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PRELIMINARY REPORT

RONGELAP REASSESSMENT PROJECT

APRIL 20, 1988

TO: The President and Congress of the United States

FROM: Henry I. Kohn, Referee

Rongelap Reassessment Project
1203 Shattuck Av., Berkeley, CA 94709
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ABSTRACT

This preliminary report provides the basis for testimony to be given on April 26, 1988, before the House Appropriation Committee on Interior, Representative Sidney Yates, Chairman.

It was considered important for both the Congress and the Rongelap people to present an overview of the material now available rather than to wait until all questions have been answered. Meeting the hearing date has involved some last minute pressures. The final report will probably be issued within 2 - 3 months.

The chief conclusion is that, based on the estimation of adult dosage, Rongelap Island may be resettled now. That conclusion, however, presupposes certain conditions for living which are set out and discussed in Section 5 (which may be read without reference to the rest of the Report).

The chief unsettled point is the dose to infants; it is currently under review.

Another unsettled point is the transuranic dosage (plutonium-293, -240, americium-241).

It is important to bear in mind that the dosage under discussion is that from continued residence on Rongelap Island from 1978 (or the present), onwards. This adult dosage over the next 30 years is estimated to be no more than 1 to 2% of that experienced from fallout in 1954 from the Bravo shot. The historical data included in the Report are of interest for general orientation.

As referee, I am solely responsible for the contents of this report. However, two consultants have strongly objected to major portions of it and I am therefore putting their comments together, in their entirety, in Note 13. For comparison, I suggest that they be read in conjunction with Section 5 of the Report (Discussion and Recommendations).

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1. INTRODUCTION

1.1 Task

Rongelap Atoll was 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 and has read this Report.

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". The absence of such comment, however, does not necessarily indicate agreement with the entire text. A major commentary by Dr. Bertell and Mr. Franke is given in Note 13.

The following scientists participated in the Project.

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Others who have informally helped in the production of this report:

2. BACKGROUND -- THE RONGELAP EXPERIENCE

Rongelap Atoll is located about 2,500 miles southwest of Hawaii, at 12°N, 167°E (Fig. 2 #1). It comprises more than 50 low-lying islands and islets, total area 3.07 sq. miles, which bound a lagoon of 400 sq. miles. The largest and by far the most important island, Rongelap, has an area of 0.3 sq. miles.

The geological structure is that of a coral reef atoll resting on a submerged volcanic mass. The islands are made of reef debris, primarily of sand and gravel size, and reef organisms.

The atoll is typical in appearance, and the islands are covered with vegetation. However, a major factor limiting the kinds of plants that can be grown as staples is the long dry season.

The Marshall Islands Statistical Abstract of 1986, issued by the 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.

2.1 Bravo test -- 1954

The initial event occurred on March 1, 1954, when a 17-megaton-yield thermonuclear device was set off at Bikini Atoll, the Bravo test. The device was 1000 times as powerful as the bombs that destroyed Nagasaki and Hiroshima; its cloud rose 25 miles above the earth, and after 10 minutes had a diameter of 70 miles.

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.

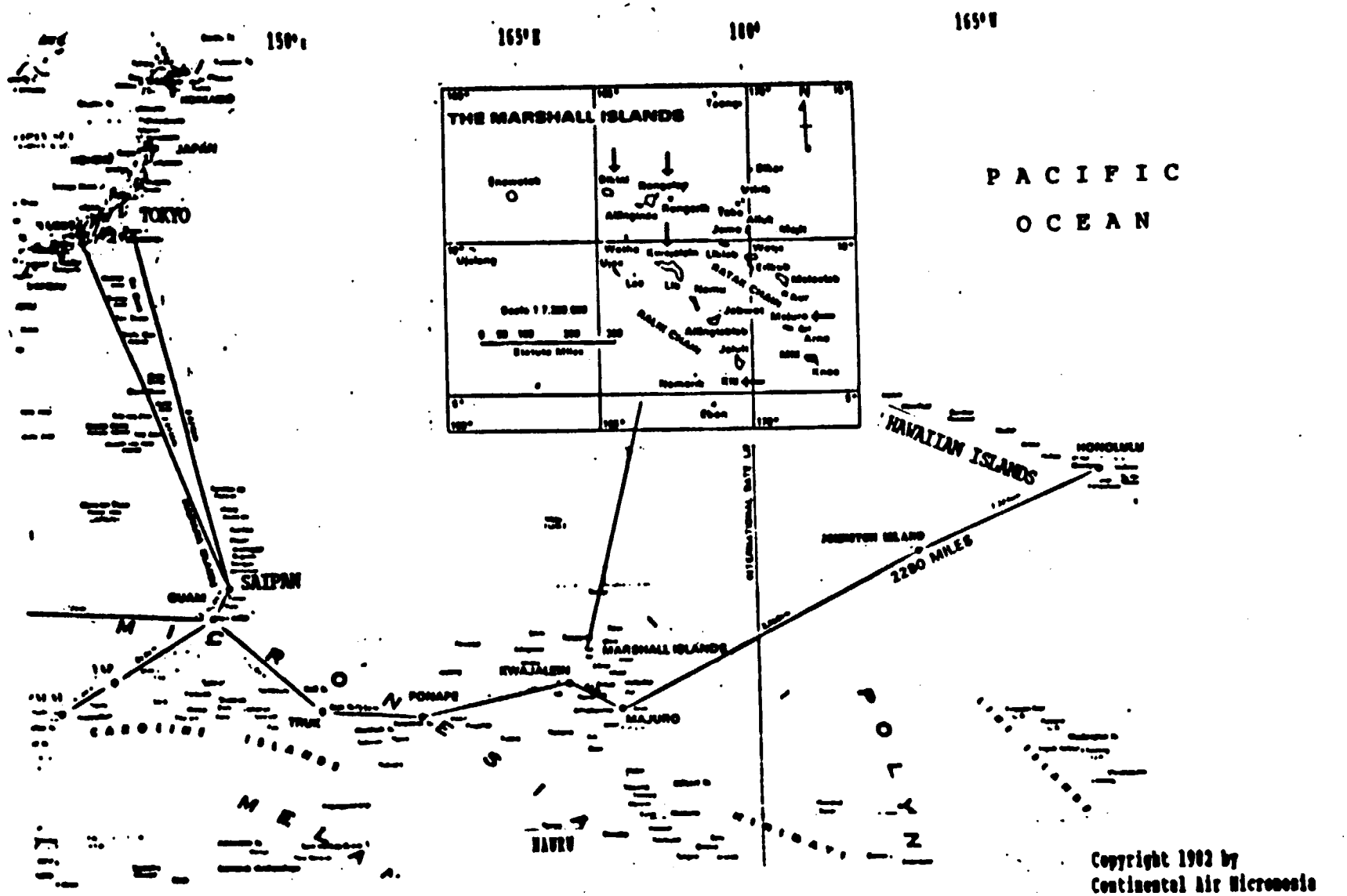

Fig. 2.1 #1 LOCATION OF THE MARSHALL ISLANDS

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 National Laboratory'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, on the basis of these reports, 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.

[1/] The AEC was the predecessor of DOE.

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.

1976-79. More thyroid nodules appeared. The Rongelap people continued to be worried. They asked for an independent health review which was not granted. A group of Brookhaven scientists proposed a comprehensive dosimetry review (Bond et al, 1978), which DOE then funded (Lessard, 1984a; Lessard et al, 1984c; Lessard et al, 1985). Independently, DOE initiated a "Northern Marshall's Survey" based on an aerial survey by EG&G and some terrestrial work by Lawrence Livermore National Laboratory (Robison et al, 1980; Robison et al, 1982b; Tipton & Meibaum,1981).

1980-84. 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, Half-Life, 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 for the thyroid gland (Cronkite,1954; Dunning, 1957). 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 very much smaller.

(c) The occurrence of thyroid tumors ($\sim$ 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) in the 81 persons at risk.

(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 length of 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.

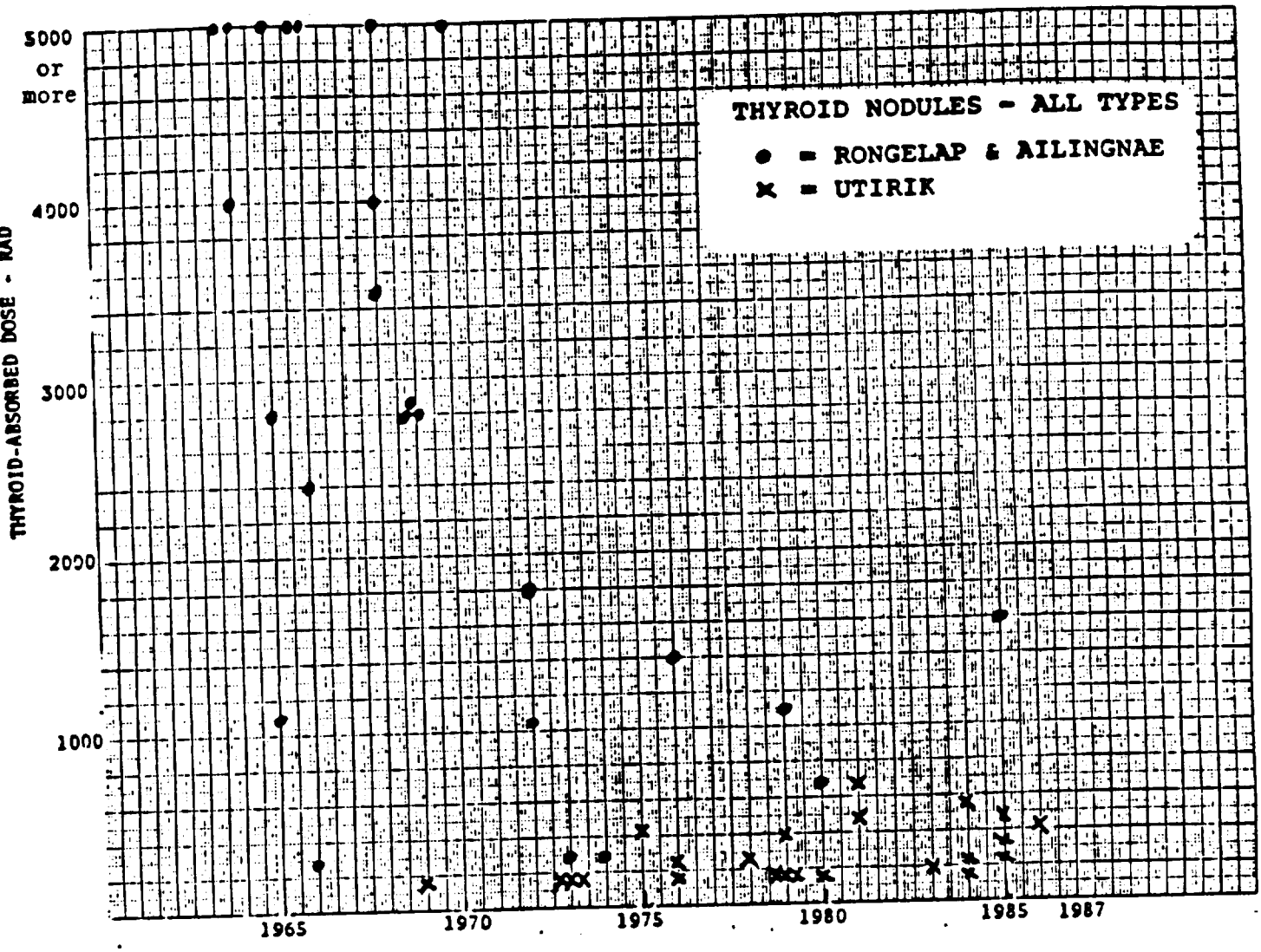

Figure 2.3 #1. Latency period for appearance of thyroid nodules related to thyroid dose received in 1954 at Rongelap & Ailingnae, and Utirik. Details on thyroid dosage are given in Table N.4 #2.

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

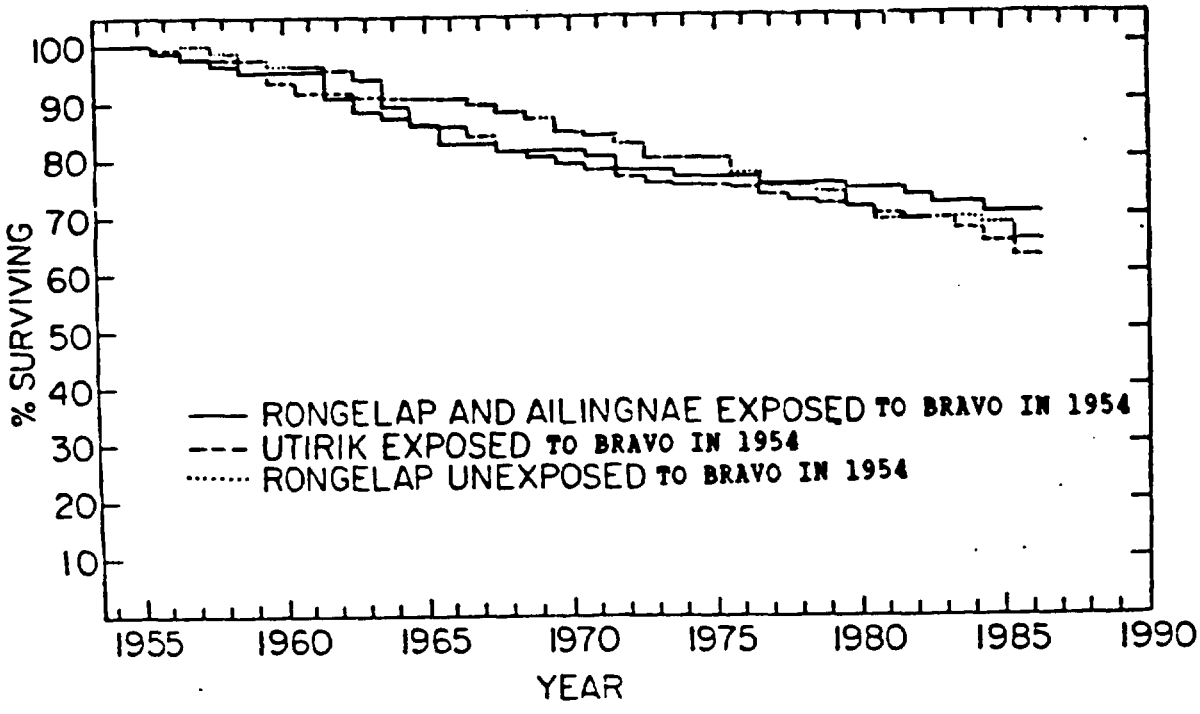

FIGURE 2.3 #2 Survival as a function of time after 1954.

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.

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 five: 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.

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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.

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.

TABLE 3 #1 SOURCES OF FALLOUT RADIATION AT RONGELAP

Radionuclide	Half-life [a/]	Principal radiations [a/]			ICRP-derived limit on daily oral intake [e/]	Fraction absorbed from gut in adults [f/]
		α [b/]	β [c/]	γ [c,d/]		
	years	MeV	MeV	MeV	pCi/d [f/]	
Cesium-137	30	-	0.187	.66	9860 * 5920 **	1.0
Strontium-90	29	-	1.13	-	2470 * 1480 **	.3
Plutonium-239	24,065	5.23	-	-	30 ** (60)	.001
-240	6,537	5.24	-	-	30 ** (60)	.001
Americium-241	432	5.57	-	-	37 ** (67)	.001

a/ ICRP Publication 38. (Radionuclide transformations)

b/ Quality factor, 20

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	10.6(7)	6.9		3.2		1.0	1.7(3)
5-10		9		7.7		2.0		.78	
10-15	10-20	5.4		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.

4. DOSE

DOE-1982 reported three doses for the Rongelap people who would live on Rongelap Island for the period 1978-2008, tacitly assuming a constant diet. To this DOE-1982 added the stipulation that the diet would be based on "local food only from Rongelap Island" (Note 1).

It should be pointed out, however, that the stipulation of "local food only" is incorrect. The doses used by DOE-1982 were estimated by Robison et al (1982b), who based them on the type B community diet described by Naidu et al (1980). That diet involves imported foods brought in on a regular basis by supply ship.

The three doses are as follows:

(1) The "highest average amount of radiation the people might receive in any part of the body" was 2.5 rem. I take this to be Livermore's "integral dose" in which each year's delivery is summed over 30 years (Robison et al, 1982b, Table 17). I will compare it to the committed whole-body dose (rem) over 30 years (i.e., the committed effective dose equivalent for a standard man).

(2) The corresponding bone marrow average would be 3.3 rem (Robison 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 that DOE's whole-body and bone-marrow doses are for practical purposes confirmed by recalculations employing the original data and corrected assumptions, and by those employing subsequent findings on additional field samplings.

However, 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, apparently not great enough to prevent a decision from being made. This matter will be discussed.

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

4.1 External Dose

The aerial survey (Tipton & Meibaum, 1981) provided DOE with important information on exposure to fallout in the Northern Marshall Islands. As the survey proceeded south and east from Bikini Atoll, the seat of the Bravo shot, the external exposure rate fell (Table 4.1 #1). It was calculated for 1 meter above ground level.

At Rongelap Atoll (Figure 4.1 #1), the islands fell into four exposure groups (microreoentgens per hour) from north to south: Naen, Yugui, Lomuilal (28-43 μR/h), Eniaetok, Kabelle, Gogan (10-27 μR/h); Busch, Borukka, Gabelle, Tufa (5-9 μR/h); Rongelap and Arbar (4.1-4.5 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).

These estimated external gamma-ray dose rates are maximal ones. Indoors the rate is reduced by about 50%. Likewise, the rate is reduced by about 50% in the immediate vicinity of houses owing to the coral gravel that is spread around them (Shingleton et al, 1987 and Robison et al, 1982b).

Other annual contributions to external dosage which are <u>not</u> included come from cosmic radiation (.028 rem) and medical exposure.

In summary, the contribution of fallout to the total external radiation dose at Rongelap Island in 1978 was approximately .028 rem per year uncorrected for the shielding within or around buildings, which 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.

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