[redacted]

This probably introduced a small element of conservation.

4. For estimating birth defects neither BEIR-I or BEIR-III is very clear about what is meant by parental dose, thus it is not clear whether birth defects should be based on the dose to one parent or both parents. In the latter case, the 30-year whole body dose would be doubled. We assumed the BEIR-I risk of 0.2% rem was based on both parents being irradiated. Also because we believed the risk coefficient from BEIR-I was already conservative based on comparisons with BEIR-III, we elected to use the 30-year whole body dose as provided us--not doubled.

5. For the 140 persons who returned to Bikini and were removed in August 1978, it was assumed that no children will be conceived by persons above age 40, that 300 children will be born after August 1978, and that all children born will be offspring of parents, both of whom returned to Bikini. The parental dose was obtained as follows:

Average dose to males < 40 years old	=	1.36 rem
Average dose to females < 40 years old	=	1.08 rem
Total parental dose	=	2.44 rem
Parental dose used in calculations	=	1.22 rem

6. The average dose values for persons who lived on Bikini were calculated from individual dose data (whole body and bone marrow) for 50 males and 49 females. These values are tabulated in the ~~A~~ppendix.

7. The spontaneous incidence of birth defects was taken to be 10.7% of all live births from BEIR-III.

8. The normal incidence of cancer deaths was assumed to be 15%. A value less than the approximately 20% given for the U.S. population

[redacted]

of other risks such as drowning, poisoning, etc. Other causes of death are probably higher in the Bikini population than in the U.S. population. We also suspected the average life span was less than in the U.S. population, which might tend to reduce the number of cancers that would occur in the elderly.

9. The largest dose a person might receive in a year was estimated to be three times the average dose. Data in the appendix for individuals show that the highest individual dose is more than twice the average but less than three times.

II. Population Estimate (CAPS) (CENTER)

To estimate the number of births, deaths and the magnitude of the Bikini population after 30 years, information was used from the final draft of the Marshall Islands five year health plan prepared by the Trust Territories' Department of Health Services' Office of Health Planning and the Resources Department. The document is undated, but the presence of data from 1976 indicates that it must have been prepared in the period of 1977 to 1979 when we received it. It was noted that there are apparent inconsistencies among several of the different tables. For example, Table III-1 gives data for the Marshall Islands for the period 1955-1975 and Table III-5 gives data for the infant mortality rate for 1976. In Table III-1, the infant death rate per 1000 births for 1970 through 1975 is given as 28.3, 33.6, 25.4, 46.4, 21.1 and 37.0. However, Table III-5 indicates the infant mortality rate to be only 17.04. We used the data of Table III-1 in the

[redacted]

of a more technical environment.

For the estimates the last 5 or 6 year average of the data were used because they are probably the most representative of current conditions. From this, the following were obtained:

1. Rate of increase of the population has been about 3.8%/year.
2. Infant death rate is about 3.2% per birth.
3. Overall death rate is 0.54% per year.
4. Birth rate is 4.2% per year.

A population of 550 was assumed for the one that might move back to Bikini Atoll. Values for other initial populations were obtained by ratios of the results.

The total population at the end of 30 years is given by the compounding equation:

$$P_{30} = 550\ (1 + 0.038)^{30} = 1684$$

[redacted]

and summing. This gave 8949 rads for the total population including the original 550. The total dose received by the original 550, assuming that all live for the 30 years, is

$$P' = \frac{550}{\lambda} (1 -$$

$$P' = \frac{550}{\lambda} (1 - e^{-\lambda t}) = 11{,}902 \text{ rads}$$

For those born after the return, the population would be the difference between the total population in 30 years, the number of deaths and the original 550 people or 1134. Thus, the per capita dose for this group is 8949/1134 = 7.9 rads. For the original 550, the per capita dose is 11,902/550 = 22 rads. The ratio of these two to give an estimate of the fraction of the full 30 year dose received by the children is 0.36.

The assumption of no deaths in the original 550 returning was made for simplicity and the lack of good death rate data.

We also compared the age characteristics of the Marshallese from Table IV-3 and the U.S. population in 1970. This comparison is given in the attached curve. The slopes are similar above age 35 but the magnitudes are distorted by the high birth rate in the Marshall Islands. However, in terms of the relative risk the similar slopes suggest that if the natural cancer rates in the two populations are similar, the relative risk for people above 35 in both populations would be similar because most of the cancer occurs at ages from about 40 and above. However, the magnitude of the relative risk in the U.S. used for the Marshallese will be high by a factor of somewhere around 2-3 because of the distortion caused by the very high proportion of young people who have a relatively low natural cancer incidence.

Using the preceding calculations for a population of 550, calculations were made for other population sizes. For a population of 550 (from preceding):

Deaths in 30 years $= 164 \sim 160$

Births in 30 years $= 1277 \sim 1300$

For a population of 140 (the number that returned to Bikini):

Deaths in 30 years, $\frac{164}{550} = \frac{x}{140}$, $x = \underline{41.7} \sim 40$

Births in 30 years, $\frac{1277}{550} = \frac{x}{140}$, $x = \underline{325.} \sim 300$

For a population of 235:

Deaths in 30 years, $\frac{164}{550} = \frac{x}{235}$, $x = 70.07 \sim 70$

Births in 30 years, $\frac{1277}{550} = \frac{x}{235}$, $x = 545.62 \sim 550$

For a population of 350:

Deaths in 30 years, $\frac{164}{550} = \frac{x}{350}$, $x = 104.36 \sim 100$

Births in 30 years, $\frac{1277}{550} = \frac{x}{350}$, $x = 812.63 \sim 800$

III. Risk Coefficients

CENTER & CAPS

At the time the Bikini book was prepared no agency in the U.S. government had accepted the risk coefficients in BEIR-III. Thus we were constrained to use risk coefficients from BEIR-I. While not included in the printed book, risk estimates based on BEIR-III were calculated for comparison purposes. The following gives the origin of the risk coefficients used.

A. BEIR-I

1. Cancer (Tables 3-3 and 3-4)

	Cancer deaths/year in U.S. from 0.1 rem/year (pop = 197,863,000)		Derived Cancer deaths/10^6 person rem	
	Absolute	Relative	Absolute	Relative
Leukemia	516	738	26	37
Other Cancers				
30 year elevated risk	1210	2436	61	123
lifetime elevated risk	1485	8340	75	421
Range	1726-2001	3174-9078	87-101	160-458

From the above the minimium estimate of cancer risk would be given by a risk coefficient of $87/10^6$ person rem and the maximum by $458/10^6$ person rem. Thus, these two risk coefficients were used to define a range of estimated cancer deaths.

2. Genetic Effects (from Page 1 & 2 BEIR-I)

   a. Based on specific defects

      5 rem/30 year reproductive generation would cause in the first generation 100-1800 cases of dominant diseases and defects per year (3.6 million births/year) or 5 times this amount at equilibrium. The 1800 cases represent an increase of 0.05% incidences per year first generation and 0.25% at equilibrium.

In addition there would be a few chromosomal defects and recessive diseases and a few congenial defects due to a single gene defects and chromosome aberrations.

The total incidence at equilibrium is 1100 to 27,000/year.

- The total incidence at equilibrium is 1100 to 27,000/year. These at equilibrium, the maximum would be 0.75% or 0.15% in the first generation.

- These are equivalent to 0.15% per rem at equilibrium and 0.03%/rem in the first generation.

b. Based on Overall Ill Health

Overall ill health: 5% - 50% of ill health is proportional to the mutation rate using 20% and doubling dose of 20 rem, 5 rem per generation would eventually lead to a 5% increase in ill health.

Thus the rate of overall ill health is 1%/rem at equilibrium or 0.2%/rem in first generation.

For estimating the potential genetic derived health defects in the Bikini population it was decided to use a risk coefficient of 0.2% per rem in the first generation recognizing that it was probably very conservative.

B. BEIR-III

1. Cancer (Table V-4)

Lifetime Risk of Cancer Death

(deaths/10^6/rad)

Model	Single exposure to 10 rad Absolute	Single exposure to 10 rad Relative	Continous Exposure to 1 rad/yr Absolute	Continous Exposure to 1 rad/yr Relative
L-Q, ~~LQ-L~~	77	226	67	182
L-L, $\overline{\text{L-L}}$	167	501	158	430
Q-L, $\overline{\text{Q-L}}$	10	28	---	---

2. Birth Defects--pages 166-169 A

(mean parental age = 30 years)

- 1 rem per generation (1 rem parental exposure) per 10^6 live offspring 5 to 75 birth defects, this is 0.0005--0.0075%--First generation.

- Since the spontaneous rate is given as 10.7%, in the U.S. population, 1 rem will increase the rate from 10.7% to 10.7005--10.7075%.

- In terms of the spontaneous rate 1 rem per generation gives $\frac{0.0005}{10.7}$ = 0.000047 = 0.0047% increase and $\frac{0.0075}{10.7}$ = 0.0007 = 0.07% increase.

IV. CALCULATIONS OF RISK

Table 1 gives the radiation dose values provided by Dr. Robison for use in developing estimates of increased health risks in the Bikini population.

A. RISKS FOR 14 DIFFERENT LIVING CONDITIONS

1. Cancer Risks

Table 3 shows the calculations for estimates of increased cancer risk for 14 diferent living conditions.

2. Birth Defects Risks

Table 3 gives the calculations for the estimates of birth defects.

B. RISK ESTIMATES BASED ON BEIR-III

Table 4 gives risk estimates based on BEIR-III risk coefficients. These were calculated for compar~~at~~ision purposes only and was not used in the Bikini book. The highest estimates for cancer risk result from using the linear relative risk model and are about the same as those given in Table 2 for ~~the relative risk model. The lowest estimates result from the linear~~-quadratic

Table 2 for the relative risk model. The lowest estimates result from the linear-quadratic absolute risk model and are slightly less than those for the absolute model in Table 2. Thus, as far as estimates of cancer risk are concenred, those obtained using risk coefficients from BEIR-I are in the same general range as those obtained using risk coefficients from BEIR-III.

Risk estimates for birth defects obtained using the risk factor from BEIR-I gives values about three times those obtained using the upper value of the range of risk factors given in BEIR-III. If BEIR-III risk factors for bith defects represent a more enlightened assessment of this potential consequence of radiation exposure than the factor taken from BEIR-I for overall health defects, then the estimates given in the Bikini book may be conservative by a factor of three.