, and at the end of 15 years after the effective date of the Compact, shall make from the total amount so retained and the proceeds thereof annual disbursements sufficient to continue to make payments for the provision of health services as specified in paragraph (1) of this subsection to such extent as may be provided in contracts between the Government of the Marshall Islands and appropriate United States providers of such health services.

Hazardous materials.

(k) ENJEBI COMMUNITY TRUST FUND.—Notwithstanding any other provision of law, the Secretary of the Treasury shall establish on the books of the Treasury of the United States a fund having the status specified in Article V of the subsidiary agreement for the implementation of Section 177 of the Compact, to be known as the

Post, p. 1812.

N-3 The following comments relate to the timing of the evacuation of the Rongelap people.

(a) According to C. L. Dunham, Director of the AEC Division of Biology and Medicine, (Cronkite et al, 1956), "unexpected changes in the wind structure deposited radioactive materials on inhabited atolls and on ships of Joint Task Force 7, which was conducting the tests. Radiation surveys of the areas revealed radiation levels above permissible levels: therefore evacuation was ordered, and was carried out as quickly as possible with the facilities available to the Joint Task Force".

(b) According to Merril Eisenbud (personal communication, see references) a scientific member of the Task Force, "There are many unanswered questions about the circumstances of the 1954 fallout. It is strange that no formal investigation was ever conducted. There have been reports that the device was exploded despite an adverse meterological forecast. It has not been explained why an evacuation capability was not standing by, as had been recommended, or why there was not immediate action to evaluate the matter when the Task Force learned (seven hours after the explosion) that the AEC Health & Safety Laboratory recording instrument on Rongerik was off scale. There was also an unexplained interval of many days before the fallout was announced to the public".

(c) Since the Rongelapese had been evacuated prior to previous tests, it is inot clear why the usual procedure was changed. In February 1954, Dr. Bertell has told me, Magistrate John Anjain of Rongelap was told about the Bravo test, but was not given the date. He said that "there are no orders from Washington to evacuate the people".

(d) Rongelap was evacuated on March 3, 1954, approximately 50-55 hours after the shot.

N-4

Part A of this Note deals with thyroid dosage relating to the Bravo event in 1954. It comprises two tables.

Part B consists of a letter from Dr. W. H. Adams of Brookhaven National Laboratory to Dr. Roger Ray of DOE. It deals with the question of whether or not prolonged residence on Rongelap since 1957 has resulted in an increase in thyroid neoplasia. It also considers changes in longevity and blood counts.

TABLE N.4A #1 THYROID DOSE FROM INDIVIDUAL RADIONUCLIDES IN FALLOUT TO THE ADULT MALE [a,b]

Source	Half-life	Per cent physical decay in 3 weeks	Dose rads
Internal exposure			
Iodine-135	6.6 h	100%	190 rad
Iodine-134	53.2 min	100%	3
Iodine-133	21 h	100%	550
Iodine-132	2.3 h	100%	7
Iodine-131	8.04 d	84%	130
Tellurium-131	30 h + 8.04 d	79%	120
Tellurium-131m	25 min + 8.04 d	84%	13
External exposure			190
Total dose			1203

a/ Lessard et al, (1985)

b/ Exposure to the fallout on Rongelap Island occurred for about 45 hours. The fallout fell for about 7 hours.

TABLE N.4A #2 Total Thyroid Absorbed-Dose Estimate (1954)

Age	Rongelap Island Internal	Rongelap Island External	Rongelap Island Total	Sifo Island Internal	Sifo Island External	Sifo Island Total	Inte
Average Estimate, rad[a]							
Adult Male	1000	190	1200	280	110	400	1
Adult Female	1100	190	1300	290	110	410	1
Fourteen-Year-Old	1400	190	1600	410	110	530	2
Twelve-Year-Old	1600	190	1800	450	110	570	2
Nine-Year-Old	2000	190	2200	540	110	660	3
Six-Year-Old	2400	190	2600	640	110	760	3
One-Year-Old	5000	190	5200	1300	110	1400	6
Newborn	250	190	440	-	-	-	
In Utero, 3rd tri.	680	190	870	-	-	-	
In Utero, 2nd tri.	-	-	-	490	110	610	2
Maximum Estimate, rad							
Adult Male	4000	190	4200	1120	110	1200	6
Adult Female	4400	190	4600	1160	110	1300	6
Fourteen-Year-Old	5600	190	5800	1600	110	1700	8
Twelve-Year-Old	6400	190	6600	1800	110	1900	[illegible]
Nine-Year-Old	8000	190	8200	2200	110	2300	[illegible]
Six-Year-Old	9600	190	9800	2600	110	2700	[illegible]
One-Year-Old	20000	190	20000	5200	110	5300	[illegible]
Newborn	1000	190	1200	-	-	-	[illegible]
In Utero, 3rd tri.	2700	190	2900	-	-	-	[illegible]
In Utero, 2nd tri.	-	-	-	2000	110	2100	[illegible]

[a]Multiply by 0.01 to obtain Gy.

Source: Lessard et al, 1985, p.61

N-4B

The following letter is from Dr. W. H. Adams of Brookhaven National National Laboratory to Dr. Roger Ray of DOE.

2108

July 18, 1985

Mr. Roger Ray
Deputy for Pacific Operations
Nevada Operations Office
Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

Dear Roger:

In view of the recent evacuation of Rongelap, which appears to have been precipitated by concern about harmful residual radioactivity on the atoll, we have reviewed our medical records to see if there is any clinical evidence that supports this conclusion and course of action.

Since 1957 an unexposed population of Marshallese of Rongelap ancestry has been examined periodically by the Brookhaven medical team. This population (the Comparison group) is similar in age and sex distribution to the exposed people of Rongelap. The reason for examination of the unexposed group has been to obtain baseline incidences of diseases in the general Marshallese population as an aid in detection of previously unidentified radiation hazards which might affect the exposed group.

Collected data on the unexposed people are sufficient to assess the effect of residence on Rongelap (since 1957) on longevity, thyroid neoplasia, and blood counts. We have done a retrospective analysis of their medical records; 133 of the group are living and 54 are deceased. We have arbitrarily selected for analysis the following divisions of years of residence on Rongelap:

Short-term - <3 years (average, 1.0 years)
Intermediate - 4 - 14 years (average, 7.5 years)
Long-term - >15 years (average, 20.9 years)

The place of residence for a given year is defined as the place where an individual received his medical examination. Since there is considerable migration of Marshallese among the atolls, the site of examination may not always be the same as the site of residence. Overall, however, there should be a good correlation between the two.

Mr. Roger Ray
July 18, 1985
Page 2

Effects on Longevity

There is no evidence that prolonged residence on Rongelap since 1957 has resulted in a shortening of life expectancy:

Residence Category		Number of Deaths		Mean age at Death
Short-term		20		61.4 years
Intermediate		27		66.6 years
Long-term		5		70.0 years
	Total	52*	Average	64.9 years

* Does not include 2 accidental deaths.

Effects on Thyroid Neoplasia

There is no evidence that prolonged residence on Rongelap since 1957 has resulted in an increase in thyroid neoplasia. Nine unexposed persons in the Comparison group have had surgery for thyroid nodules:

Residence Category	Number of Persons	Mean Age in 1985 (yr)	Number with Thyroid Nodules Removed	Number of Thyroid Cancers
Short-term	58	47.1	4 (7%)	1
Intermediate	46	46.4	3 (7%)	0
Long-term	29	46.9	2 (7%)	1
Total	133		9	2

These figures apply to the 133 unexposed persons in the Comparison group who are living. All of the 9 persons who had thyroid nodules removed are still alive.

Effects on Blood Counts (1985 data)

There is no detectable effect of residence on Rongelap on blood counts:

Residence Category	Number Tested	Neutrophils/ul ±SD	Lymphocytes/ul ±SD	Platelets/ul$\times 10^3$ ±SD
Short-term	24	4851±2089	2754±1006	279±111
Intermediate	40	3838± 992	2835± 908	292± 59
Long-term	26	4366±1551	2612± 787	262± 51

A test of equality of means showed no statistically significant differences among the three categories. Note that the number of blood tests performed (90) is less than the number of persons in the Comparison group. This is because not all were seen in the March-April, 1985, survey.

Mr. Roger Ray
July 18, 1985
Page 3

We have also considered thyroid nodules and current blood cell counts as they may relate to early residence on Rongelap, since a greater radiation risk would have existed during the early years after the 1954 fallout. Thirty-four persons in the Comparison group resided in Rongelap for 4-6 years commencing with the return to the atoll in 1957. Only 1 nodule, an "occult carcinoma",, has occurred in this subgroup (3.0%), whereas the other 8 nodules, including the two true thyroid carcinomas, occurred in the other 99 persons in the Comparison group (8.1%). There was also no difference in blood cell counts:

Time of Residence	Number Tested (1985)	Neutrophils/ul ±SD	Lymphocytes/ul ±SD	Platelets/ul$\times10^3$ ±SD
Early	29	4032±1543	2713±836	267±57
Late	77	4349±1599	2756±951	284±80

If you wish us to examine any other parameters do not hesitate to ask.

Sincerely yours,

William H. Adams, M.D.

WHA/elr

[redacted] marrow. These regulations, now administered by EPA, are still in force.

(d) In the period 1985-87, the ICRP (1985) and the NCRP (1987) dropped their recommendations for the general population to .1 rem per year.

When the Rongelap people returned in 1957, therefore, the guide employed by the AEC was 0.5 rem per year. It is not clear to me that this guide was met, although it may have been approximately, i.e., within a factor of two. The external dose was stated to be less than 0.5 R/year, and strontium-90 was considered to be the only significant radionuclide determining the internal dose (Dunning 1957). Lessard (Note 7), by extrapolation, found the committed effective dose equivalent to be about 0.7 rem in 1957, .44 rem in 1958, and .36 rem in 1959. These estimates do not allow for the contributions of plutonium and americium.

N-6 To be rewritten.

For the nonprofessional reader, the following is an explanation of the specific radiological meaning of the terms, exposure and dose. Very simply, the medical analogy would be this. A patient takes a spoonful of heart medicine -- radiologically considered, that is his exposure.

Of the swallowed medicine, three-quarters are eliminated but one-quarter passes from the intestine into the circulation and is absorbed by the heart -- that one-quarter is the dose. It would be expressed per gram of heart tissue.

For exposure to radiation per se, the unit is the roentgen (R), measured in air. For radionuclides (atoms which spontaneously decay and emit radiation), the units are the bequerel (Bq), equal to 1 atomic disintegration per second, or the curie (Ci), 3.7×10^{10} disintegrations per second. The microcurie (uCi) and the picocurie (pCi) are respectively 1 millionth of a curie, and 1 millionth of a microcurie (27 pCi equal 1 Bq).

The units of dose are the rad (for any type of ionizing radiation: 100 ergs absorbed per gram of tissue); the rem (dose equivalent in biological effect to 1 rad of standard radiation). The particular point to remember about radiation dose is that it is per gram of tissue. A whole-body dose of 100 rad means that every gram (on average) received 100 rad; it does not mean that the entire body received 100 rad to be distributed throughout the tissues.

Both exposure and dose are referred to as resulting from external or internal sources. An external exposure or external dose is the result of a radiation source outside of the body, e.g., fallout contaminated soil. An internal dose would result from a source inside of the body, e.g., radioactive iodine due to the use of fallout-contaminated drinking water.

In the case of radionuclides, we shall use the term whole-body dose in the technical sense of committed effective dose equivalent. For a particular tissue, the tissue dose would be the committed dose equivalent. Such doses can be calculated for 1 year or 30 years, etc.

Dose: in rads
Dose equivalent: in rem
Effective dose equivalent refers to the whole-body dose
Committed effective dose equivalent: whole-body dose for radionuclides in the body over a period of time

N-7

The whole-body counter measures the quantity and the energy of the gamma ray photons that have been emitted by cesium-137, or other radionuclides, and that escape from the body. In principle, the machine is calibrated by measuring the escape of gamma rays from a phantom which has been loaded with the radionuclides in question. Obviously, the whole-body counter comes closest to giving a direct measurement of the body-burden. The collected data obtained with it are presented in Tables N.7, #1, #2, and #3.

In the case of radionuclides that emit beta rays (strontium-90 or alpha particles (transuranics), whose range in tissue before absorption may be at most a centimeter or so down to some micrometers, another method must be used. Recourse is had to measuring the daily radionuclide excretion in the urine. The body content is then calculated from knowledge of the metabolism of the radionuclide in question. This method is not as reliable as whole-body counting. Fortunately in the present case, the detection of strontium and the transuranic elements is not as important as the detection of cesium.

The dose can also be calculated from the diet. The primary obstacle here is that the diet is very difficult to ascertain accurately, and in addition more assumptions must be made regarding the metabolism of the radionuclide than would be the case above. The Livermore results are based on this method.

Conversely, knowing the daily urinary output of a radionuclide, it is possible to calculate the daily intake by ingestion. For example, based on the work of Jones et al (1985), Skrable et al (1987) and Moss (1988), Dr. E. T. Lessard of the Brookhaven Laboratory has calculated the factors for plutonium-239 given in Table N.4 # 4. When the daily intake is multiplied by the factor, the urinary output is obtained. Conversely, when the urinary output is known, dividing it by the factor will predict the daily intake. The Jones and Moss alternatives are offered; at 20-30 years on a constant diet, they differ by a factor of 1.75. I used the Moss-based factor for the calculations used in the text, Section 4.3, because it corrects for earlier errors in the data base which Jones did not know about.

(Cont.)

Note 7 (cont.)

The distribution of the data supplied by Dr. Lessard was not normally distributed:

(a)	Below 30 x 10^{-6} pCi/day (the method's limit)	= 19
(b)	30 - 499	= 11
(c)	500 - 999	= 2
(d)	999 - 3400	= 3

Perhaps two or more unrecognized populations were being tested. I therefore took the median value to represent the whole group--which would be no more than 30 x 10^{-6} pCi/day. Among the causes for the wide distribution might be technical error, but also abnormal or hitherto unrecognized physiological factors which would be of interest to define.

I would also note that the predicted daily oral intake of plutonium-239 based on urine is .13 picocuries/day, not much different from the dietary estimate of .23 picocuries/day. The factor of two tends to parallel the ratio of their cesium determinations. (The activity radio plutonium-240/plutonium-239 is 0.6.)

I understand that DOE is formulating plans to look into the matter.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8.9×10^3	23	7.8×10^3	29	8.3×10^3	52	9540	1983
3.9×10^3	43	3.4×10^3	35	3.7×10^3	78	9910	1984

A = Number of individuals not recorded.
B = Measured at Argonne National Laboratory.
C = No females measured.

(This table was supplied by Dr. E. T. Lessard, Brookhaven National Laboratory)

[redacted]

7	1961	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]
8	1962	0.27	123	0.08	2.81	2.99	[redacted]
9	1963	0.11	112	0.02 *195*	2.58	2.31	90
10	1964	0.05	102		2.37	1.78	80
11	1965	0.02 *34*	92.4		2.17	1.38	73
12	1966		83.9		1.99	1.06	66
13	1967		76.2		1.83	0.82	61
14	1968		69.2		1.68	0.63	56
15	1969		62.9		1.54	0.49	52
16	1970		57.2		1.41	0.38	49
17	1971		51.9		1.29	0.29	46
18	1972		47.2		1.19	0.22	43
19	1973		42.9		1.09	0.17	41
20	1974		38.9		1.00	0.13	38
21	1975		35.4		0.92	0.10	36
22	1976		32.1		0.84	0.08	35
23	1977		29.2		0.77	0.06	33
24	1978		26.5 *1911*		0.71 *45*	0.05 *47.6*	32 *1302*
25	1979		24.1		0.65	0.04	30 millirem
26	1980		21.9		0.60	0.03	29
27	1981		19.9		0.55	0.02	28
28	1982		18.1		0.50	0.02	27
29	1983		16.4		0.46	0 01	26
30	1984		14.9		0.42	0.01	25
31	1985		13.5		0.39	0.01 *.14*	24
32	1986		12.3		0.36		23
33	1987		11.2		0.33		23
34	1988		10.2		0.30		22
35	1989		9.22		0.28		21
36	1990		8.38		0.25		21
37	1991		7.61		0.23		20
38	1992		6.92		0.21		19
39	1993		6.28		0.20		19
40	1994		5.71		0.18		18
41	1995		5.19		0.16		18
42	1996		4.71		0.15		17
43	1997		4.28		0.14		17
44	1998		3.89		0.13		16
45	1999		3.53		0.12		16
46	2000		3.21		0.11		15
47	2001		2.92		0.10		15
48	2002		2.65		0.09		15
49	2003		2.41		0.08		14
50	2004		2.19		0.08		14
51	2005		1.99		0.07		14
52	2006		1.80		0.06		14
53	2007		1.64		0.06		13
54	2008		1.49 *245*		0.05 *7*		13 *410*
55	2009		1.35		0.05		13 millirem

[1] Multiply by 10^{-5} to convert to Sv.
[2] Multiply by 0.7 to obtain rem (~~whole-body~~).

Σ to 1978 = 2233 + 1302 = 3535
Σ 1979–2008 = 252 + 410 = 662

This table was supplied by Dr. E. T. Lessard of the Brookhaven National Laboratory.

Table N-7 #3

SUMMARY OF BROOKHAVEN RESULTS FOR INTERNAL & EXTERNAL DOSE [a/]

Radionuclide	1957-78	1979-08
	mrem	mrem
Internal dose		
cesium-137	1911	245
strontium-90	45	7
cobalt-60	34	0
iron-55	48	0
zinc-55	195	0
Total	2,233	252
External dose	1,302	410

[a/] Based on the data in Table N-7 #2. The external exposure rates were multiplied by 0.7 to obtain the whole-body dose. The transuranics are omitted.

[redacted]

factors given. For example, after 20 years of intake, the daily excretion is found to be 3×10^{-5} picocuries. Then the intake is: $(3 \times 10^{-5}) / 2.3 \times 10^{-4} = .13$ picocuries/day.

[redacted]
ratio at .007 mm depth (basal cell layer, skin) should be approximately the same. Therefore, by extrapolation from the determinations at Eneu (Shingleton et al) the Rongelap basal-cell dose would be 46 mrem/y, and at 1 cm depth practically zero (ICRP 51, Table 26). Since the radiation protection guide for skin is 5 rem/y (NCRP 1987b), the skin dose is a trivial one.

Query: Where does the citation go?

plutonium-239,-240 at Bikini Island (Shinn et al 1980). In calculating the results, it was assumed that a person would be exposed to maximum dust conditions for 5 hours per day throughout life (tilling fields), an unrealistic assumption bound to give very high exposures (tilling deposits 1.5 x 10^{-3} picocuries per hour in the lungs).

To obtain the Rongelap dose, it was assumed by Robison et al (1982b) that the distribution of particle sizes and of radionuclides was practically the same on Bikini and Rongelap Islands. Therefore, the inhalation dose on Rongelap would be to that on Bikini as the transuranic specific activity of Rongelap soil (0-5 cm) was to that of Bikini Island.

Island	Specific activity in top 5 cm of soil in 1978	Inhalation 30-year dose to bone marrow c/
	pCi/g	rem
Bikini a/		
plutonium-239,-240	11	.033
americium-241	8.7	.035
Rongelap b/		
plutonium-239,-240	3.2	.010
americium-241	1.0	.005

a/ Robison et al (1982a, pp. 8, 12, 44, 56).
b/ Robison et al (1982b, pp. 12, 14, 47, B10, B13).
c/ The dose throughout the bone would be about 4 times as great.

The dose is greater for a growing child. Robison et al (1982a) used a factor of 2.8 to convert the adult inhalation dose to that for the age period 0-30 years (.042 rem). The dose to the adult lung is considered to be about 2.5 times that to the marrow.

Dr. Robison (personal communication, 1988) has reviewed these dose estimates according to the more recent ICRP factors. He has reduced dust consumption by a factor of 3.5, which would reduce the dose proportionally. This is still a liberal allowance for every day of life from birth to death, but in any case a much more reasonable one. The net result is a reduction in dose for plutonium by a factor of about 3, and for americium by a factor of 4.

[redacted]

ship did not come at all. Robison selected the adult female subgroup of the population for calculation because its consumption was greatest. DOE-1982 took this calculation for the minimal level of contaminated-food consumption.

For the MLSC diet it has been found that cesium-137 accounts for about 95% of the whole-body dose and 85% of the bone marrow dose. Strontium-90 accounts for 5% and 15%, respectively, and the transuranics for less than 1% during the first 70 years. When the supply ship is on schedule, coconut accounts for 80% or so of the radionuclide intake.

In summary, then, DOE-1982 used the Naidu type B commuunity diet for its dose calculations. When it wished to indicate a range, it used both the type B community (high) and the MLSC diet (low). The diets are given in Table N-11 #1.

An additional fact about the preparation of fish is worth noting. The skin and bones of fish may have 50-100 times the strontium-90 specific activity of the meat. Also, the contents of the intestinal tract may be high. What is the effect of all this on dosage? First, Noshkin et al (1981) found the strontium-90 specific activities of all tissues to be below 1 pCi/g. Robison et al (personal communication, 1988), have confirmed this for mullet caught off the reef of Bikini Island (contamination levels 5-10 times those at Rongelap Island). Roast mullet and stewed mullet were tested. For stew, neither the meat, nor broth, nor skin and bones exceeded .01 pCi per gram (Table N 11.# 2). The cooking was done by natives in the customary way (the intestines were discarded).

TABLE N-11 #1 DAILY FOOD CONSUMPTION -- TWO DIETS [a/]

Food	Community B (adult) grams/day	MLSC Diet (adult female) grams/day
Arrowroot	0	3.9
Breadfruit	36	27.2
Banana	19	0.02
Coconut		
Drinking meat	100	--
Drinking fluid	514	--
Copra	68	--
Milk	125	--
Sprouting	100	--
Coconut "fluid"	--	142
Coconut "meat"	--	63.3
Papaya	0	6.6
Pumpkin	0	1.2
Pandanus	96	9.2
Fish	194	41.5
Eggs	--	10.7
Poultry	3	--
Wild birds	9	4.2
Domestic meat	--	21.2
Pork	1.4	--
Clams	15	8.9
Crabs	--	3.1
Octopus	20	4.5
Turtle	.1	4.3
Snails	12	--
Coconut crab	1	--
Lobster	.14	--
Shellfish	--	5.1
Total	1313.64	356.92

a/ Imported foods are not included in the lists. The data are from Tables 4 and 11 in Robison et al, UCRL 52835 (1982b). Imported staples include rice (especially), sugar, flour, canned meat, canned drinks, and baby foods.

TABLE N.11 #2

STRONTIUM-90 DISTRIBUTION IN MULLET; FRESH, ROASTED, AND AS A STEW[a/]

	Strontium-90, pCi/g wet weight		
	Roast mullet	Mullet stew	Fresh mullet[b/]
Muscle (meat)	9.5 E-4	---	5.2 E-4
Bones	5.4 E-2	4.2 E-2	1.8 E-2
Duplicate bones	6.0 E-2	--	--
Skin	8.0 E-2	--	2.7 E-2
Broth	--	4.5 E-4	--
Skin + meat	--	1.8 E-3	--

[a/] The table was supplied by Dr. W. L. Robison of the Lawrence Livermore National Laboratory.

[b/] From V. Noshkin et al, UCID-20754, 1986, "Concentrations of Radionuclides in Fish Collected from Bikini Atoll between 1977 and 1984".

A major weakness in the DOE-1982 dose calculations was the small number of samples on which it was often based (URCL-52853, Pt. 1). For example, in the case of Rongelap Atoll the number of vegetation samples per island were as follows: Rongelap 35, Aibar 6, Borukka 4, Mellu 6, Kabelle 6, Naen 7. On Ailingnae Atoll, there wer 7 on Sifo and 2 on Uwanen.

To make up for this deficiency, vegetation specific activities were at times calculated by applying a factor to the soil's specific activity. Robison has subsequently found that such a method may give erroneous results (personal communication to H. I. Kohn).

Table N.12 #1 shows some of the inconsistencies that arise when such data are tabulated. For example, pork has the same cesium specific-activity on all islands in Rongelap Atoll; the total dose on Kabella and Mellu islands is 4.4 rem (30-year), but the internal exposures are 5500 and 8000 pCi/day, respectively.

TABLE N.12 # 1 EXPOSURE AND SPECIFIC ACTIVITY COMPARED

Location	External Exposure a/ (1978)	Total 30-year dose b/ (external & internal)	Cesium-137 internal exposure c/	Cesium specific activities in 1978 (pCi/g-fresh) d/				
				Pig: muscle, heart	Pandanus	Coconut		
						copra, cake, milk	fluid	drinking meat
	μR/hour	rem	pCi/day					
Rongelap Atoll								
Rongelap	4.5	2.5	4300	8.5	11.1	7.6	1.4	5.5
Kabelle	14.0	4.4	5500	8.5	-	13.5	1.4	9.9
Mellu	--	4.4	8000	8.5	8.8	4.6	.4	3.4
Naen	43	11.0	12,100	8.5	14.2	10.9	2.6	8.0
Ailingnae Atoll e/								
Sifo	1.4	.5	600	1.2	1.3	1.0	.16	.7
Ucchuwanen	1.9	1.0	1700	1.2	1.8	1.8	.43	1.3

a/ From Figure 4.2#1 (page 31, this report)

b/ Table 17, (UCRL 52853, Part 4), BNL community B diet, whole-body dose.

c/ Table 14, (UCRL 52853, Part 4), cesium-137

d/ Appendix A, (UCRL 52853, Part 4)

e/ Ailingnae Atoll is important for food collection, especially Sifo. Island where a Rongelap party was visiting when the Bravo shot was fired.