Determining the Future Loss of Use
of Rongelap, Rongerik and Ailinginae Atolls

Final Report

Prepared by

Bernd Franke
ifeu-Institut für Energie- und Umweltforschung Heidelberg GmbH
Institute for Energy and Environmental Research, Heidelberg
Wilckensstr. 3, 69120 Heidelberg, Germany

Prepared for the people of Rongelap Atoll
under contract with the Rongelap Atoll Local Government
for submission before the Nuclear Claims Tribunal of the Republic of the Marshall Islands

revised version

April 7, 2006

Executive Summary

This report describes work performed at the Institute for Energy and Environmental Research based in Heidelberg, Germany (IFEU) under contract with the Rongelap Atoll Local Government. It was prepared for submission to the Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands (RMI). Large areas of Rongelap, Rongerik and Ailinginae Atolls currently exceed the cleanup criterion adopted by the Nuclear Claims Tribunal[1] of 15 mrem/yr EDE (effective dose equivalent) above background to individuals that are anticipated to receive high-end exposures.

The objective of this project is to determine, separately for each island in the three atolls, the expected time period for the radioactivity to naturally drop below the 15-mrem/yr level. Consequently, no remediation was assumed. The calculations are based on a variety of dose model assumptions. Radiological decay and environmental depletion was considered on the basis of available data.

The report presents
- An adjustment of island specific acreages that is consistent with the NCT stipulated atoll acreages;
- Dose estimates to individuals that are anticipated to receive high-end exposures, also termed the reasonably maximum exposed individual (RMEI);
- An analysis of Cs-137 whole body counting data of Rongelap residents that serve as empirical evidence of past exposures over time. The time trend in observed exposures is used to determine the effective half-life of Cs-137 in Rongelap Atoll;
- Results of the calculations for a variety of scenarios.

The dose estimates for the high-end individuals from the SC&A (2000) and the Rongelap Resettlement Project (1995) were found to be in good agreement. The SC&A (2000) estimates of the Cs-137 Concentration in 0-40 cm soil at the high-end location of each island in the 2005 served as baseline. The RMEI dose was calculated by the use of a conversion factor of 19.4 mrem/yr per pCi/g. The mean effective half-life of Cs-137 was determined to be 13.1 years; the 5th and 95th percentile of the uncertainty distribution was found to be 8.0 years and 22.4 years, respectively. The 95th percentile (22.4 years) of the effective half-life of Cs-137 is considered for the baseline calculations because it adequately addresses the uncertainties in the projection of dose estimates. The loss of future use was calculated in unit of acre-years (land area multiplied by the number of years where the RMEI dose exceeds 15 mrem/yr). For the baseline case, the loss of future use (from the year 2000 onwards) was calculated as follows.
- For Rongelap Atoll without Rongelap Island: 169,871 acre-years
- For Rongelap Island only: 47,355 acre-years
- For Rongerik Atoll: 28,727 acre-years
- For Ailinginae Atoll: 9,679 acre-years

The baseline case (Tables 6-3 & 6-4; Figure 6-3) is the preferred assessment with respect to the future radiological conditions for the islands. The report also contains results for other values of the effective half-life. The sensitivity analysis showed that varying the dose conversion factor by ± 20% yields variations in the acre-years of less than 10%.

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[1] Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands. Memorandum of Decision and Order, NCT No. 23-0902. December 21, 1998

Contents

1   Introduction

This report was prepared under contract with the Rongelap Atoll Local Government (RALGOV) or submission before the Nuclear Claims Tribunal of the Republic of the Marshall Islands.

Large areas of Rongelap, Rongerik and Ailinginae Atolls currently exceed the cleanup criterion adopted by the Nuclear Claims Tribunal[2] of 15 mrem/yr EDE (effective dose equivalent) above background to individuals that are anticipated to receive high-end exposures.

The objective of this project is to determine, separately for each island in the three atolls, the expected time period for the radioactivity to naturally drop below the 15-mrem/yr level. The calculations will be based on a variety of dose model assumptions. Radiological decay and environmental depletion will be considered on the basis of available data.

Chapter 2 contains a summary of the qualifications of the principal investigator.

Chapter 3 summarizes the data on island acreages that were used in this project.

Chapter 4 presents the dose estimates to individuals that are anticipated to receive high-end exposures, also termed the reasonably maximum exposed individual (RMEI).

Chapter 5 presents an analysis of Cs-137 whole body counting data of Rongelap residents that serve as empirical evidence of past exposures over time. The time trend in observed exposures is used to determine the effective half-life of Cs-137 in Rongelap Atoll.

Chapter 6 provides the results of the calculations for a variety of scenarios.

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[2] Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands. Memorandum of Decision and Order, NCT No. 23-0902. December 21, 1998

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2 Qualifications

Bernd Franke has the German equivalent of a master's degree in biology and geography from the University of Heidelberg. He has 25 years of professional experience in radioecology and environmental risk assessment. In 1978, he was a co-founder of the IFEU-Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research) in Heidelberg, Germany, where he currently holds the position of Scientific Director. He also was a co-founder of the US-based Institute for Energy and Environmental Research (IEER) in Takoma Park, Maryland, where he served as Executive Director from 1984 to 1998. In both Institutes, he was the principal investigator in a substantial number of radiation risk assessment projects for clients representing the public and private sector.

In 1982, he was responsible for the assessment of radiation exposures due to potential accidents in the proposed fast breeder reactor at Kalkar, a study funded by the Federal German Department of Research and Technology. In 1986, he evaluated radiation exposures and associated health risks for residents in Hamburg due to fallout from the Chernobyl nuclear accident, for the State of Hamburg Department for Environmental Protection. From 1992 to 1996, Mr. Franke was a member of the Scientific Management Team of the Rongelap Resettlement Project. The project was funded by the U.S. Department of Interior and administered by the Government of the Marshall Islands and the Rongelap Local Government. In this project, he was responsible for a detailed assessment of the diet for residents on Mejatto Island, Kwajalein Atoll, and the determination of plutonium content in the remains of deceased residents of Rongelap Atoll. Together with the other members of the team, he prepared the prospective dose assessment for residents of Rongelap Island after resettlement.

In recent years, Mr. Franke has conducted dose reconstructions for residents and workers in legal claims against U.S. nuclear plants (e.g. the Feed Materials Production Center (FMPC) in Fernald, Ohio; Hanford Site, Washington; the Apollo, Pennsylvania uranium fuel facility),;evaluated the risks after cleanup at a radioactive waste disposal site near Point Hope, Alaska, under contract with the North Slope Borough, Barrow, Alaska; monitored the Independent Audits of Los Alamos National Laboratory for Compliance with the Clean Air Act, 40CFR61, Subpart H, under contract with Concerned Citizens for Nuclear Safety, Santa Fe, NM; and reviewed properties of radioactive wastes shipped from Los Alamos National Laboratory (LANL) under contract with the Attorney General of New Mexico.   Since the beginning of 2001, Mr. Franke has been a member of the German Radiation Protection Commission, an official body of experts advising the Federal Minister of the Environment in Germany with respect to many radiological issues.

In 2002, Mr. Franke performed a review of the past, present and future radiation exposures to residents of Utrik Atoll and presented the finings before the Nuclear Claims Tribunal.

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3   Determining the acreage of islands and atolls

A prerequisite of the project is a correct determination of island acreages in the three atolls. IFEU was provided by Bill Graham, Public Advocate, with the following data[3]:

- Island specific acreages from *Guide to Place Names in the Trust Territory of the Pacific Islands*, compiled by E. H. Bryan, Jr., and published by the Pacific Scientific Information Center at the Bernice P. Bishop Museum in Honolulu, Hawaii, in 1971
- Atoll specific acreages from the UN System-Wide Earthwatch website. Included as part of that website is the Island Directory (http://www.unep.ch/islands/isldir.htm), providing "basic environmental and geographic information on the significant islands of the world."
- Island specific acreages from digitized aerial photographs taken during the radiological survey conducted by U.S. Department of Energy contractors in 1978. The digitization was performed by SC&A, McLean, VA. The digitization distinguished between vegetated areas and areas above the water line. Area errors on the order of 7% could be expected for that method.

The acreage data in *Guide to Place Names in the Trust Territory of the Pacific Islands* is subject to errors as evident from inspection of Ailinginae Atoll. Even a casual glance at the Place Names map for Ailinginae reveals that Kuoben Island (said to be 556.8 acres) is slightly smaller than neighbouring Ribinouri (said to be 67.2 acres). The author of Place Names (E. H. Bryan, Jr.) cautions in the Introduction section that areas "are approximate only, made by measuring maps or air photographs"; it may well be that decimal points were in error for Kuoben as well as for some other islands in Ailinginae.

In order to resolve these inaccuracies, the Nuclear Claims Tribunal (NCT) stipulated in August 2001 the following areas: 1,946.1 acres for Rongelap, 467.5 acres for Rongerik and 753.3 acres for Ailinginae for a total of 3,166.9 acres. The NCT did not stipulate islands specific acreages. In order to determine future loss-of-use, island specific data is required because the radiological contamination differs from island to island.

Tables 3-1 to 3-3 contain the data from the *Guide to Place Names in the Trust Territory of the Pacific Islands* (TT), the results from the SC&A digitization (vegetated areas = SC&A veg; areas above the water line = SC&A awl), as well as the adjusted acreage for each island. The adjusted values were calculated by apportioning the NCT stipulated total for the respective atoll on the basis of the SC&A awl values.

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[3] Email received on January 26, 2006

Table 3-1   Islands and acreages in Rongelap Atoll

Rongelap Atoll	Island size (acres)			
	TT	SC&A veg	SC&A awl	Adjusted
Lomuilal*	51.2	51.6	67.76	57.9
Gejen (Keen)	16.64	17.56	22.61	19.3
Lukuen (Likukoon)	24.96	20.82	23.33	19.9
Eriippu	6.4	3.63	4.46	3.8
Kiloken/Kimejkan (Giragoen)	-	2.27	5.33	4.6
Anielap	18.56	54.80**	89.89***	76.8
Bokolok (Enewetakan)/Bikkako (Enejejkan	-	12.51	16.38	14.0
Kabelle (Enessesegan)	64	76.29	92.67	79.2
Namen (Namoan?)	8.32	22.82	30.27	25.9
Mejatto	23.04	4.18	8.04	6.9
Airkij	2.56	0.81	1.59	1.4
Yuzugan (Baren)	4.48	2.66	5.02	4.3
Ribiyurgan (Libirukan)	7.8	7.29	10.48	9.0
Labaredj	31.36	34.43*	55.01*	47.0
Aijkan	-	not listed	not listed	0.0
Bokoen	19.2	16.34	21.73	18.6
Gabelle (Kabelle)*	31.36	48.05	55.33	47.3
Mellu*	120.32	67.04	142.92	122.1
Northeast Pass	-	0	0	0.0
Anidjet (Enejet)	48	35.79	54.14	46.3
Gogan Pass	-	0	0	0.0
Gogan (Jorkan)	40.32	31.75	45.31	38.7
Bokekke/Bokliwij	22.4	3.26*	13.46*	11.5
Kieshiechi (Kiejej)	-	22.6	27.37	23.4
Enybarbar Pass	-	0	0	0.0
Enybarbar	12.16	10.03	14.36	12.3
Bokalikmeltu	89.6	7.37	10.01	8.6
Biguanno/Enellapkan	11.52	4.03	7.98	6.8
Erapuotsu (Erabot)*	23.04	15.98	18.78	16.0
Eniaetok/Bikden*	160	133.4	158.06	135.1
Bogontorinaai (Bikden)	23.04	3.71	6.56	5.6
Rochi (Bok or Looj)	12.8	0.17	2.39	2.0
Enialo	31.36	10.16	22.97	19.6
Rigonman (Likaman)	19.2	7.57	14.72	12.6
Weobiji (Eonbeje)	16	2.9	8.22	7.0
Busch (Lokommon or Likoteka)	240	28.29	37.07	31.7
Roggutsu (Bokanrekut)	8.96	4.51*	9.29*	7.9
Bokujarito (Bokjelot or Bokjalto)	13.44	4.37	11.63	9.9

Table 3-2   Islands and acreages in Rongelap Atoll

Rongelap Atoll	Island size (acres)			
	TT	SC&A veg	SC&A awl	Adjusted
Rongelap	512	529.39	651.7	556.9
Jaboan (Japtan) Village	-	0	0	0.0
South Pass	-	0	0	0.0
Arubaru (Arbar)	108.8	85.91	114.19	97.6
Bikien (pass)	-	0	0	0.0
Bikien	3.84	3.1	3.28	2.8
Enirolul	0.64	3.61	7.74	6.6
Eniran Pass	-	0	0	0.0
Eniran (Anekan)	44.8	26.61*	39.16*	33.5
Kaeroga Pass	-	0	0	0.0
Tufa (Kaeroka)	103.68	56.41*	70.10*	59.9
Arugaren (Alnaren)	8.96	2.73	5.29	4.5
Bokanetao	0.003	not found	not found	0.0
Burok (Burokku)	64	45.46	58.13	49.7
Pokoreppo (Bokelap)	0.002	no trees	no trees	0.0
West Pass	-	0	0	0.0
Maen	72.32	80.94	97.54	83.3
Naen	15.36	21.2	29.08	24.8
Bokenkear	23.04	17.37	22.59	19.3
Aerik	19.84	21.86*	27.29*	23.3
Narrow pass for small boats	-	0	0	0.0
Yugui (Ekaj)	-	19.98	25.77	22.0
Bwokwankidudiet	-	4.32	10.44	8.9
Total	**1964.8**	**1714.55**	**2277.38**	**1946.1**

*   indicates total of two acreages listed separately under the same name
**   indicates total of seven acreages listed separately under the same name (three of which are noted
        to be "combined")
***   indicates total of five acreages listed separately under the same name

Table 3-3   Islands and acreages in Rongerik Atoll

Rongerik Atoll	Island size (acres)			
	TT	SC&A veg	SC&A awl	Adjusted
Jedibberdib	8.32	6.25	10.96	11.3
Latoback (Batbat)	40.32	36.98	46.97	48.6
Bokalikan	-	not listed	not listed	0.0
Moterik (Moterikku)	3.84	0.15	0.74	0.8
Mortlock (Motlap)	3.2	6.13	10.88	11.3
Bigonattam (Bekanare)	49.92	35.19	48.91	50.6
Rongerik	111.36	115.16	132.99	137.7
Bokenkemej	0.002	not listed	not listed	0.0
Bokentuak	0.003	not listed	not listed	0.0
Tarrowatt (Karoka)	0.03	not listed	not listed	0.0
Bokeredj	-	not listed	not listed	0.0
Eniwetak (Enyvertok)	1.92	74.15	101.64	105.2
Bock	64	46.81	98.53	102.0
Total	**416**	**320.82**	**451.62**	**467.5**

Table 3-7   Islands and acreages in Ailinginae Atoll

Ailinginae Atoll	Island size (acres)			
	TT	SC&A veg	SC&A awl	Adjusted
Najibuen	8.96	6.58	12.08	11.0
Bokonikaiaru	5.76	6.31	12.21	11.2
Charaien (Jelaen)	4.48	1.58	3.82	3.5
Bokoryuren (Bokarran)	31.36	16.68	34.2	31.3
Two unnamed sandspits (Bok)	0.013	not listed	not listed	0.0
Majokoryaan (Majkoran)	43.52	7.38	32.06	29.3
Bekenarar	0.025	not listed	not listed	0.0
Bokoen	23.68	14.42	29.5	27.0
Knox (Jorea)	48	65.61	82.46	75.4
Kungeekan (Korekan)	0.032	not listed	not listed	0.0
Bok	0.015	not listed	not listed	0.0
Bokanchinre (Bokarok)	0.045	not listed	not listed	0.0
Ucchuwanen	448	43.3	83.4	76.2
Pigessharukku (Bikejarok)	192	12.63	38.67	35.3
Kuoben	556.8	32.92	73.66	67.3
Ribinouri (Drebenwod)	67.2	55.6	119.69	109.4
Airuken (Aerik)	19.2	(combined with Ribinouri)	0	0.0
Bikenaen	3.84	2.19	8.07	7.4
Eniuetakku (Enewetak)	12.8	10.46	27.95	25.5
Enibuk	35.2	25.56	51.55	47.1
Enibuk Pass	-	0	0	0.0
Mogiri (Mokil)	83.2	78.96	103.78	94.8
Mogiri Pass	-	0	0	0.0
Manchinikon (Maniknik)	28.16	16.46	25.33	23.1
Sifo (Karwe)	47.36	59.29	79.51	78.5
Total	**691.2**	**459.29**	**824.34**	**753.3**

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4   Baseline data for the year 2005

The report by SC&A contains a thorough review of the data on existing contamination on the islands in the three atolls. Their summary and estimate of Cs-137 levels in soil on average and high-end locations is contained in Tables 4-1, 4-2 and 4-3 for Rongelap, Rongerik and Ailiniginae Atolls.

The Cs-137 external and internal dose for the high-end individual was estimated by using the conversion factor of 19.4 mrem/yr per pCi/g that was derived by SC&A[4]. On this basis, the resulting dose for the high-end individual on Rongelap Island in the year 2005 was calculated to be 176 mrem/yr EDE (effective dose equivalent) above background when no potassium application is considered.

The dose estimate may be compared to that provided by the Rongelap Resettlement Project (RRP)[5]. The final report of the project contains estimates of radiation doses to determine compliance with the predetermined dose limit specified in the Memorandum of Understanding.[6] The 95th percentile of the estimated dose in the Rongelap Resettlement Project, adjusted for decay to the year 2005 is as follows.

>   Calculation 1, males: 104 mrem/yr, females: 91 mrem/yr, males&females: 97 mrem/yr
>   Calculation 2, males: 223 mrem/yr, females: 172 mrem/yr, males&females: 197 mrem/yr

The average of the two RRP calculations is 147 mrem/yr. In conclusion, the SC&A and RRP approaches are in good agreement while uncertainties due to the model assumptions remain. It was decided to not to consider the contributions from Pu-239/240, Am-241 and Sr-90 for the following reasons:

- The analysis of Pu-239/240, Am-241 in bones from exhumed former Rongelap residents indicates that the doses are significantly below 1 mrem/yr EDE[7].
- The contribution of Sr-90 was determined in the Rongelap Resettlement Project to be less than 2% of the Cs-137 dose.[8]

In order to address the remaining uncertainty in the estimate of the total dose, a sensitivity analysis is performed whereby the dose factor (mrem/yr per pCi/g) is varied by + 20%.

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[4] Mauro J.J., Behling H., Anigstein R. (2000), Statement before the Nuclear Claims Tribunal regarding the Potential Radiation Dose and Health Risks to a Resettled Population of Rongelap Atoll, Rongerik Atoll, and Ailinginae Atoll and an Evaluation of the Costs and Effectiveness of Alternative Strategies for Reducing the Doses and Risks, Final Report, S. Cohen & Associates, McLlean, VA, August 2000

[5] Baverstock K., Franke B., Simon S.L (1994)., Rongelap Resettlement Project, Summary of First Phase: Determining Compliance with Agreed Limits for Total Annual Dose-Rate on Rongelap Island and Actinide Contamination of Soils on Rongelap Island and Neighbouring Islands, Rongelap Resettlement Project, P.O.Box 1766, Majuro, MI 96960, May 1994

[6] Republic of the Marshall Islands, Rongelap Atoll Local Government, U.S. Department of Energy and U.S. Department of Interior (1992), Memorandum of Understanding for the Rongelap Resetllement Project, February 1992

[7] Franke B., Schupfner R., Schüttelkopf H. and Spennemann D.H.R., "Transuranics in Bone of Deceased Former Residents of Rongelap Atoll, Marshall Islands", Applied Radiation and Isotopes, 46:1253-1258: 1995

[8] RRP report page 15

Table 4-1   Cs-137 contamination on islands of Rongelap Atoll

Island	No of profiles	Estimated Cs-137 in 0-40 cm soil (pCi/g in the year 2005)	
		Average location	High-end location
Lomuilal*	14	15.5	46.6
Gejen (Keen)		15.5	46.6
Lukuen (Likukoon)		15.5	46.6
Eriippu		15.5	46.6
Kiloken/Kimejkan (Giragoen)		15.5	46.6
Anielap		15.5	46.6
Bokolok (Enewetakan)/Bikkako (Enejejkan		15.5	46.6
Kabelle (Enessesegan)		15.5	46.6
Namen (Namoan?)		15.5	46.6
Mejatto		6.8	20.5
Airkij		6.8	20.5
Yuzugan (Baren)		6.8	20.5
Ribiyurgan (Libirukan)		6.8	20.5
Labaredj		6.8	20.5
Aijkan		6.8	20.5
Bokoen		6.8	20.5
Gabelle (Kabelle)*	16	6.8	20.5
Mellu*	14	12.4	37.3
Northeast Pass		12.4	37.3
Anidjet (Enejet)		12.4	37.3
Gogan Pass		12.4	37.3
Gogan (Jorkan)		12.4	37.3
Bokekke/Bokliwij		12.4	37.3
Kieshiechi (Kiejej)		12.4	37.3
Enybarbar Pass		7.0	21
Enybarbar		7.0	21
Bokalikmeltu		7.0	21
Biguanno/Enellapkan		7.0	21
Erapuotsu (Erabot)*	3	7.0	21
Eniaetok/Bikden*	20	3.7	11.2
Bogontorinaai (Bikden)		7.8	23.3
Rochi (Bok or Looj)		7.8	23.3
Enialo		7.8	23.3
Rigonman (Likaman)		7.8	23.3
Weobiji (Eonbeje)		7.8	23.3
Busch (Lokommon or Likoteka)	5	7.8	23.3
Roggutsu (Bokanrekut)		7.8	23.3

Table 4-1 (c'd)   Cs-137 contamination on islands of Rongelap Atoll

Island	No of profiles	Estimated Cs-137 in 0-40 cm soil (pCi/g in the year 2005)	
		Average location	High-end location
Bokujarito (Bokjelot or Bokjalto)		7.8	23.3
Rongelap	108	3.0	9.09
Jaboan (Japtan) Village		3.0	9.09
South Pass		3.0	9.09
Arubaru (Arbar)	9	4.3	12.8
Bikien (pass)		4.3	12.8
Bikien		4.3	12.8
Enirolul		4.3	12.8
Eniran Pass		3.7	11
Eniran (Anekan)	6	3.7	11
Kaeroga Pass		6.8	20.5
Tufa (Kaeroka)	8	6.8	20.5
Arugaren (Alnaren)		6.1	18.2
Bokanetao		6.1	18.2
Burok (Burokku)	13	6.1	18.2
Pokoreppo (Bokelap)		3.7	11.2
West Pass		3.7	11.2
Maen		20.2	60.6
Naen	15	20.2	60.6
Bokenkear		20.2	60.6
Aerik		30.3	99
Narrow pass for small boats		30.3	99
Yugui (Ekaj)	11	30.3	90.9
Bwokwankidudiet		30.3	90.9

Table 4-2   Cs-137 contamination on islands of Rongerik Atoll

Island	No of profiles	Estimated Cs-137 in 0-40 cm soil (pCi/g in the year 2005)	
		Average location	High-end location
Jedibberdib		1.6	4.8
Latoback (Batbat)	5	1.6	4.8
Bokalikan		1.7	4.9
Moterik (Moterikku)		1.7	4.9
Mortlock (Motlap)	1	1.7	4.9
Bigonattam (Bekanare)	6	2.2	6.6
Rongerik	10	1.7	5.2
Bokenkemej		1.7	5.2
Bokentuak		0.1	0.2
Tarrowatt (Karoka)	2	0.1	0.2
Bokeredj		0.7	2.0
Eniwetak (Enyvertok)	7	0.7	2.0
Bock	7	2.0	6.1

Table 4-3   Cs-137 contamination on islands of Ailinginae Atoll

Island	No of profiles	Estimated Cs-137 in 0-40 cm soil (pCi/g in the year 2005)	
		Average location	High-end location
Najibuen	1	0.05	0.13
Bokonikaiaru	1	0.25	0.75
Charaien (Jelaen)		0.25	0.75
Bokoryuren (Bokarran)	3	0.69	2.06
Two unnamed sandspits (Bok)		0.69	2.06
Majokoryaan (Majkoran)	7	0.46	1.38
Bekenarar		0.46	1.38
Bokoen	3	0.37	1.11
Knox (Jorea)	7	0.32	0.97
Kungeekan (Korekan)	1	0.01	0.03
Bok		0.01	0.03
Bokanchinre (Bokarok)	2	0.01	0.04
Ucchuwanen	5	0.37	1.10
Pigessharukku (Bikejarok)	1	0.45	1.34
Kuoben	5	0.24	0.73
Ribinouri (Drebenwod)	6	0.31	0.94
Airuken (Aerik)	1	0.02	0.06
Bikenaen		0.02	0.06
Eniuetakku (Enewetak)	2	0.23	0.69
Enibuk	4	0.36	1.08
Enibuk Pass		0.36	1.08
Mogiri (Mokil)	8	0.30	0.90
Mogiri Pass		0.30	0.90
Manchinikon (Maniknik)	3	0.08	0.25
Sifo (Karwe)	3	0.29	0.88

5   Estimating the effective half-life of Cs-137

Aside from radioactive decay, Cs-137 is removed from the atoll environment via environmental loss. The effective half-life (EHL) of Cs-137 has two components: the radioactive decay (30.17 yrs) and the environmental half-life. Evidence for environmental removal is the presence of Cs-137 and Sr-90 in the fresh water portion of the groundwater at all contaminated atolls. This suggests that a portion of the soluble fraction of Cs-137 and Sr-90 inventory in the soil is lost by transport to groundwater when rainfall is heavy enough to cause recharge of the freshwater lens, resulting in loss of Cs-137 from the soil column and root zone of the plants.

5.1   Estimate by Robison et al.

Robison et al. (2003)[9] estimated the effective and environmental half-life of Cs-137 on the basis of time-series data by two methods:
- indirectly, from time-dependent studies of the Cs-137 concentration in leaves of *Pisonia. grandis, Guettarda specosia, Tournefortia argentea* (also called *Messeisch,nidia), Scaevola taccada,* and fruit from *Pandanus* and coconut trees *(Cocos nucifera L.),* and
- more directly, by evaluating the Cs-137/Sr-90 ratios at Bikini Atoll.
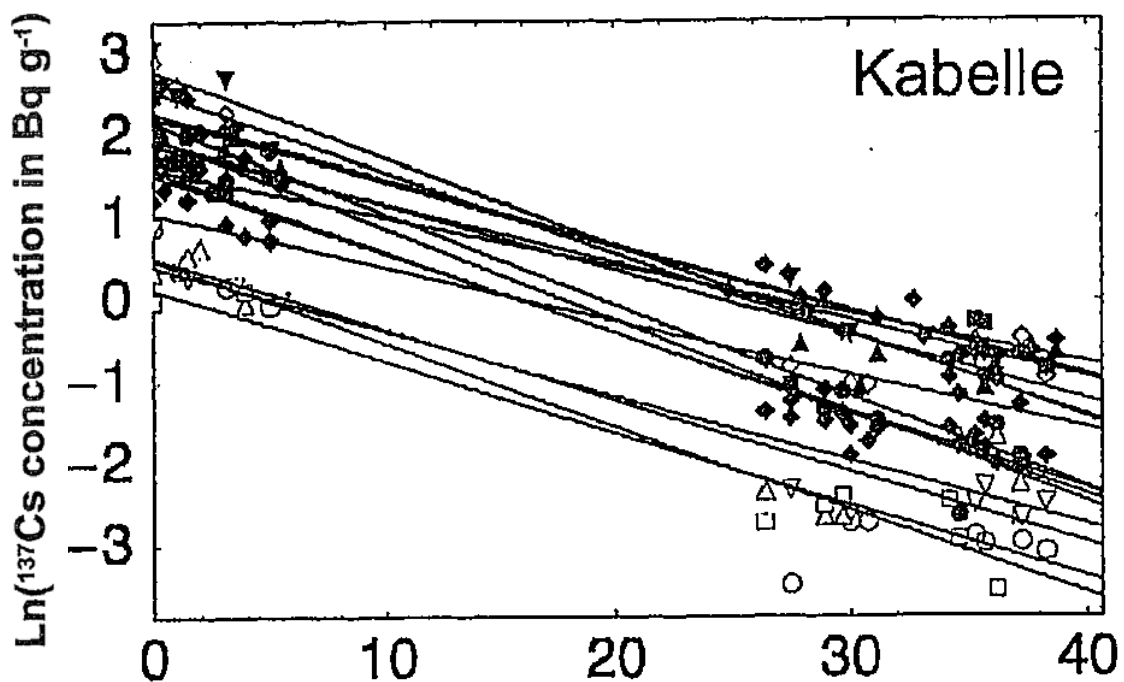
Figure 5-1   Measured Cs-137 concentration in fruits and leaves of 16 trees sampled periodically over many years on Kabelle Island at Rongelap Atoll (Robsion et al., 2003)

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[9] William L. Robison, Cynthia L. Conrado, Kenneth T. Bogen and A. Carol Stoker ,The effective and environmental half-life of 137Cs at Coral Islands at the former US nuclear test site Journal of Environmental Radioactivity Volume 69, Issue 3 , 2003, Pages 207-223

Figure 5-1 shows the considerable spread of the tree-specific data for Kabelle Island. For each tree, a linear regression analysis was performed as indicated by a line.

Robison et al determined the mean (and its lower and upper 95% confidence limits) for effective half-life and for environmental-loss half-life (ELH) based on all the trees studied on Rongelap, Bikini, and Enewetak Atolls are 8.5 years (8.0 years, 9.8 years), and 12 years (11 years, 15 years), respectively. The ELH based on the Cs-137/Sr-90 ratios in soil in 1987 relative to the Cs-137/Sr-90 ratios at the time of deposition in 1954 is less than 17 years.

5.2 Estimate on the basis of whole-body counting data

A direct way to determine the effective half-life from ingested radionuclides on Rongelap Atoll is the analysis of historical whole body counting data for residents for the time period 1957 through 1993. These data allow the determination of annual radiation doses under the following assumptions:

- the data are accurate (i.e. correct calibration);
- the body burden for a given individual is representative for the entire year in question;
- the sample of monitored individuals is representative for the entire age and sex group.

Under these assumptions, the data allow to evaluate the variability of the radiation exposure, which reflects the diet pattern, as they existed in a particular year. The raw WBC data for a total of 2519 separate measurements was received from the U.S. Department of Energy at the request of the Marshall Islands Government in database format (file: DOE_BNL_WBC_PUBIOASSAY.mdb). The data included measurements for Rongelap residents. The number of records contained in the database is summarized in Table 5-1.

Table 5-1   Whole-body counting records for Rongelap residents in the DOE database

Year	Females<=15 yr	Females>15 yr	Males<=15 yr	Males>15 yr
1958	0	16	4	54
1959	8	49	7	56
1961	5	39	4	45
1965	6	71	7	72
1974	0	23	0	23
1977	4	22	7	29
1979	16	15	23	16
1981	21	30	30	36
1982	16	18	27	29
1983	25	29	38	24
1984	36	37	43	44

It appears that each record represents a different person. Furthermore, the data were evaluated on an "as is" basis, which implies that any systematic bias could not be corrected. The data for either body weight or age were entered incorrectly in a number of cases. Since the

discrepancies could not be resolved, it was concluded that age data were more reliable because dose conversion factors are generally given only for adult body sizes. Hence only data for residents were analyzed for which the age was recorded to be greater than 15 years.

For a given activity in the body, the internal dose was calculated using the conversion factors for adults that were derived from ICRP 72 metabolic data. The effective dose per unit body burden is calculated to be 3.7×10^{-8} Sv/y per Bq (137 mrem/y per µCi). It was further assumed that the observed concentration in the body was representative for the entire year in question. Using the above assumptions, the doses to residents were calculated.

The estimates of the radiation exposures were then used to as the basis for a linear regression analysis of the time series data. The uncertainty in the regression analysis was evaluated by fitting the values for a given year to a lognormal distribution, males and females separately. Monte Carlo error propagation was used to define the uncertainty of the effective half-life. The results of the analysis are summarized in Table 5-2.

On this basis, the mean value of the effective half-life was determined to be 13.1 years. The 5th and 95th percentiles of the uncertainty distribution were determined to be 8.0 years and 22.4 years, respectively.

Table 5-2   Effective half-life of Cs-137 as determined on the basis of whole-body counting data for Rongelap residents

Parameter	Females >15 yr	Males >15 yr	All >15 yr
2.5-percentile	8.4	6.6	7.5
5-percentile	9.0	7.1	8.0
50-percentile	13.8	10.9	12.4
95-percentile	23.8	21.0	22.4
97.5-percentile	25.8	23.9	24.9
Mean value	14.4	11.7	13.1

Figures 5-2 and 5-3 illustrate the mean value and 95% confidence interval of the estimated annual internal dose from Cs-137 among males and females on Rongelap Atoll for whole body counting missions and atoll population in a given year. Also shown are the projected doses that are estimated from the 1958 mean value using the 5th, mean value and 95th percentile of the effective half-life (EHL).

5.3   Conclusion

The time-series data on individual trees shows a considerable uncertainty and may be subject to bias because of cesium depletion in the root zone of trees. The use of whole-body counting data implies a constant range of diets whereas the local food component is likely to have decreased over time.   In general observations of Cs-137 contents in the human body are more representative and reflect the food supply on Rongelap Island better than single-tree time series. The 95th percentile (22.4 years) of the effective half-life of Cs-137 is considered for the baseline calculations because it adequately addresses the uncertainties in the projection of dose estimates.
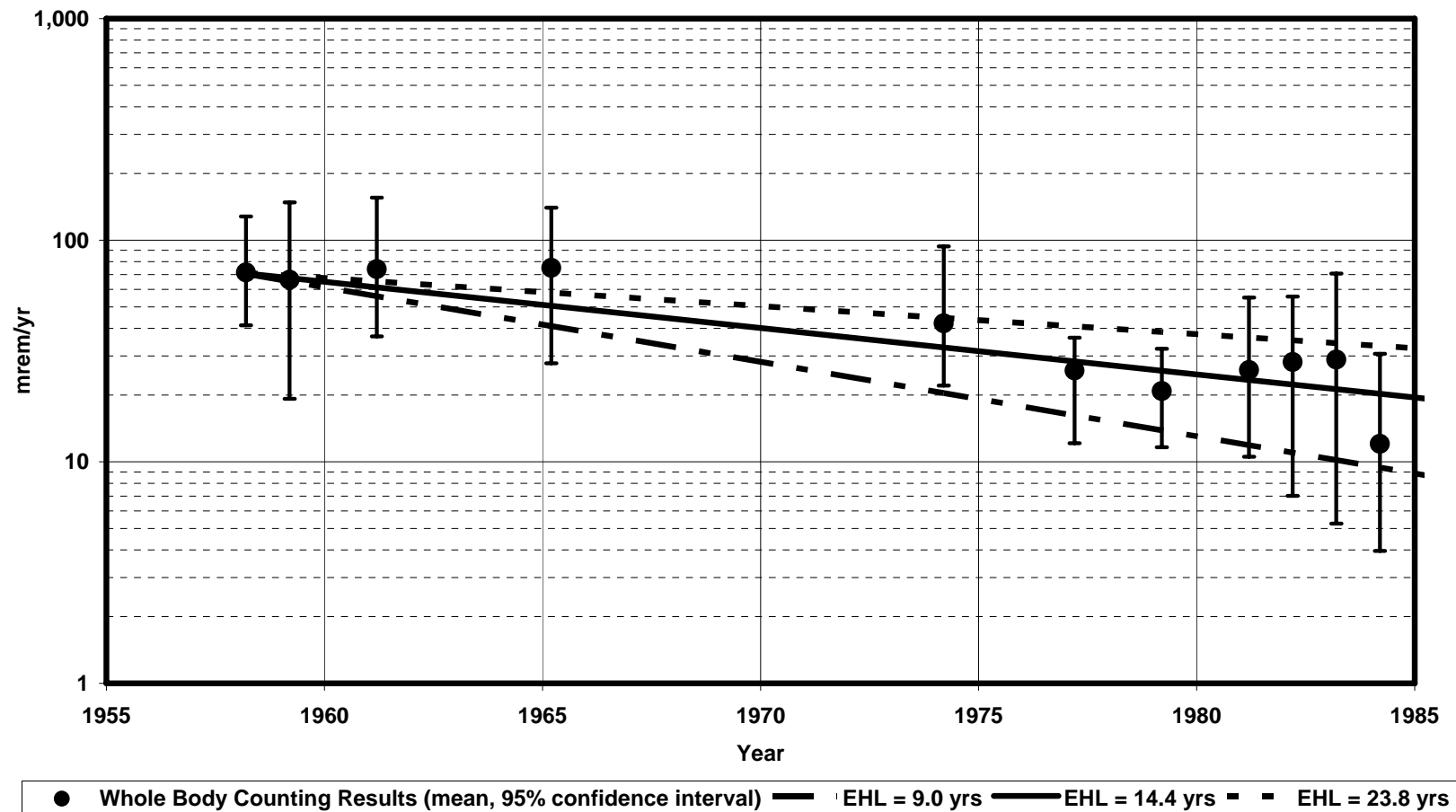
Figure 5-2   Estimated annual internal dose from Cs-137 among females > 15 years on Rongelap Atoll, based on data provided by DOE for whole body counting missions and atoll population in a given year. Also shown are the projected doses that are estimated from the 1958 mean value using the 5[th 8], mean value and 95th percentile of the effective half-life (EHL).

Figure 5-3 Estimated annual internal dose from Cs-137 among males > 15 years on Rongelap Atoll, based on data provided by DOE for whole body counting missions and atoll population in a given year. Also shown are the projected doses that are estimated from the 1958 mean value using the 5th [8], mean value and 95th percentile of the effective half-life (EHL).

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6   Future loss-of-use calculation

The data in the previous chapters was used to determine, separately for each island in the three atolls, the expected time period for the radioactivity to naturally drop below the 15-mrem/yr level. Consequently, no remediation was assumed. The calculations were based on a variety of assumptions as follows:

- Adjusted values for island acreages for each island (Table 3-1 to 3-3)
- Cs-137 in high-end locations in the year 2005 (Tables 4-1 to 4-3)
- Effective half-life of Cs-137 based on whole-body counting data (Table 5-2)

The loss of future use was calculated in the unit of acre-years (land area multiplied by the number of years where the RMEI dose exceeds 15 mrem/yr). The year-by-year calculations are presented in Tables 6-1 for the 5th percentile, in Table 6-2 for the mean value and in Table 6-3 for the 95th percentile of the effective half-life. The results are shown in graphical form in Figures 6-1 to 6-3.

The 95th percentile (22.4 years) of the effective half-life of Cs-137 is considered for the baseline calculations because it adequately addresses the uncertainties in the projection of dose estimates. For this, the loss of future use from the year 2000 onwards was calculated as follows.

- For Rongelap Atoll without Rongelap Island: 169,871 acre-years
- For Rongelap Island only: 47,355 acre-years
- For Rongerik Atoll: 28,727 acre-years
- For Ailinginae Atoll: 9,679 acre-years

A summary of the acreage totals is provided in Table 6-4. Tables 6-5 and 6-6 show the results of the sensitivity analysis which indicates that the variation of the dose conversion factor by ±20% yields variations in the acre-years of less than 10%.

Table 6-1 Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 8.0 years (5th percentile of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2000	1,389	557	468	712	3,125
2001	1,389	557	468	712	3,125
2002	1,389	557	468	712	3,125
2003	1,389	557	468	712	3,125
2004	1,389	557	468	686	3,100
2005	1,389	557	468	604	3,018
2006	1,389	557	468	604	3,018
2007	1,389	557	468	431	2,844
2008	1,389	557	468	246	2,660
2009	1,389	557	468	199	2,613
2010	1,389	557	468	96	2,509
2011	1,389	557	468	96	2,509
2012	1,389	557	468	31	2,445
2013	1,389	557	468	31	2,445
2014	1,389	557	468	31	2,445
2015	1,389	557	468	31	2,445
2016	1,389	557	362	31	2,340
2017	1,389	557	362	0	2,308
2018	1,389	557	362	0	2,308
2019	1,389	557	362	0	2,308
2020	1,389	557	362	0	2,308
2021	1,389	557	362	0	2,308
2022	1,389	557	362	0	2,308
2023	1,389	557	362	0	2,308
2024	1,389	557	362	0	2,308
2025	1,389	557	362	0	2,308
2026	1,389	557	362	0	2,308
2027	1,389	557	153	0	2,099
2028	1,389	557	153	0	2,099
2029	1,389	557	51	0	1,997
2030	1,389	557	0	0	1,946
2031	1,389	557	0	0	1,946
2032	1,389	557	0	0	1,946
2033	1,389	557	0	0	1,946
2034	1,389	0	0	0	1,389
2035	1,389	0	0	0	1,389

Table 6-1 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 8.0 years (5th percentile of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2036	1,221	0	0	0	1,221
2037	1,221	0	0	0	1,221
2038	1,114	0	0	0	1,114
2039	1,114	0	0	0	1,114
2040	1,114	0	0	0	1,114
2041	1,114	0	0	0	1,114
2042	1,060	0	0	0	1,060
2043	865	0	0	0	865
2044	822	0	0	0	822
2045	725	0	0	0	725
2046	725	0	0	0	725
2047	725	0	0	0	725
2048	725	0	0	0	725
2049	725	0	0	0	725
2050	483	0	0	0	483
2051	483	0	0	0	483
2052	483	0	0	0	483
2053	182	0	0	0	182
2054	182	0	0	0	182
2055	182	0	0	0	182
2056	54	0	0	0	54
2057	54	0	0	0	54
2058	54	0	0	0	54
2059	54	0	0	0	54
2060	54	0	0	0	54
2061	23	0	0	0	23
2062	0	0	0	0	0

Table 6-2   Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 13.1 years (mean value of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2000	1,389	557	468	712	3,125
2001	1,389	557	468	712	3,125
2002	1,389	557	468	712	3,125
2003	1,389	557	468	686	3,100
2004	1,389	557	468	619	3,032
2005	1,389	557	468	604	3,018
2006	1,389	557	468	604	3,018
2007	1,389	557	468	604	3,018
2008	1,389	557	468	431	2,844
2009	1,389	557	468	322	2,735
2010	1,389	557	468	246	2,660
2011	1,389	557	468	246	2,660
2012	1,389	557	468	96	2,509
2013	1,389	557	468	96	2,509
2014	1,389	557	468	96	2,509
2015	1,389	557	468	96	2,509
2016	1,389	557	468	31	2,445
2017	1,389	557	468	31	2,445
2018	1,389	557	468	31	2,445
2019	1,389	557	468	31	2,445
2020	1,389	557	468	31	2,445
2021	1,389	557	468	31	2,445
2022	1,389	557	468	31	2,445
2023	1,389	557	362	31	2,340
2024	1,389	557	362	0	2,308
2025	1,389	557	362	0	2,308
2026	1,389	557	362	0	2,308
2027	1,389	557	362	0	2,308
2028	1,389	557	362	0	2,308
2029	1,389	557	362	0	2,308
2030	1,389	557	362	0	2,308
2031	1,389	557	362	0	2,308
2032	1,389	557	362	0	2,308
2033	1,389	557	362	0	2,308
2034	1,389	557	362	0	2,308
2035	1,389	557	362	0	2,308

Table 6-2 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 13.1 years (mean value of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2036	1,389	557	362	0	2,308
2037	1,389	557	362	0	2,308
2038	1,389	557	362	0	2,308
2039	1,389	557	362	0	2,308
2040	1,389	557	302	0	2,248
2041	1,389	557	153	0	2,099
2042	1,389	557	153	0	2,099
2043	1,389	557	153	0	2,099
2044	1,389	557	153	0	2,099
2045	1,389	557	51	0	1,997
2046	1,389	557	0	0	1,946
2047	1,389	557	0	0	1,946
2048	1,389	557	0	0	1,946
2049	1,389	557	0	0	1,946
2050	1,389	557	0	0	1,946
2051	1,389	557	0	0	1,946
2052	1,389	0	0	0	1,389
2053	1,389	0	0	0	1,389
2054	1,389	0	0	0	1,389
2055	1,389	0	0	0	1,389
2056	1,221	0	0	0	1,221
2057	1,221	0	0	0	1,221
2058	1,221	0	0	0	1,221
2059	1,114	0	0	0	1,114
2060	1,114	0	0	0	1,114
2061	1,114	0	0	0	1,114
2062	1,114	0	0	0	1,114
2063	1,114	0	0	0	1,114
2064	1,114	0	0	0	1,114
2065	1,060	0	0	0	1,060
2066	1,060	0	0	0	1,060
2067	865	0	0	0	865
2068	822	0	0	0	822
2069	822	0	0	0	822
2070	725	0	0	0	725
2071	725	0	0	0	725
2072	725	0	0	0	725

Table 6-2 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 13.1 years (mean value of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2073	725	0	0	0	725
2074	725	0	0	0	725
2075	725	0	0	0	725
2076	725	0	0	0	725
2077	725	0	0	0	725
2078	725	0	0	0	725
2079	483	0	0	0	483
2080	483	0	0	0	483
2081	483	0	0	0	483
2082	483	0	0	0	483
2083	182	0	0	0	182
2084	182	0	0	0	182
2085	182	0	0	0	182
2086	182	0	0	0	182
2087	182	0	0	0	182
2088	54	0	0	0	54
2089	54	0	0	0	54
2090	54	0	0	0	54
2091	54	0	0	0	54
2092	54	0	0	0	54
2093	54	0	0	0	54
2094	54	0	0	0	54
2095	54	0	0	0	54
2096	23	0	0	0	23
2097	0	0	0	0	0

Table 6-3   Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 22.4 years (95th percentile of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2000	1,389	557	468	712	3,125
2001	1,389	557	468	712	3,125
2002	1,389	557	468	686	3,100
2003	1,389	557	468	686	3,100
2004	1,389	557	468	604	3,018
2005	1,389	557	468	604	3,018
2006	1,389	557	468	604	3,018
2007	1,389	557	468	604	3,018
2008	1,389	557	468	604	3,018
2009	1,389	557	468	604	3,018
2010	1,389	557	468	526	2,939
2011	1,389	557	468	431	2,844
2012	1,389	557	468	322	2,735
2013	1,389	557	468	246	2,660
2014	1,389	557	468	246	2,660
2015	1,389	557	468	246	2,660
2016	1,389	557	468	199	2,613
2017	1,389	557	468	96	2,509
2018	1,389	557	468	96	2,509
2019	1,389	557	468	96	2,509
2020	1,389	557	468	96	2,509
2021	1,389	557	468	96	2,509
2022	1,389	557	468	96	2,509
2023	1,389	557	468	61	2,474
2024	1,389	557	468	31	2,445
2025	1,389	557	468	31	2,445
2026	1,389	557	468	31	2,445
2027	1,389	557	468	31	2,445
2028	1,389	557	468	31	2,445
2029	1,389	557	468	31	2,445
2030	1,389	557	468	31	2,445
2031	1,389	557	468	31	2,445
2032	1,389	557	468	31	2,445
2033	1,389	557	468	31	2,445
2034	1,389	557	468	31	2,445
2035	1,389	557	362	31	2,340

Table 6-3 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 22.4 years (95th percentile of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2036	1,389	557	362	31	2,340
2037	1,389	557	362	0	2,308
2038	1,389	557	362	0	2,308
2039	1,389	557	362	0	2,308
2040	1,389	557	362	0	2,308
2036	1,389	557	362	31	2,340
2041	1,389	557	362	0	2,308
2042	1,389	557	362	0	2,308
2043	1,389	557	362	0	2,308
2044	1,389	557	362	0	2,308
2045	1,389	557	362	0	2,308
2046	1,389	557	362	0	2,308
2047	1,389	557	362	0	2,308
2048	1,389	557	362	0	2,308
2049	1,389	557	362	0	2,308
2050	1,389	557	362	0	2,308
2051	1,389	557	362	0	2,308
2052	1,389	557	362	0	2,308
2053	1,389	557	362	0	2,308
2054	1,389	557	362	0	2,308
2055	1,389	557	362	0	2,308
2056	1,389	557	362	0	2,308
2057	1,389	557	362	0	2,308
2058	1,389	557	362	0	2,308
2059	1,389	557	362	0	2,308
2060	1,389	557	362	0	2,308
2061	1,389	557	362	0	2,308
2062	1,389	557	362	0	2,308
2063	1,389	557	362	0	2,308
2064	1,389	557	362	0	2,308
2065	1,389	557	290	0	2,236
2066	1,389	557	290	0	2,236
2067	1,389	557	153	0	2,099
2068	1,389	557	153	0	2,099
2069	1,389	557	153	0	2,099
2070	1,389	557	153	0	2,099
2071	1,389	557	153	0	2,099

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Table 6-3 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated
year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The
calculations are based on the effective half-life of 22.4 years (95th percentile of
distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2072	1,389	557	51	0	1,997
2073	1,389	557	51	0	1,997
2074	1,389	557	51	0	1,997
2075	1,389	557	0	0	1,946
2076	1,389	557	0	0	1,946
2077	1,389	557	0	0	1,946
2078	1,389	557	0	0	1,946
2079	1,389	557	0	0	1,946
2080	1,389	557	0	0	1,946
2081	1,389	557	0	0	1,946
2082	1,389	557	0	0	1,946
2083	1,389	557	0	0	1,946
2084	1,389	557	0	0	1,946
2085	1,389	0	0	0	1,389
2086	1,389	0	0	0	1,389
2087	1,389	0	0	0	1,389
2088	1,389	0	0	0	1,389
2089	1,389	0	0	0	1,389
2090	1,389	0	0	0	1,389
2091	1,356	0	0	0	1,356
2092	1,221	0	0	0	1,221
2093	1,221	0	0	0	1,221
2094	1,221	0	0	0	1,221
2095	1,221	0	0	0	1,221
2096	1,114	0	0	0	1,114
2097	1,114	0	0	0	1,114
2098	1,114	0	0	0	1,114
2099	1,114	0	0	0	1,114
2100	1,114	0	0	0	1,114
2101	1,114	0	0	0	1,114
2102	1,114	0	0	0	1,114
2103	1,114	0	0	0	1,114
2104	1,114	0	0	0	1,114
2105	1,114	0	0	0	1,114
2106	1,114	0	0	0	1,114
2107	1,114	0	0	0	1,114
2108	1,060	0	0	0	1,060

Table 6-3 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 22.4 years (95th percentile of distribution).

Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2109	1,060	0	0	0	1,060
2110	1,060	0	0	0	1,060
2111	865	0	0	0	865
2112	822	0	0	0	822
2113	822	0	0	0	822
2114	822	0	0	0	822
2115	822	0	0	0	822
2116	725	0	0	0	725
2117	725	0	0	0	725
2118	725	0	0	0	725
2119	725	0	0	0	725
2120	725	0	0	0	725
2121	725	0	0	0	725
2122	725	0	0	0	725
2123	725	0	0	0	725
2124	725	0	0	0	725
2125	725	0	0	0	725
2126	725	0	0	0	725
2127	725	0	0	0	725
2128	725	0	0	0	725
2129	725	0	0	0	725
2130	725	0	0	0	725
2131	483	0	0	0	483
2132	483	0	0	0	483
2133	483	0	0	0	483
2134	483	0	0	0	483
2135	483	0	0	0	483
2136	483	0	0	0	483
2137	483	0	0	0	483
2138	182	0	0	0	182
2139	182	0	0	0	182
2140	182	0	0	0	182
2141	182	0	0	0	182
2142	182	0	0	0	182
2143	182	0	0	0	182
2144	182	0	0	0	182
2145	182	0	0	0	182

Table 6-3 (c'd) Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls in the indicated year in which the NCT compliance criterion of 15 mrem/yr is exceeded. The calculations are based on the effective half-life of 22.4 years (95th percentile of distribution).

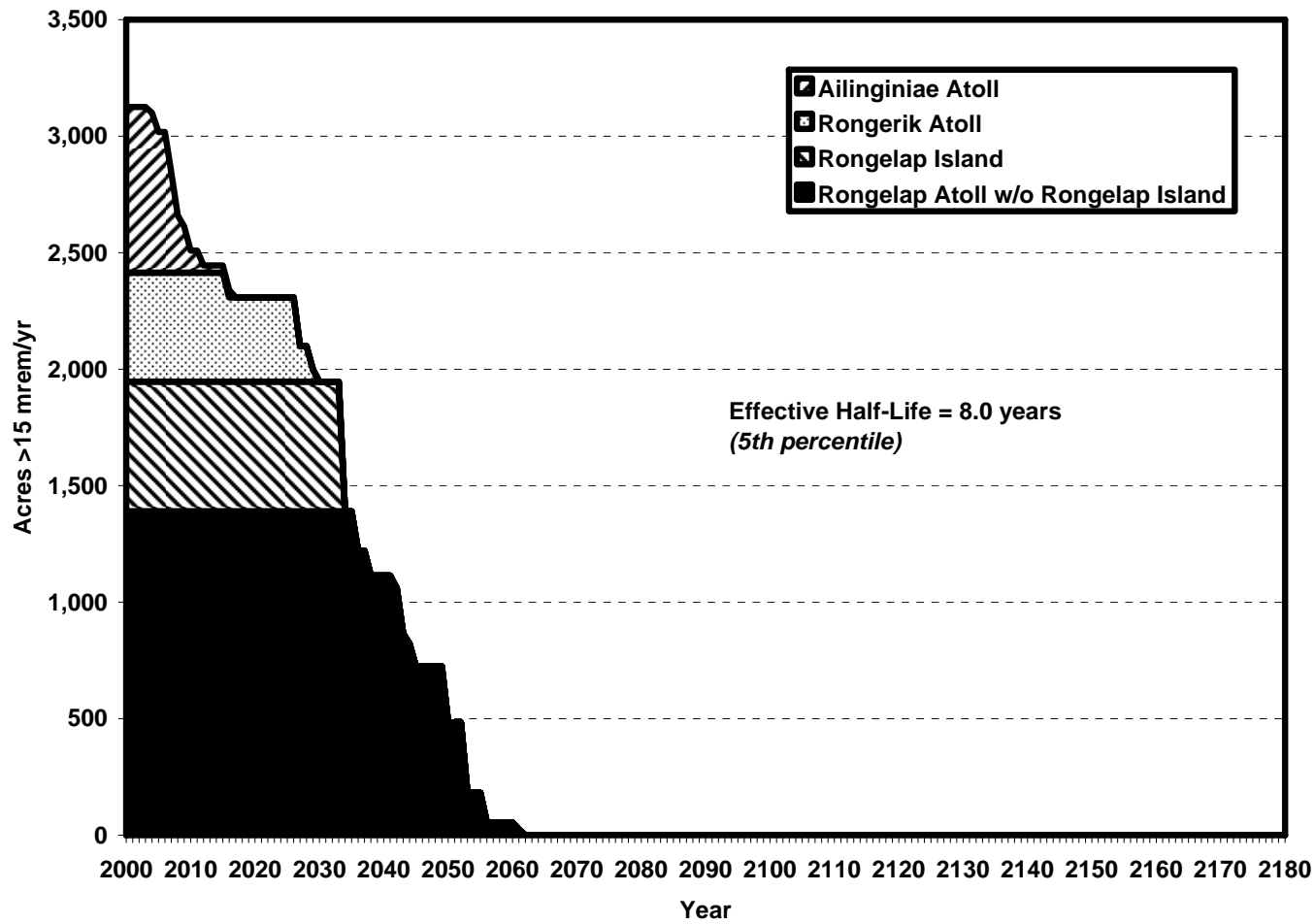| Year	Rongelap Atoll w/o Rongelap Is.	Rongelap Island	Rongerik Atoll	Ailinginae Atoll	Total
2146	54	0	0	0	54
2147	54	0	0	0	54
2148	54	0	0	0	54
2149	54	0	0	0	54
2150	54	0	0	0	54
2151	54	0	0	0	54
2152	54	0	0	0	54
2153	54	0	0	0	54
2154	54	0	0	0	54
2155	54	0	0	0	54
2156	54	0	0	0	54
2157	54	0	0	0	54
2158	54	0	0	0	54
2159	54	0	0	0	54
2160	23	0	0	0	23
2161	23	0	0	0	23
2162	0	0	0	0	0

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Figure 6-1 Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls on which the NCT compliance criterion of 15 mrem/yr would be exceeded on the future (based on the 5th percentile of the effective half-life distribution)
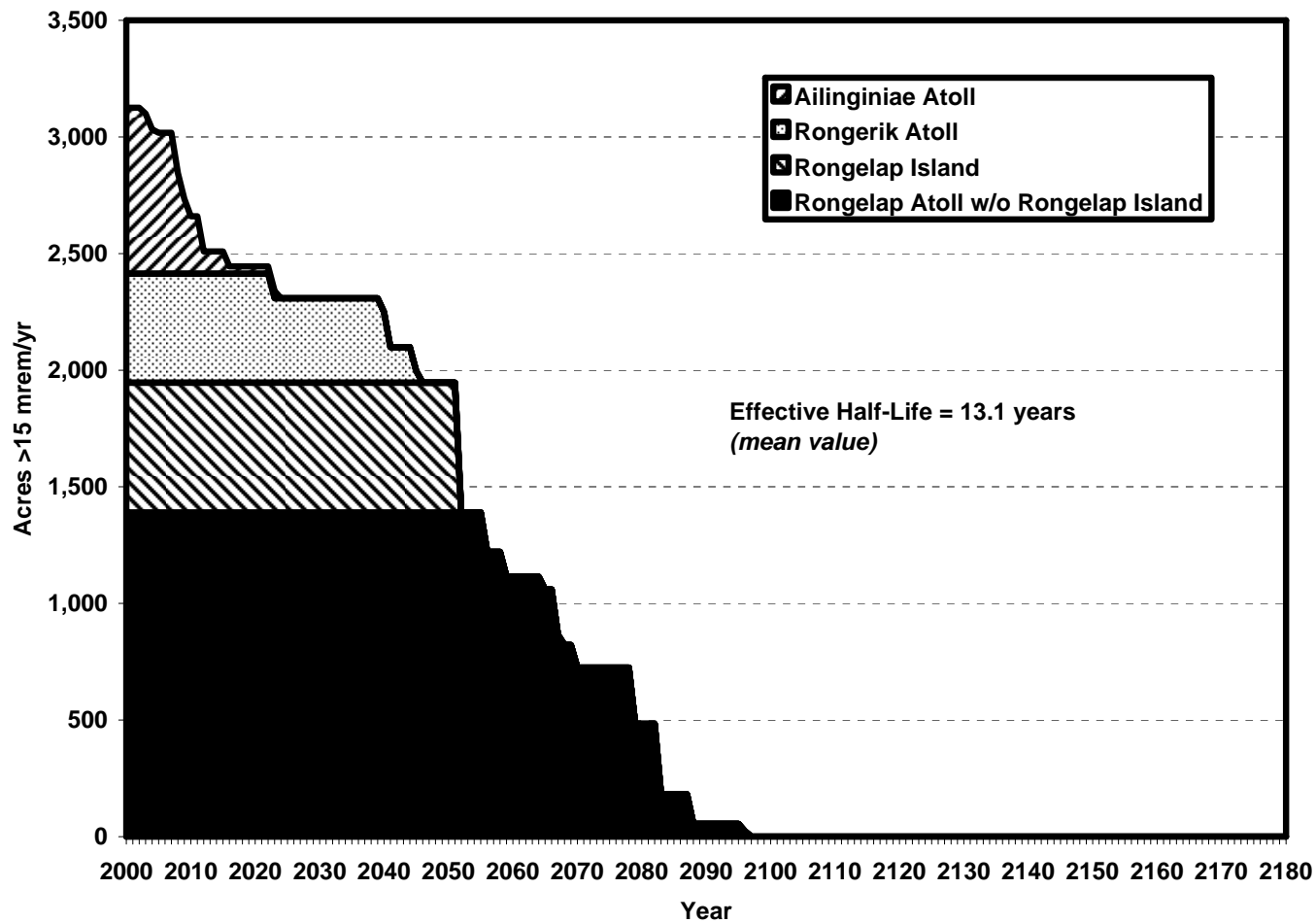
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Figure 6-2 Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls on which the NCT compliance criterion of 15 mrem/yr would be exceeded on the future (based on the mean value of the effective half-life distribution)
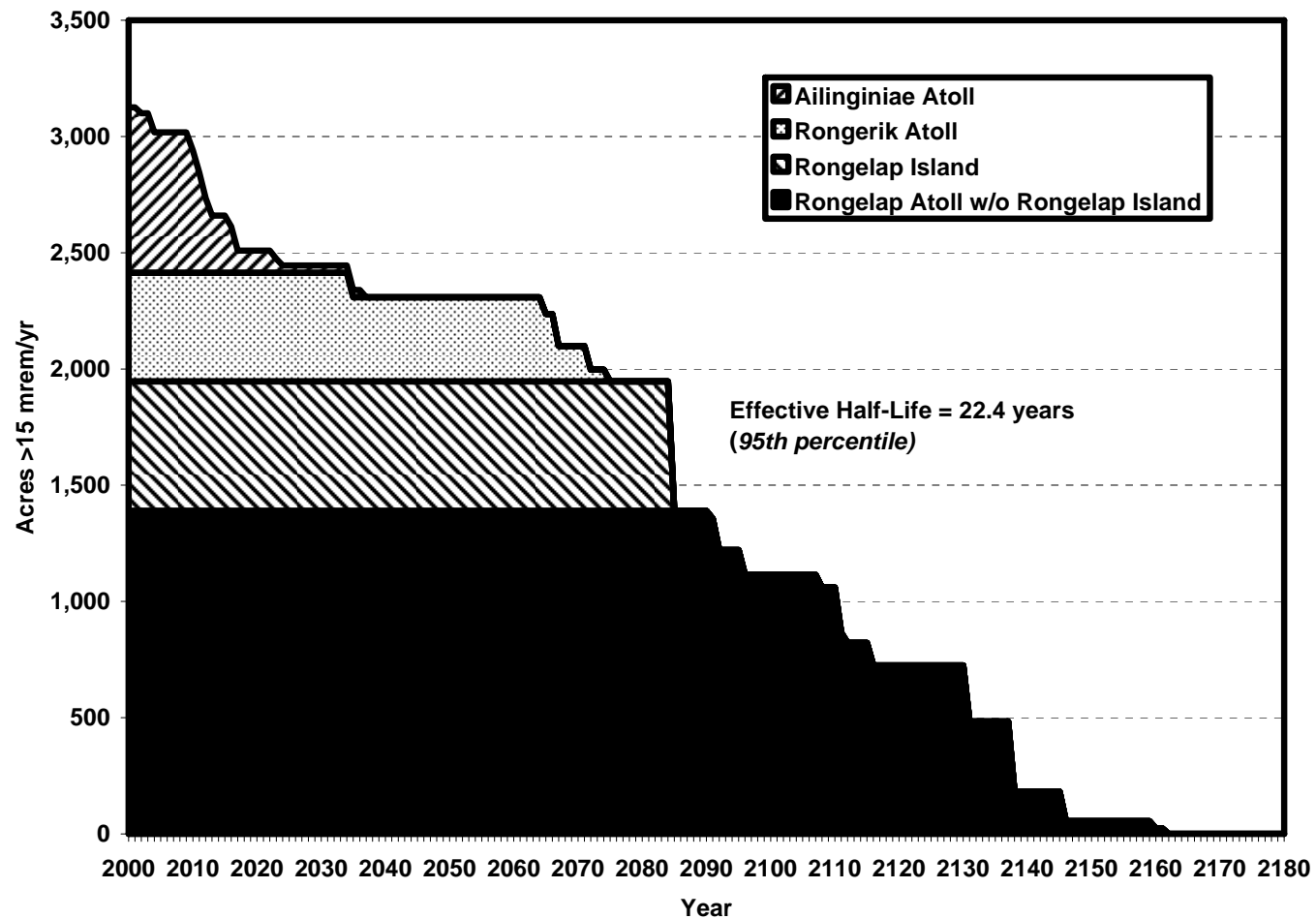
Figure 6-3   Acreage of islands in Rongelap, Rongerik and Ailinginae Atolls on which the NCT compliance criterion of 15 mrem/yr would be exceeded on the future (based on the 95th percentile of the effective half-life distribution)

Table 6-4   Estimated loss of future use, expressed in acre-years lost (baseline case)

Area	Loss of future use (acre-years lost), from the year 2000 onwards (= land area multiplied by the number of years where the RMEI dose exceeds 15 mrem/yr)		
	Effective half-life 8 years	*Effective half-life 13.1 years*	*Effective half-life 22.4 years*
Rongelap Atoll w/o Rongelap Island	65,569	102,593	169,871
Rongelap Island	18,934	28,958	47,335
Rongerik Atoll	11,821	17,875	28,727
Ailinginae Atoll	5,966	7,131	9,679
Total*)	**102,290**	**156,557**	**255,612**

*) including Rongelap Island

Table 6-5   Estimated loss of future use, expressed in acre-years lost (sensitivity analysis A: dose increased by 20% compared to baseline case)

Area	Loss of future use (acre-years lost), from the year 2000 onwards (= land area multiplied by the number of years where the RMEI dose exceeds 15 mrem/yr)		
	Effective half-life 8 years	*Effective half-life 13.1 years*	*Effective half-life 22.4 years*
Rongelap Atoll w/o Rongelap Island	68,348	107,032	178,025
Rongelap Island	20,048	31,186	50,677
Rongerik Atoll	12,894	19,415	31,421
Ailinginae Atoll	7,389	9,696	13,776
Total*)	**108,679**	**167,329**	**273,899**

*) including Rongelap Island

Table 6-6   Estimated loss of future use, expressed in acre-years lost (sensitivity analysis B: dose decreased by 20% compared to baseline case)

Area	Loss of future use (acre-years lost), from the year 2000 onwards (= land area multiplied by the number of years where the RMEI dose exceeds 15 mrem/yr)		
	Effective half-life 8 years	*Effective half-life 13.1 years*	*Effective half-life 22.4 years*
Rongelap Atoll w/o Rongelap Island	62,006	96,865	159,965
Rongelap Island	17,263	26,731	43,437
Rongerik Atoll	10,814	15,891	25,344
Ailinginae Atoll	4,117	4,310	4,897
Total*)	**94,201**	**143,796**	**233,643**

*) including Rongelap Island