UCRL-PRES-219265

Marshall Islands Program Briefing

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Prepared for : Vince McClelland
Radiological Expert Working Group of the Arctic Council's
Monitoring and Assessment Program (AMAP)

January, 2006

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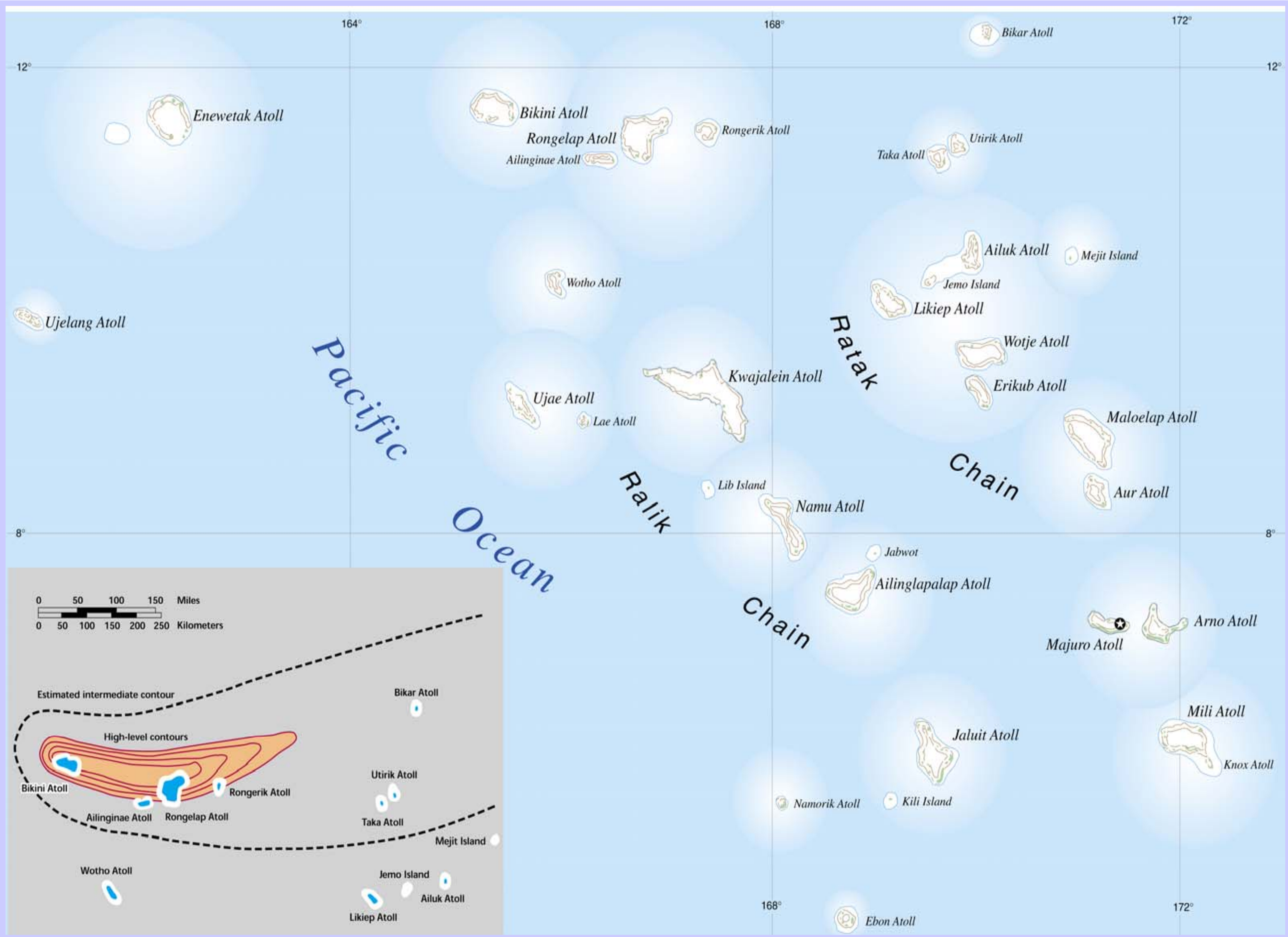
Background Points

1) The Marshall Islands Program was established at the Lawrence Livermore National Laboratory in 1974 (under the direction of the former scientific program director – Dr. William Robison)
2) Large-scale environmental characterization studies were carried out through the 1970-80s and this information used to provide predictive dose assessments for resettlement of islands and atolls.
3) A significant effort was made through the 1990s on developing potential remediation techniques to reduce doses to resettling populations.
4) We are now in the implementation phase of the project. The main focus areas are (a) to provide verification monitoring of remedial actions (b) to develop shared responsibilities with atoll communities in developing individual radiological surveillance monitoring programs (technical assistance and training).
5) Continue to provide research on the fate and transport of radionuclides in the environment, especially in relation to how changing radiological conditions impact on cleanup requirements and potentially improve prospects for early resettlement

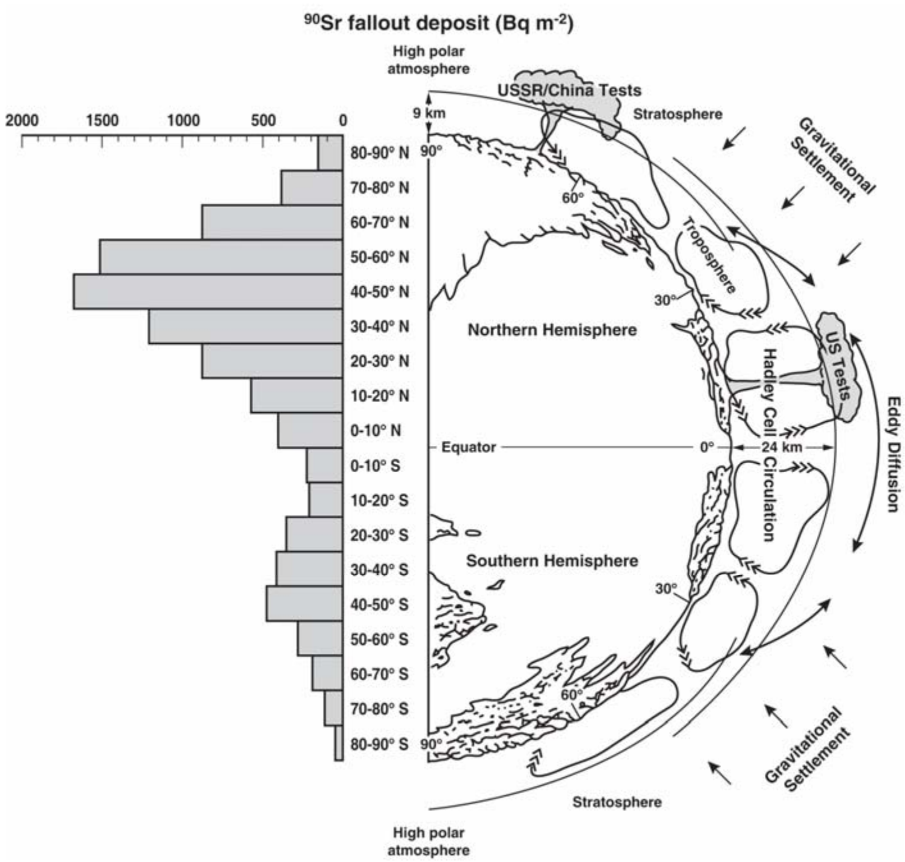


164°
168°
172°
12°
8°
Bikar Atoll
Enewetak Atoll
Bikini Atoll
Rongelap Atoll
Ailinginae Atoll
Rongerik Atoll
Utirik Atoll
Taka Atoll
Ailuk Atoll
Mejit Island
Jemo Island
Wotho Atoll
Ujelang Atoll
Likiep Atoll
Pacific Ocean
Ratak Chain
Wotje Atoll
Kwajalein Atoll
Erikub Atoll
Ujae Atoll
Lae Atoll
Maloelap Atoll
Ralik Chain
Lib Island
Namu Atoll
Aur Atoll
Jabwot
Ailinglapalap Atoll
Arno Atoll
Majuro Atoll
Mili Atoll
Jaluit Atoll
Knox Atoll
Namorik Atoll
Kili Island
Ebon Atoll
0 50 100 150 Miles
0 50 100 150 200 250 Kilometers
Estimated intermediate contour
High-level contours
Bikini Atoll
Ailinginae Atoll
Rongelap Atoll
Rongerik Atoll
Bikar Atoll
Utirik Atoll
Taka Atoll
Mejit Island
Wotho Atoll
Jemo Island
Ailuk Atoll
Likiep Atoll

Atmospheric nuclear weapons testing in the Marshall Islands

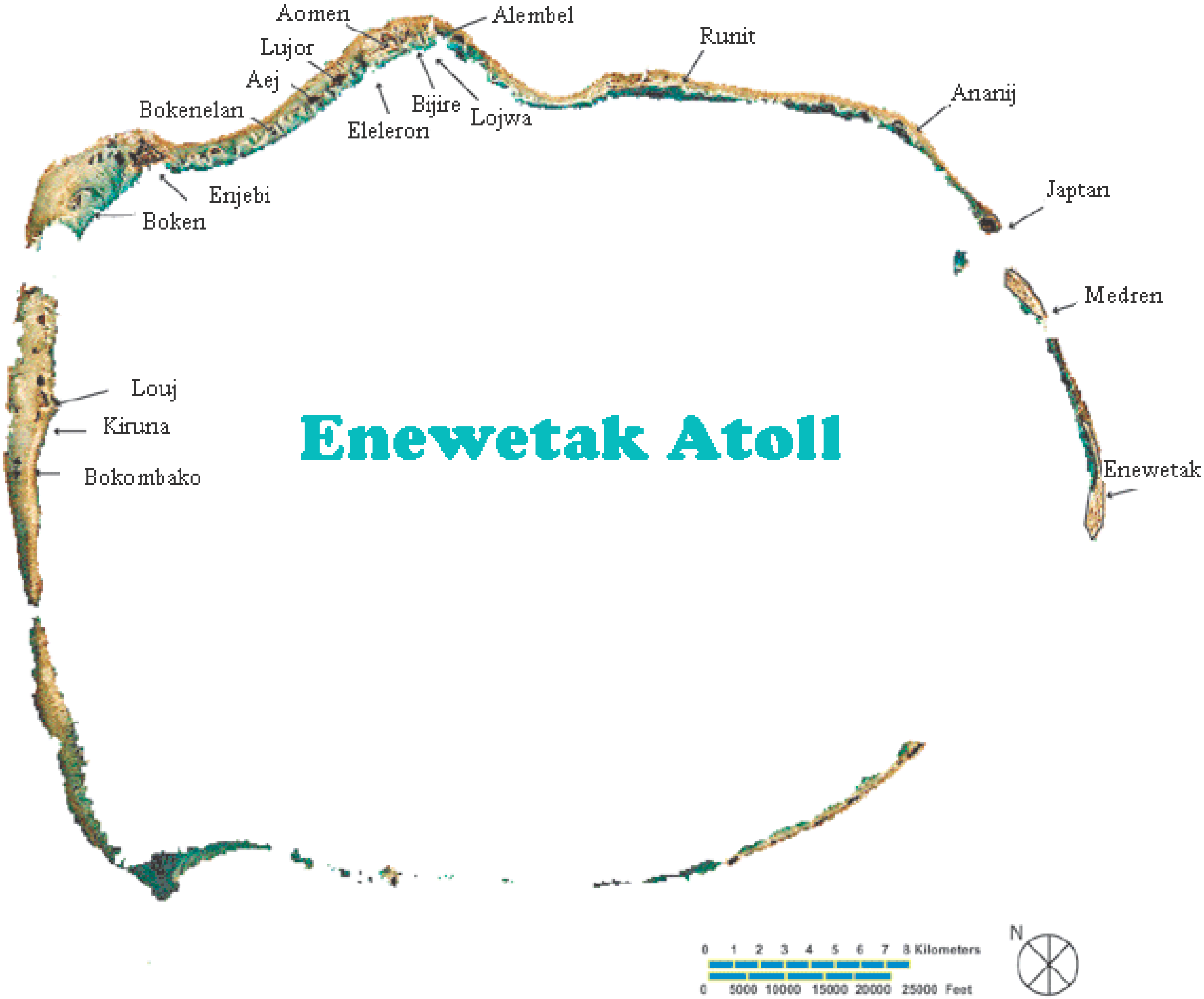
Region	Test Site	Country	Years	Number of Tests	Yield (Mt) Total	Yield (Mt) Fission
Equatorial Pacific						
	Bikini Atoll	United States	1946-1858	23	76.8	42.2
	Christmas Island	United Kingdom	*1958*	6	6.65	3.35
	Christmas Island	United States	*1962*	24	23.3	12.1
	Enewetak Atoll	United States	1947-1958	42	31.7	15.5
	Johnson Atoll	United States	1958-1962	12	20.8	10.5
	Pacific Ocean	United States	1955-1962	4	0.102	0.102
			Total	111	159	84
Northern temperate latitudes						
	Algeria	France	*1960-1961*	4	0.073	0.073
	Japan[a]	United States	*1945*	2	0.036	0.036
	Kapustin Yar	Former Soviet Union	*1957-1962*	10	0.98	0.68
	Lop Nor	China	*1964-1980*	22	20.72	12.2
	New Mexico	United States	*1945*	1	0.021	0.021
	Nevada Test Site (NTS)	United States	*1951-1962*	86	1.05	1.05
	Semipalatinsk	Former Soviet Union	*1949-1962*	116	6.59	3.74
	Totsk, Aralsk	Former Soviet Union	*1954-1956*	2	0.04	0.04
			Total	243	29.5	17.8
Polar-north	Novaya Zemlya	Former Soviet Union	*1955-1962*	91	239.6	80.8
			Total	91	239.6	80.8
Southern Hemisphere						
	Atlantic	United States	*1958*	3	0.0045	0.0045
	Fangataufa Atoll	France	*1966-1970*	4	3.74	1.97
	Malden Island	United Kingdom	*1957*	3	1.2	0.69
	Maralinga/Emu Test Ranges	United Kingdom	*1953-1957*	9	0.080	0.08
	Monte Bello Islands	United Kingdom	*1952-1956*	3	0.1	0.1
	Mururoa Atoll	France	*1966-1974*	37	6.38	4.13
			Total	59	11.5045	6.9745
Total	**all sites**	**all countries**		**504#**	**440**	**189**

Atmospheric nuclear weapons testing in the Marshall Islands, cont'd



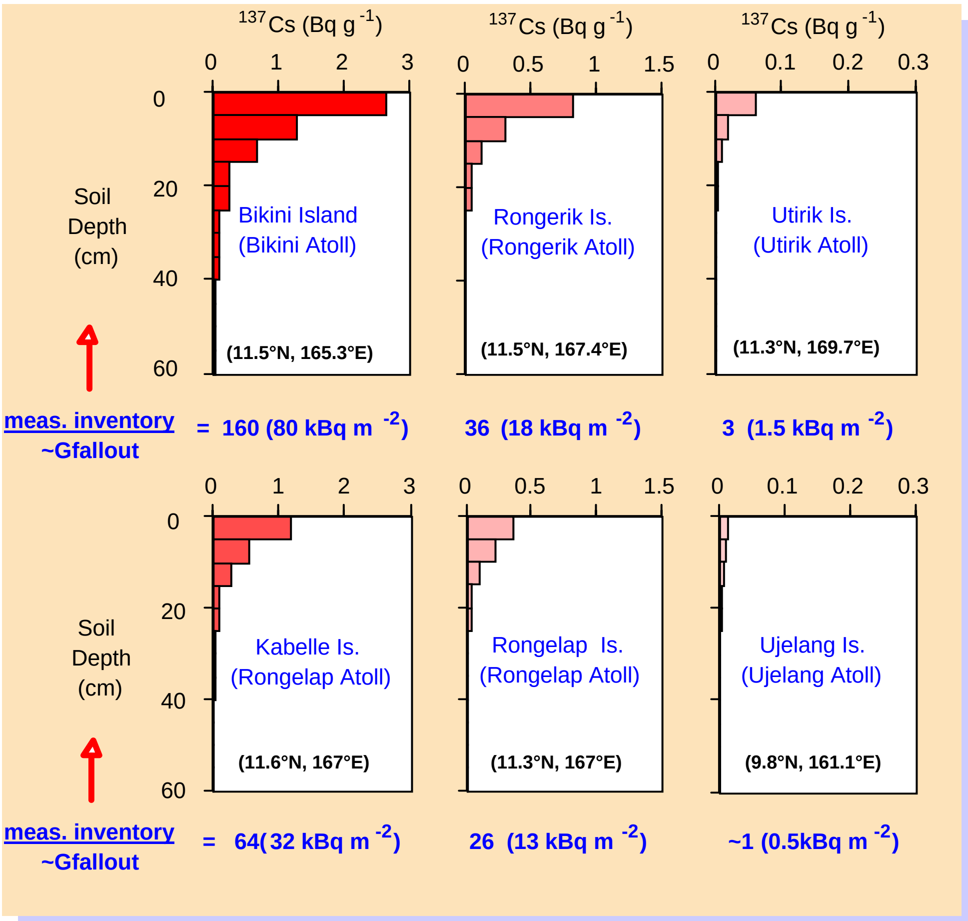
Nuclear Weapons Testing in the Marshall Islands

- **Significant contribution to world-wide fallout (15 test > 4 Mt)**
- **At the same time, most of the tests were conducted in the near surface environment where as much as 50% of the debris was deposited on a local or regional scale**
- **Marshall Islanders were severely exposed to fresh fallout**

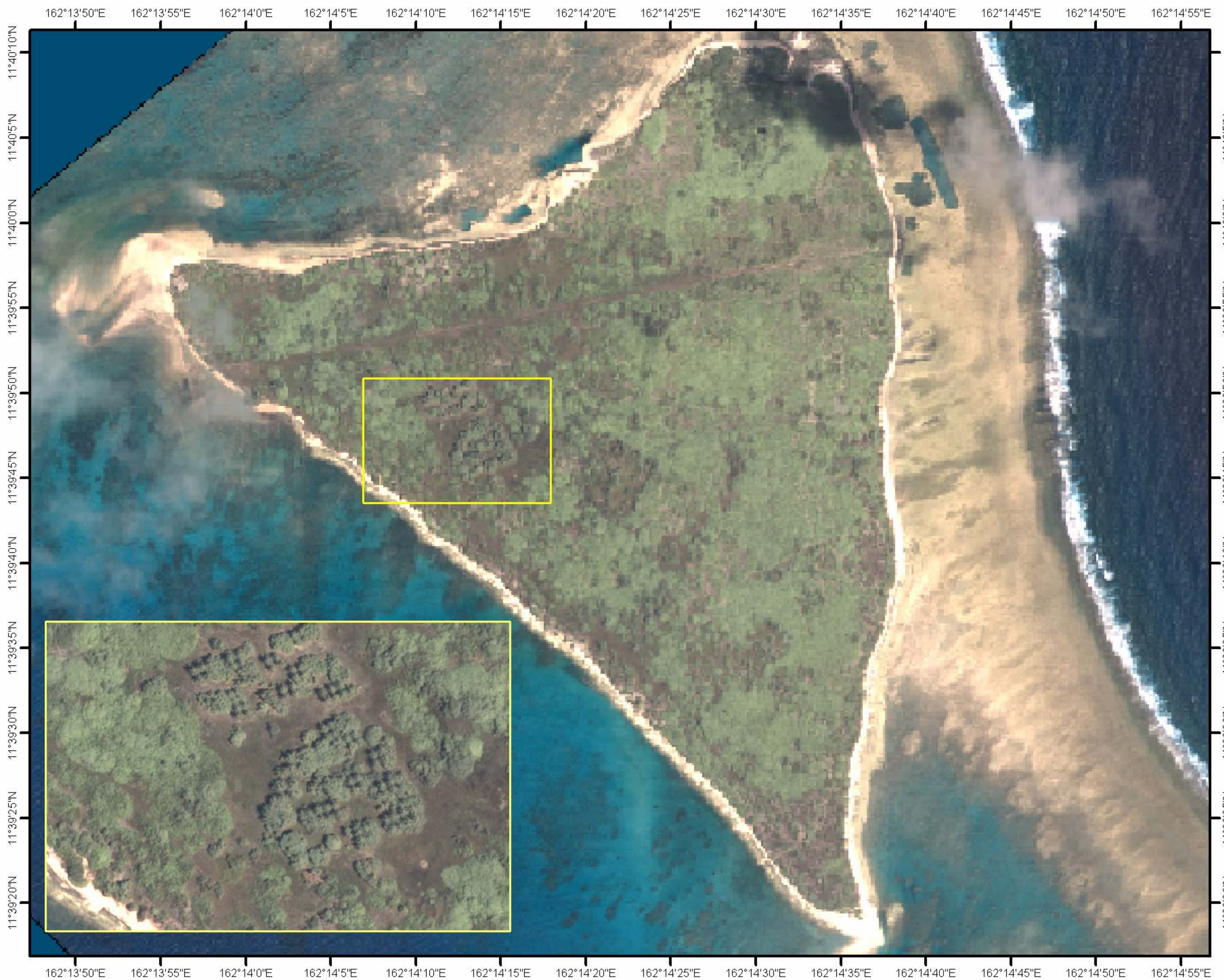


Enewetak Atoll
Aomen
Alembel
Runit
Lujor
Aej
Bokenelan
Bijire
Lojwa
Eleleron
Ananij
Enjebi
Boken
Japtan
Medren
Louj
Kiruna
Bokombako
Enewetak
0 1 2 3 4 5 6 7 8 Kilometers
0 5000 10000 15000 20000 25000 Feet
N

Residual levels of fallout contamination in the environment



- **depositional history**
- **age/stability of the soil and litter pile (cation exchange capacity)**
- **degree of erosion/disturbance**


162°13'50"E
162°13'55"E
162°14'0"E
162°14'5"E
162°14'10"E
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162°14'25"E
162°14'30"E
162°14'35"E
162°14'40"E
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11°39'45"N
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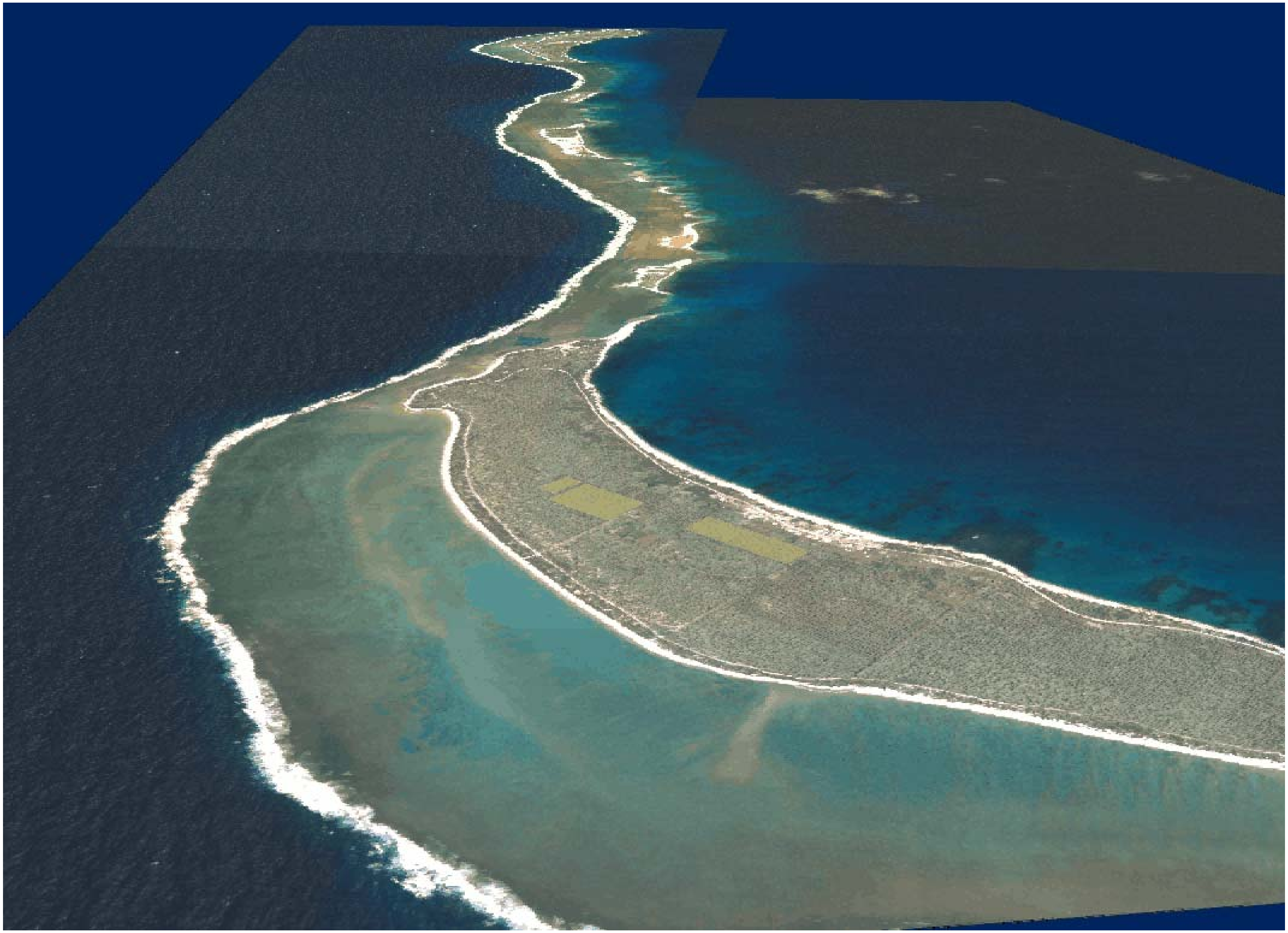
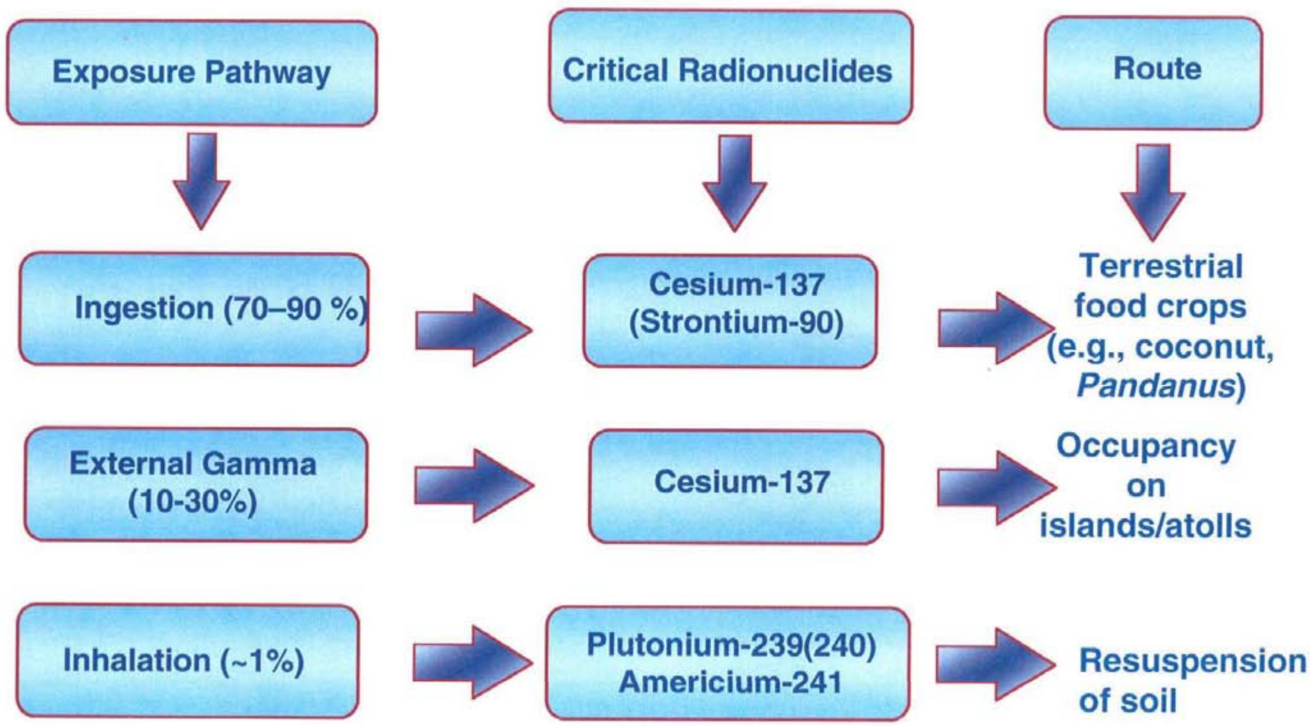
11°39'25"N
11°39'20"N

Bikini Atoll (main base of operations)




US ARMY
LCU 2021
Matson

Exposure pathways and critical radionuclides



The importance of the terrestrial pathway!

Product	Location	^{137}Cs (Bq kg^{-1}, dry weight) Soil Median	Plant Median	^{137}Cs Transfer Factor Median	Mean	Maximum	Minimum
Drinking Coconut Meat							
	Bikini island	924	13537	13	16	64	2.8
	Rongelap island	127	175	1.5	2.4	18	1.4
Pandanus							
	Bikini Island	422	20045	35	44	82	11
	Rongelap Island	117	947	9.4	12	44	0.94

Notes: Transfer factor values are expressed as Bq kg^{-1} dry weight plant to Bq kg^{-1} dry weight soil.

Variability

- 2–3 orders of magnitude between different plants
- 1–2 orders of magnitude on individual plants
- 5–6 fold in soils

^{137}Cs Transfer Factor Values

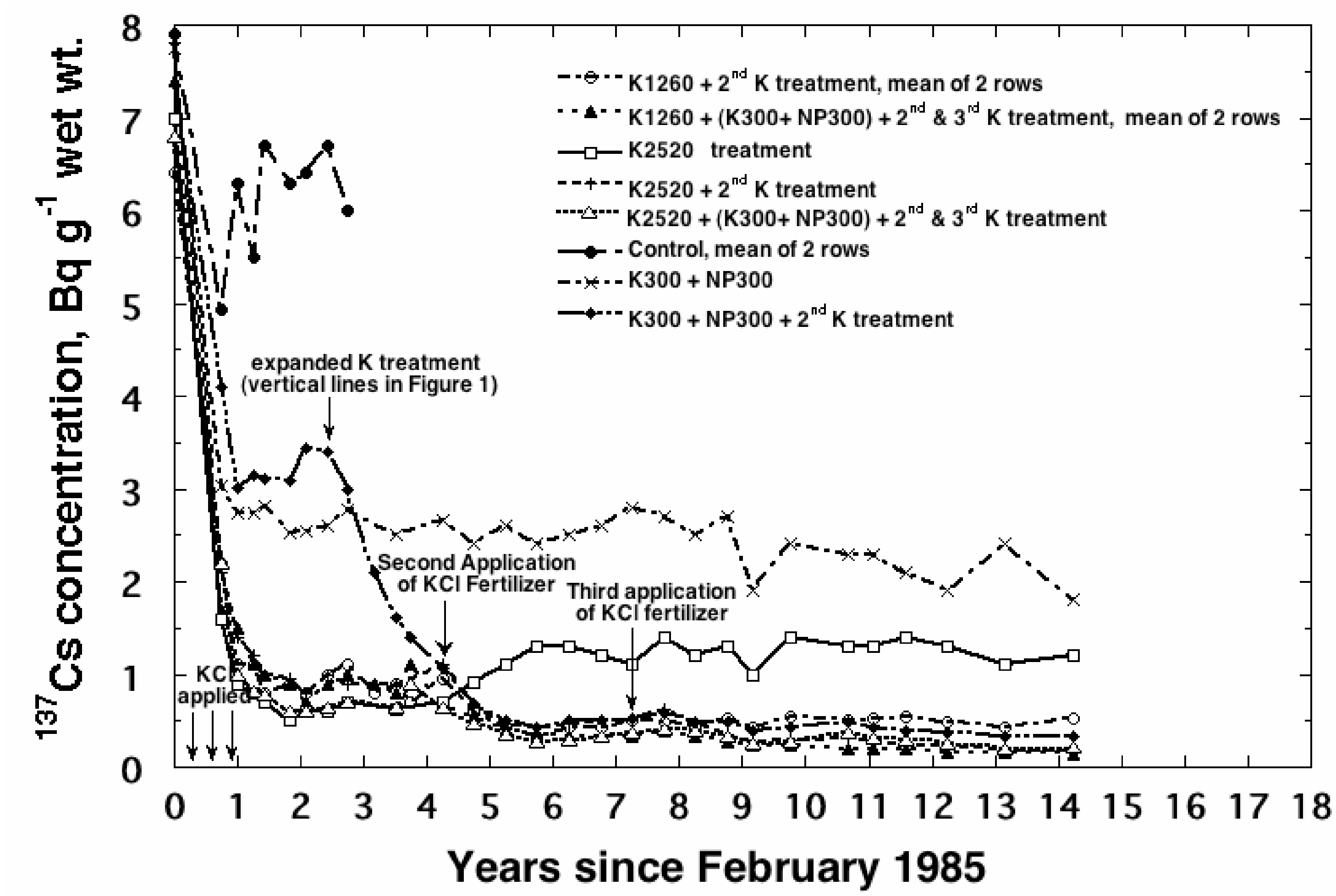
Bikini Island	0.7–144
Continental soils	0.005–0.5 (IAEA 1994)

Controls

- Absence of clays
- High cation exchange capacity of soils
- Low concentration of potassium in coral soil

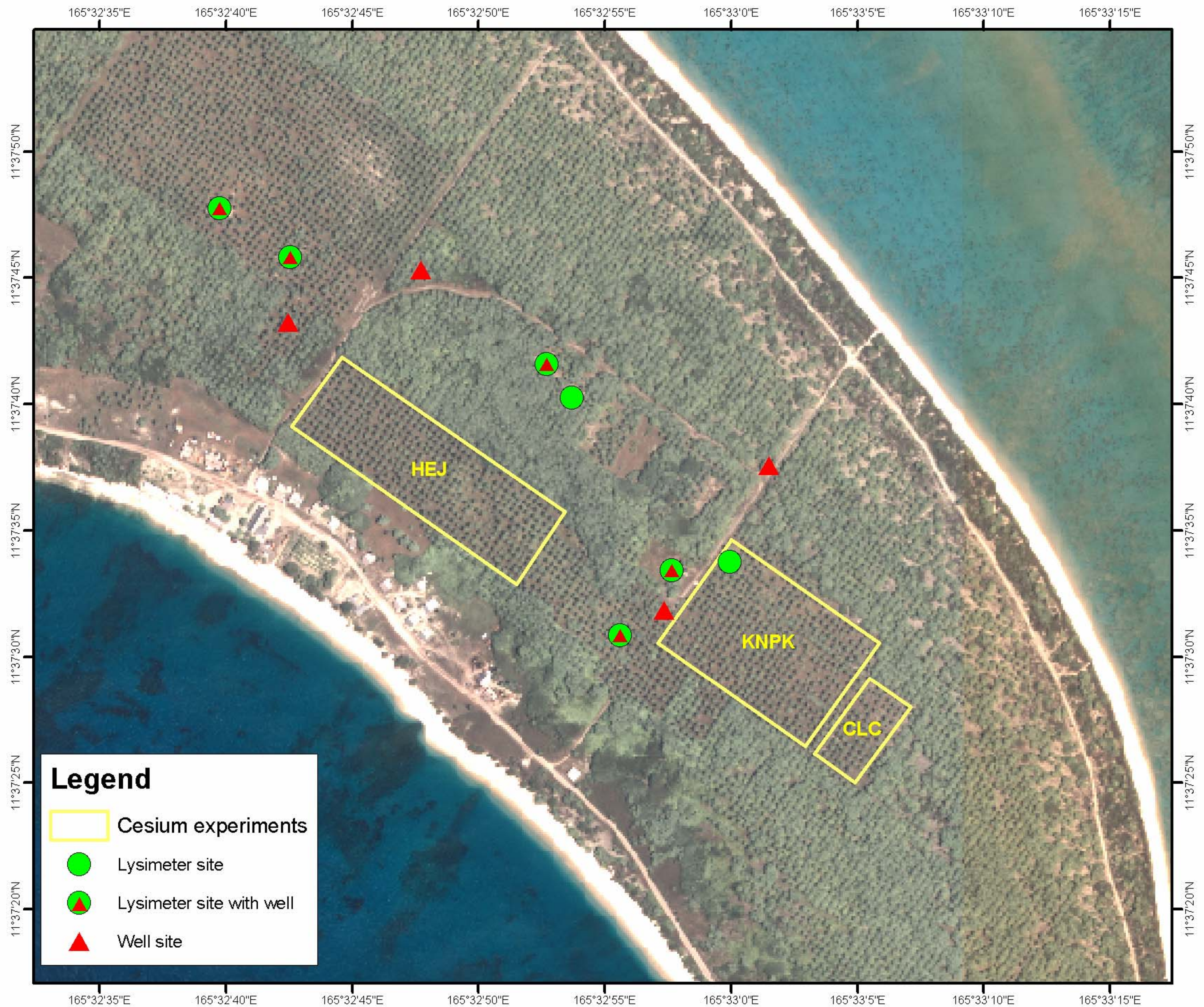

HEJ

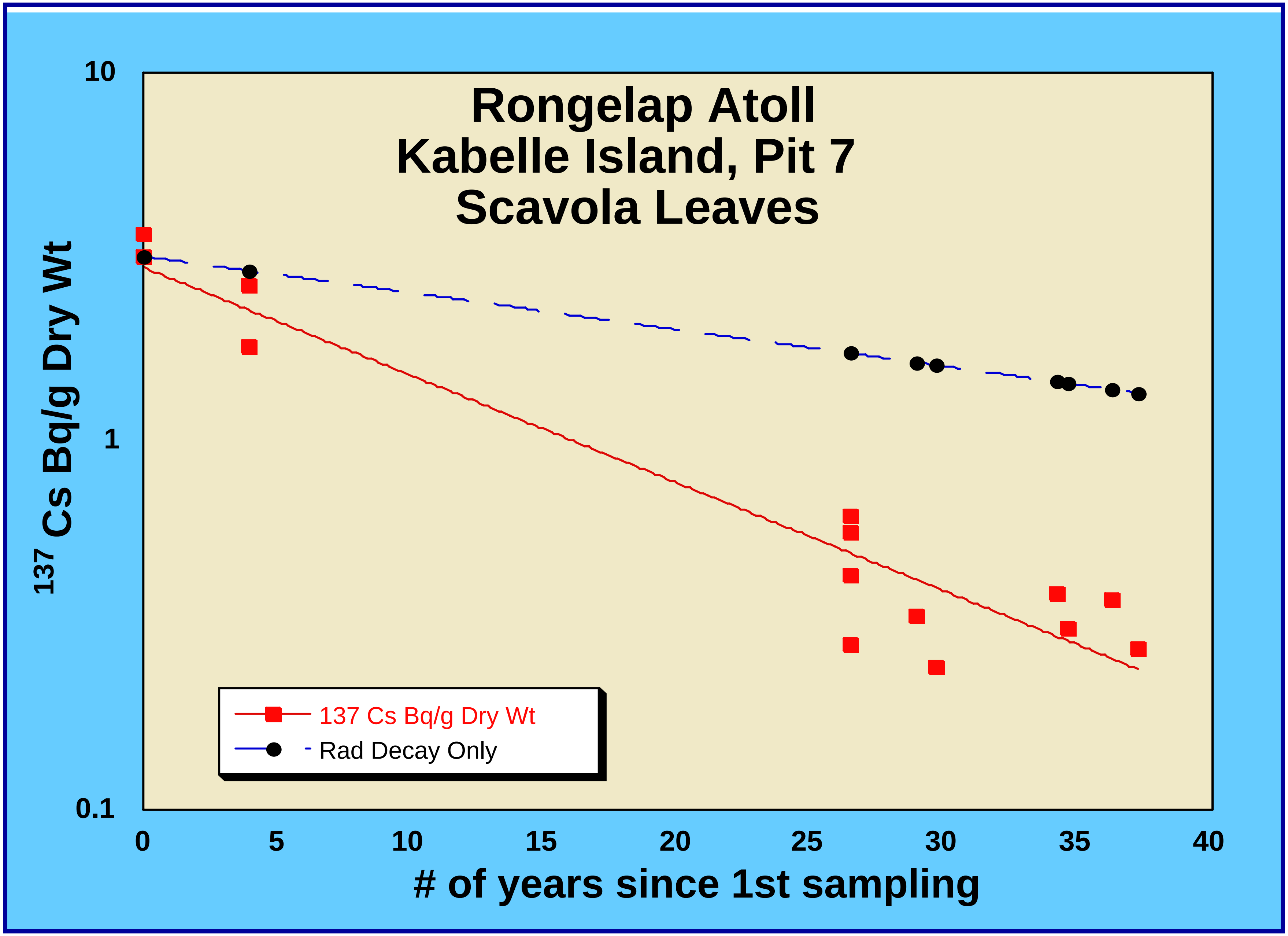
Remediation of cesium-137 uptake into locally grown foods-results from Bikini



Product	Location	^{137}Cs (Bq kg^{-1}, dry weight)		^{137}Cs Transfer Factor			
		Median	Median	Soil Median	Plant Mean	Maximum	Minimum
Drinking Coconut Meat	Bikini island	924	13537	13	16	64	2.8
	Rongelap island	127	175	1.5	2.4	18	1.4
Pandanus							
	Bikini Island	422	20045	35	44	82	11
	Rongelap Island	117	947	9.4	12	44	0.94
Breadfruit Meat							
	Bikini Island[b]	680	2217	2.9	3.4	7.4	0.44
	Rongelap Island	122	456	3.5	4.5	13	1.0
Papaya Meat							
	Bikini Island	1626	19959	11	22	62	2.1
Banana Meat							
	Bikini Island	427	487	0.78	0.71	1.2	0.27
Sorghum[a]							
	Bikini Island	3045	26103	8.1	10	24	0.81
Chinese Cabbage[a]							
	Bikini Island	1029	45364	36	41	144	2.9
Coconut Fronds							
	Bikini Island	859	2618	3.2	4.3	22	0.5
Messerschmidia Leaves							
	Bikini Island	744	13973	4.6	13	32	4.3
Scaveola Leaves							
	Bikini Island	1993	5812	8.5	12	31	1.8
Guettarda Leaves							
	Bikini Island	874	8611	23	23	44	1.9

[a] 0-20 cm root zone was used.
[b] Breadfruit trees were transplants from Eneu Island.
Notes: Transfer factor values are expressed as Bq kg^{-1} dry weight plant to Bq kg^{-1} dry weight soil.


165°32'35"E
165°32'40"E
165°32'45"E
165°32'50"E
165°32'55"E
165°33'0"E
165°33'5"E
165°33'10"E
165°33'15"E
11°37'50"N
11°37'45"N
11°37'40"N
11°37'35"N
11°37'30"N
11°37'25"N
11°37'20"N
HEJ
KNPK
CLC
Legend
Cesium experiments
Lysimeter site
Lysimeter site with well
Well site


Rongelap Atoll
Kabelle Island, Pit 7
Scavola Leaves
10
1
0.1
137 Cs Bq/g Dry Wt
0
5
10
15
20
25
30
35
40
# of years since 1st sampling
137 Cs Bq/g Dry Wt
Rad Decay Only

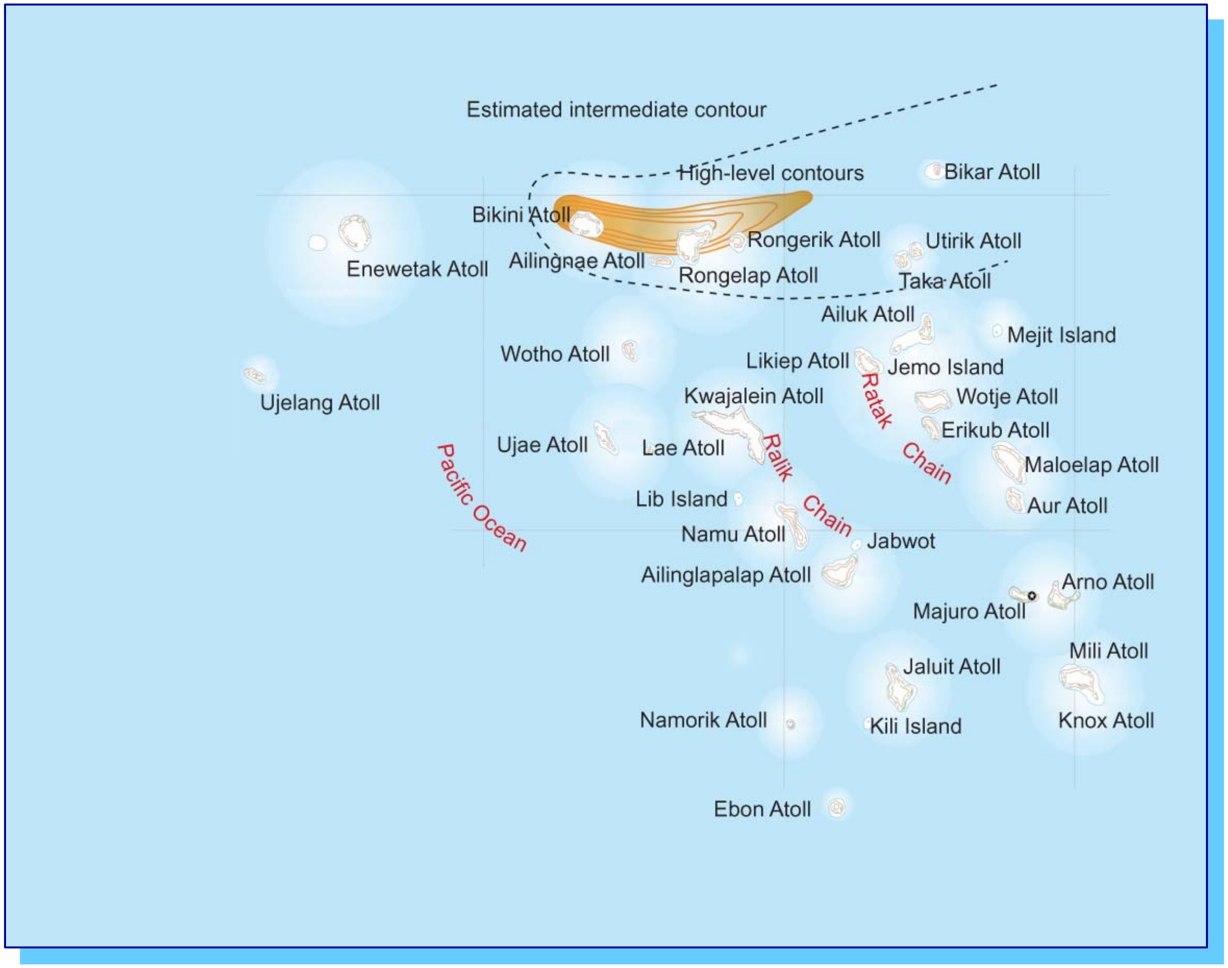
Research and monitoring studies on Bikini

1. Addition of potassium provides an effective method for reducing uptake of cesium in plants (dose to a resettled population)
2. Difficult to make predictions of soil to plant uptake based on the soil cesium-137 inventory. The effective half-life of cesium-137 in plants is around 8 years, i.e., the environmental half-life is more important than radiological decay in controlling the uptake of cesium-137 in plants.
3. Conditions are improving at an accelerated rate.

   > advance settlement and/or

   > reduce costs of cleanup
4. Continuing research on cesium-137 cycling (1) washout (lysimeter and ground water studies) and (2) fixation (soil chemistry, mineralogy, selective extraction techniques).

Rongelap Island Resettlement Support



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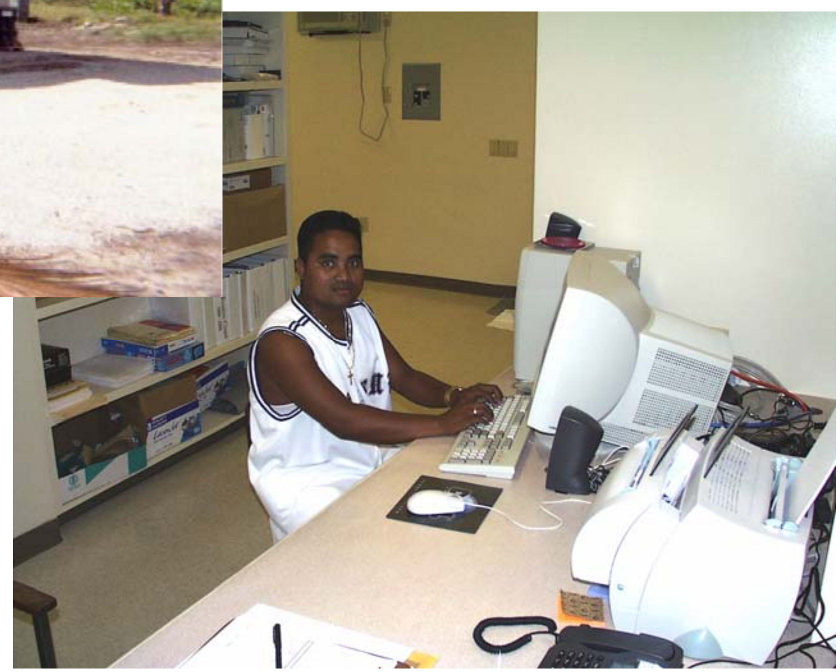
Projection: Geographic WGS84; Satellite Imagery was collected by Digital Globe May 28, 2003

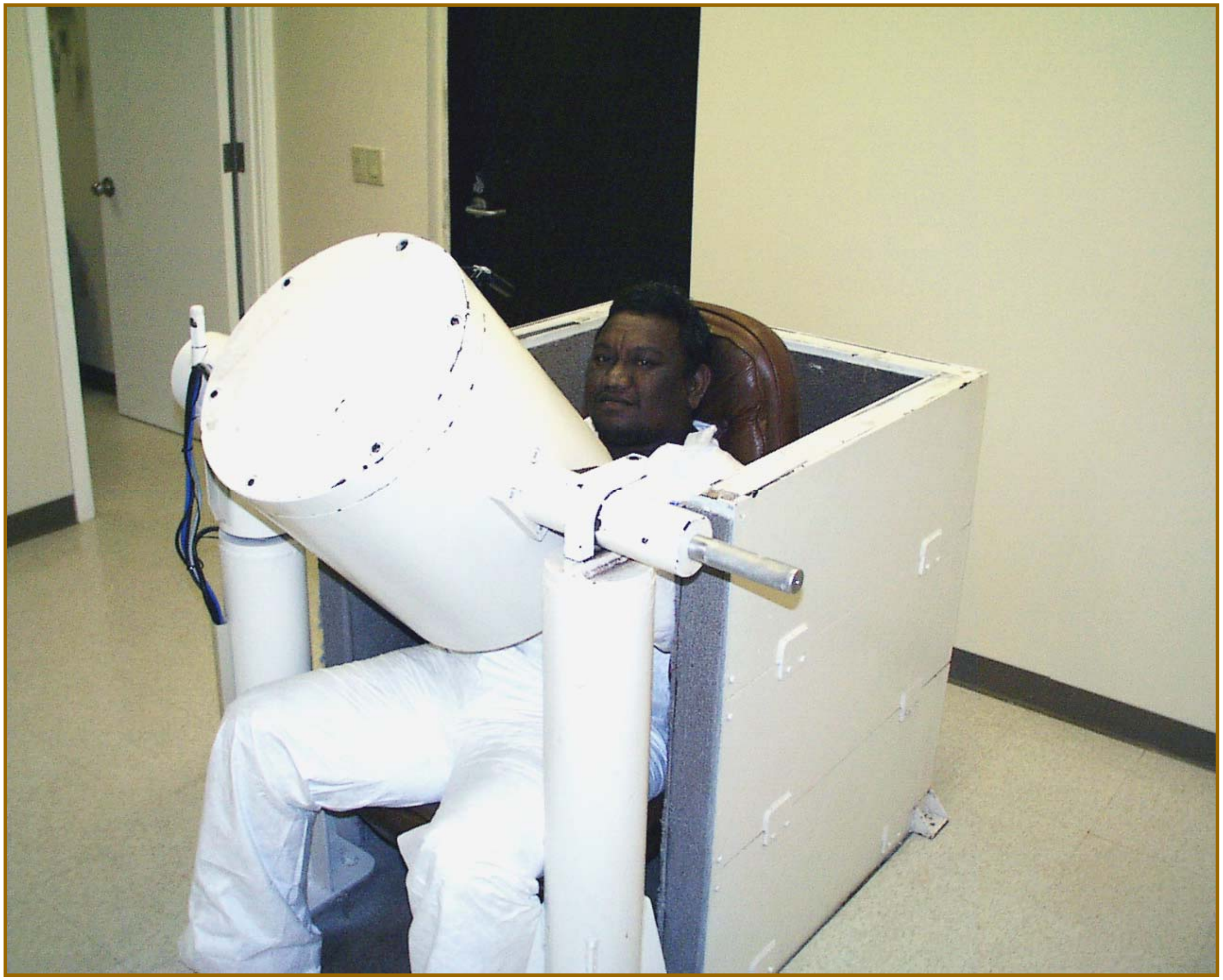
Radiological surveillance of resettlement workers

Rongelap Islands Whole

Body Counting Facility



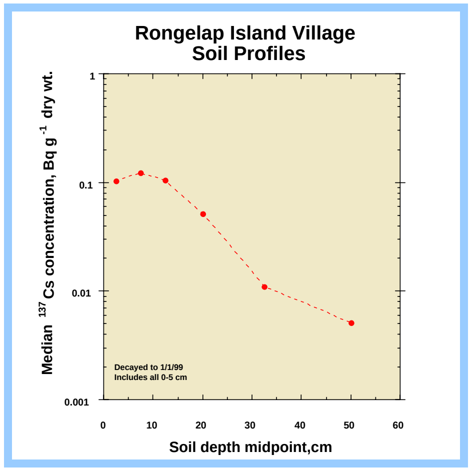
Rongelap Whole Body Counting Program

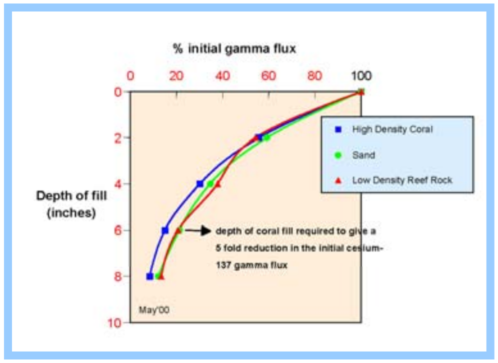


Resettlement on Rongelap Island

In support of resettlement, the Rongelap Atoll Local Government adopted a number of recommendations;

- ➢ **Shared vision for monitoring the resettlement workers and ultimately the resettled population**
- ➢ **Adopted the ‘*combined option*’ as a cleanup technique to help reduce the risk from exposure to residual fallout contamination**





<u>Combined Option</u>

(1) Addition of potassium fertilizer to the agricultural areas

(2) Limited soil removal and addition of crushed coral fill


SOKKIA

UCRL-ID-143680-Pt-1

April 2001 Lawrence Livermore National Laboratory

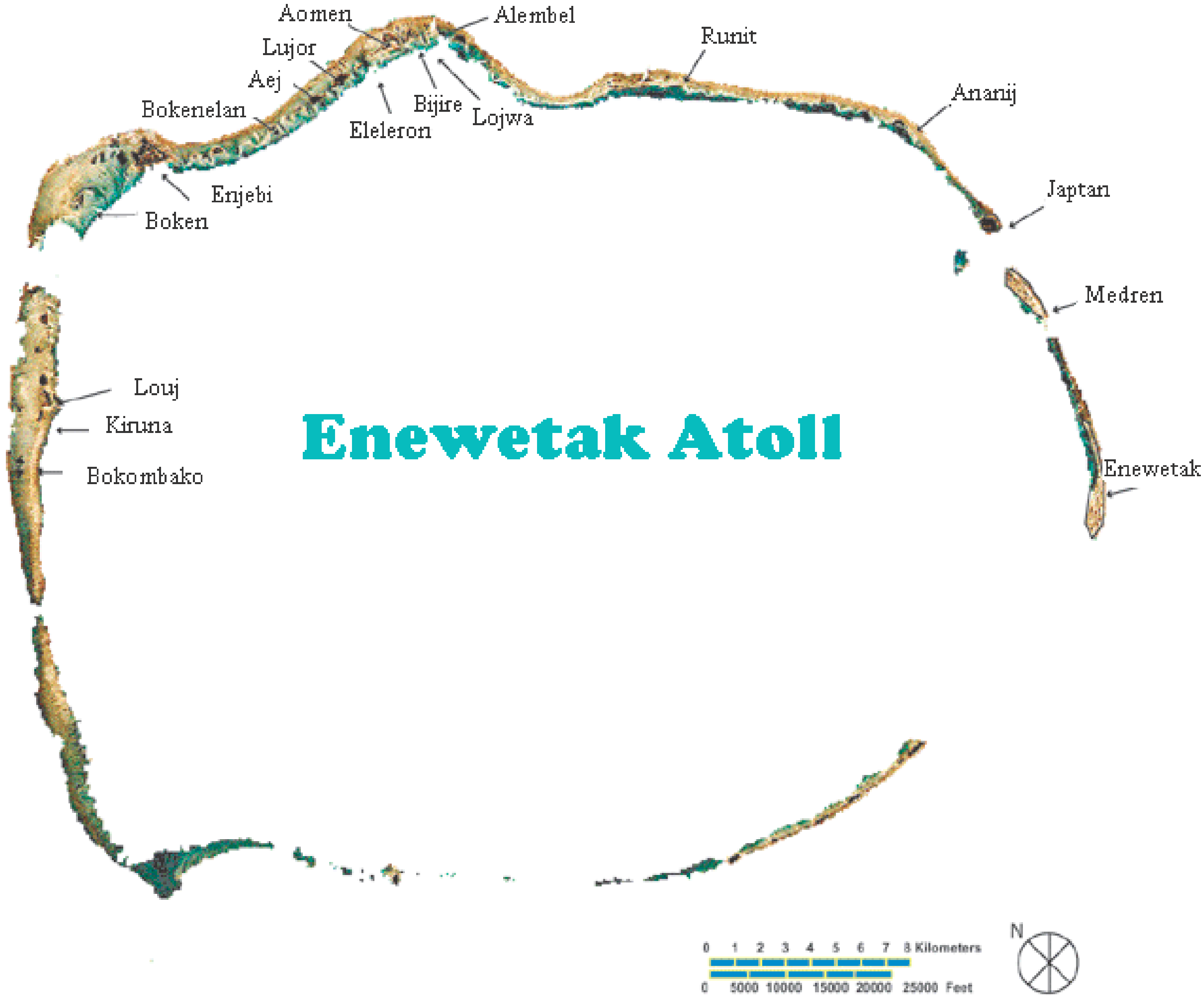
Rongelap Resettlement Support—Preliminary Report Part 1

In-Situ Gamma Spectrometric Measurements around the Service and Village Area on Rongelap Island

Terry Hamilton
Steven Kehl
James Brunk
Frank Gouveia
William Robison

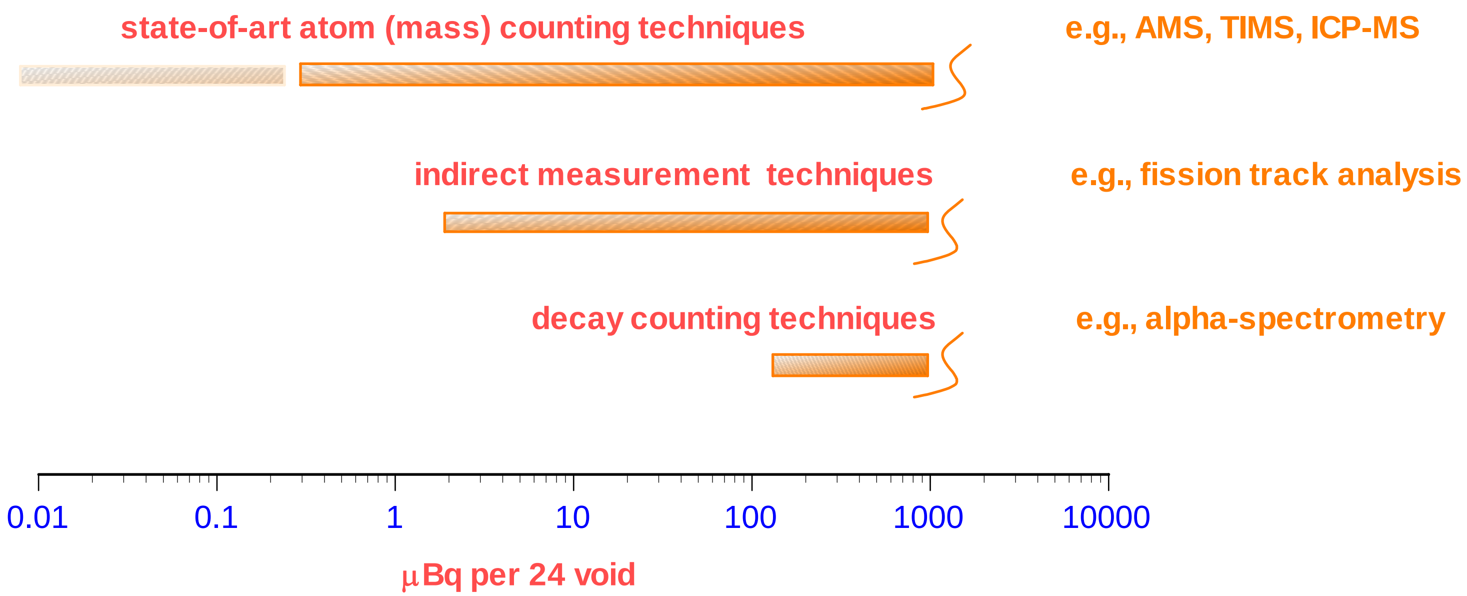
This report was prepared in partial fulfillment of LLNL program level goals and actions supporting the Rongelap Atoll settlement as formally outlined under a Memorandum of Understanding (MOU) between the U. S. Department of Energy (DOE), the Rongelap Atoll Local Government (RALGOV), and the Republic of the Marshall Islands (RMI).

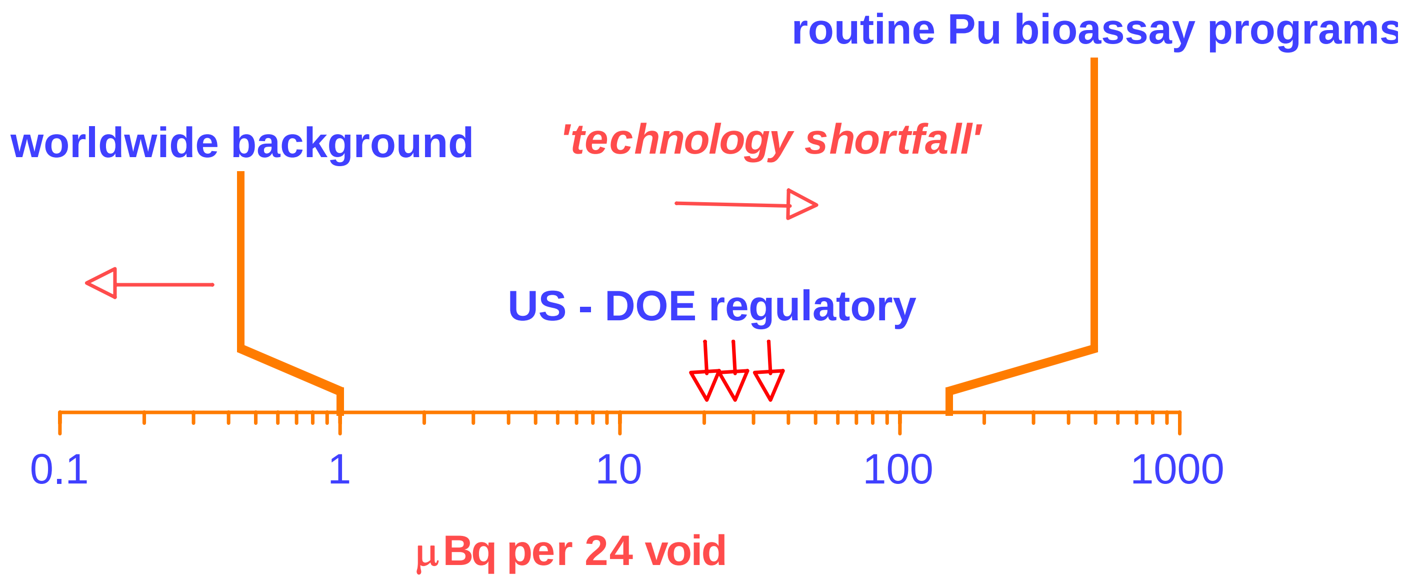
LLNL Marshall Islands Program


Enewetak Atoll
Aomen
Alembel
Runit
Lujor
Aej
Bokenelan
Bijire
Lojwa
Eleleron
Ananij
Enjebi
Boken
Japtan
Medren
Louj
Kiruna
Bokombako
Enewetak
0 1 2 3 4 5 6 7 8 Kilometers
0 5000 10000 15000 20000 25000 Feet
N


ENEWETAK
RADIOLOGICAL
LABORATORY


ENEWETAK
RADIOLOGICAL
LABORATORY

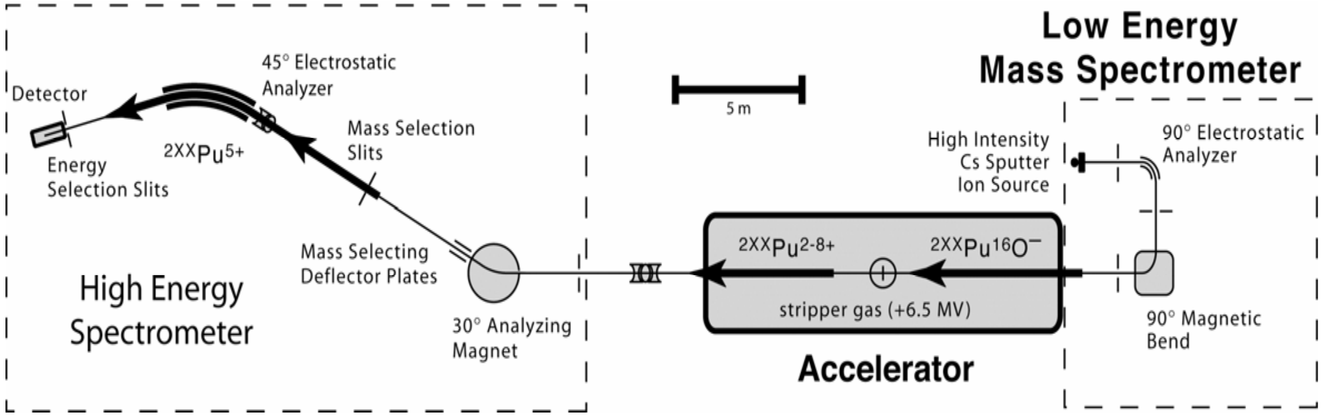

state-of-art atom (mass) counting techniques
e.g., AMS, TIMS, ICP-MS
indirect measurement techniques
e.g., fission track analysis
decay counting techniques
e.g., alpha-spectrometry
0.01
0.1
1
10
100
1000
10000
μBq per 24 void


routine Pu bioassay programs
worldwide background
'technology shortfall'
US - DOE regulatory
0.1
1
10
100
1000
μBq per 24 void

Low-level plutonium measurements at LLNL

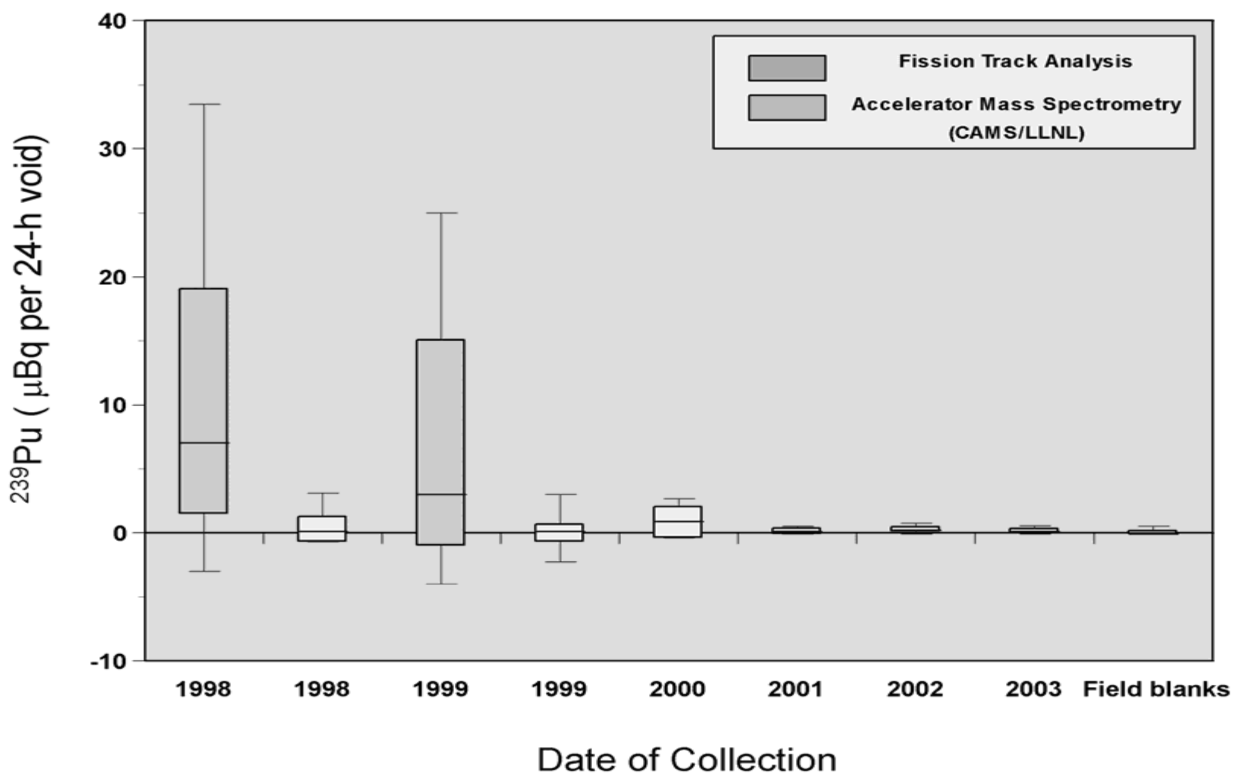
- AMS system offers advantages in terms of sensitivity and is less susceptible to interferences than many other competing mass spectrometric technologies.

- Techniques used at Livermore have been independently validated by the National Institute of Science and Technology (NIST) and the Oak Ridge National Laboratory.



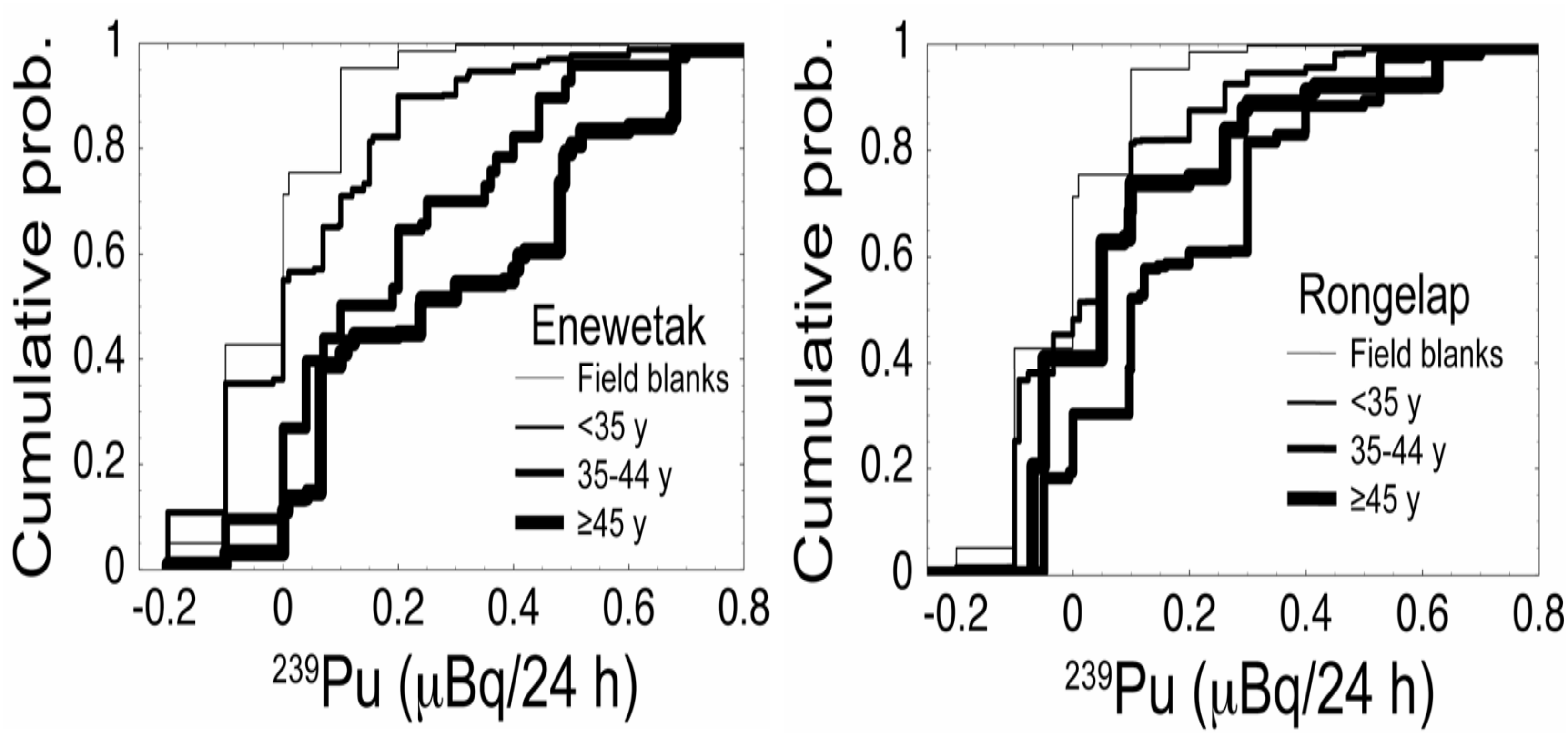
CAMS plutonium bioassay measurements

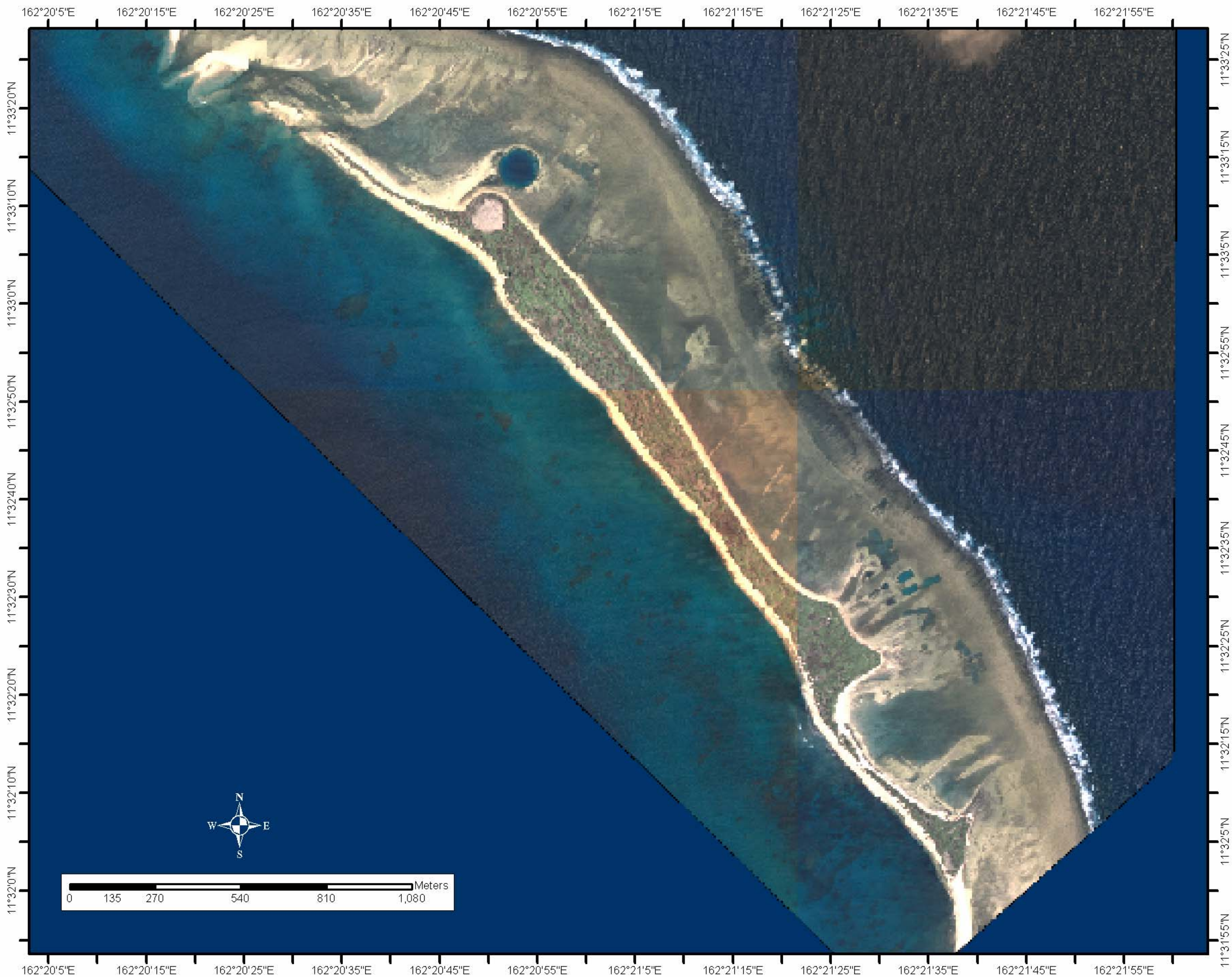
Rongelap Resettlement Workers (1998-2003)



Explanation: The lowest, second lowest, middle, second highest and highest box points represent the 10th, 25th, median, 75th and 90th percentiles, repectively.

CAMS Plutonium bioassay measurements





162°20'5"E
162°20'15"E
162°20'25"E
162°20'35"E
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162°21'5"E
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11°33'25"N
11°33'20"N
11°33'15"N
11°33'10"N
11°33'5"N
11°33'0"N
11°32'55"N
11°32'50"N
11°32'45"N
11°32'40"N
11°32'35"N
11°32'30"N
11°32'25"N
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11°32'15"N
11°32'10"N
11°32'5"N
11°32'0"N
11°31'55"N
N
W
E
S
0
135
270
540
810
1,080
Meters

Leakage from Runit Dome

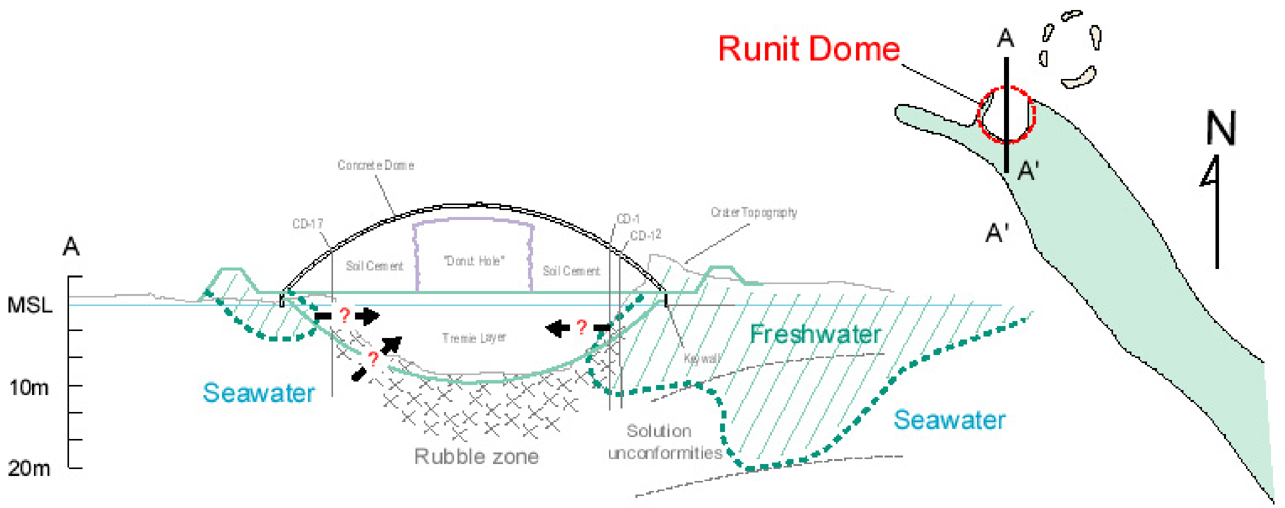


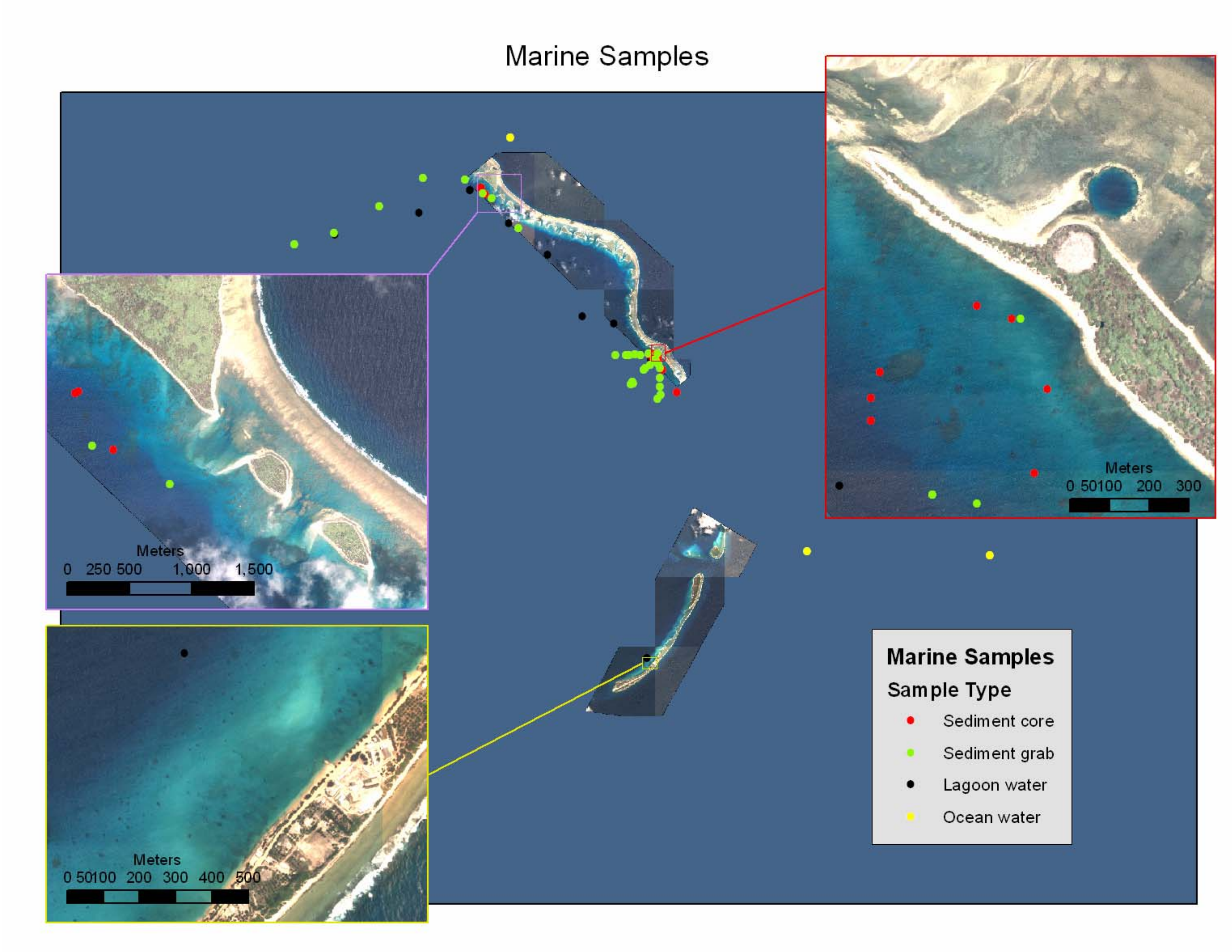
Figure 5. Illustrative east-west cross-section through Runit Dome showing possible configuration ofsubsurface freshwater/seawater interface and its potential interaction with the buried soil and debris.

Soil and Debris Beneath Runit Dome

TRU Inventory Computed for Soil and Debris Beneath Runit Dome.

		Soil Removed (m^3)	
Island	TRU GBq (Ci)	Crater (Tremie Cement)	Dome (Soil + Cement)
Aomon	48.1 (1.29)	8100	0
Aomon Crypt	33.3 (0.93)	342	7130
Boken	37.0 (1.01)	322	3450
Enjebi	96.2 (2.57)	32890	7633
Lujor	63.0 (1.70)	0	11415
Runit	267.4 (7.22)	0	8210
Total	545 (14.7)	41,654	37,838

Marine Sampling on Enewetak Atoll



Measurement of Pu isotopes in biota

Sample	Number of Samples	Location	Pu-239 (Bq/kg, dry)	UNC	Pu-240 (Bq/kg dry)	UNC	Pu-240/Pu-239 atom ratio	UNC
Fish muscle	9	Runit	0.02	0.01	0.01	0.01	0.07	0.01
Fish muscle#	7	Enjebi	0.02	0.01	0.01	0.01	0.14	0.05
Tridacna Clam -Muscle	3	Runit	3.19	2.73	0.76	0.63	0.06	0.002
Tridacna Clam -Muscle	1	Enjebi	0.28	0.01	0.25	0.01	0.25	0.01
Sea Cucumber	1	Runit	0.061	0.002	0.02	0.001	0.08	0.01
Sea Cucumber	1	Enjebi	0.053	0.001	0.04	0.002	0.20	0.01
Trochus meat	1	Runit	2.59	0.03	0.65	0.01	0.07	0.001
Trochus meat	1	Enjebi	1.42	0.02	1.62	0.01	0.31	0.004
Tridacna Clam-Stomach	3	Runit	65.3	46.5	14.5	8.1	0.06	0.01
Tridacna Clam-Stomach	1	Enjebi	0.89	0.01	0.74	0.01	0.23	0.003
Goatfish-viscera	1	Runit	0.25	0.004	0.07	0.002	0.07	0.003
Goatfish-viscera	1	Enjebi	0.73	0.01	0.65	0.01	0.24	0.003

[#] Excludes high concentration of plutonium measured in a sample of mullet muscle tissue ~ 0.19 Bq/kg dry


162°21'10"E
162°21'15"E
11°32'45"N
11°32'40"N
Meters
0 12.5 25 50 75 100
Key to features
Air Monitoring Stations
Americium-241 Bq/kg
250

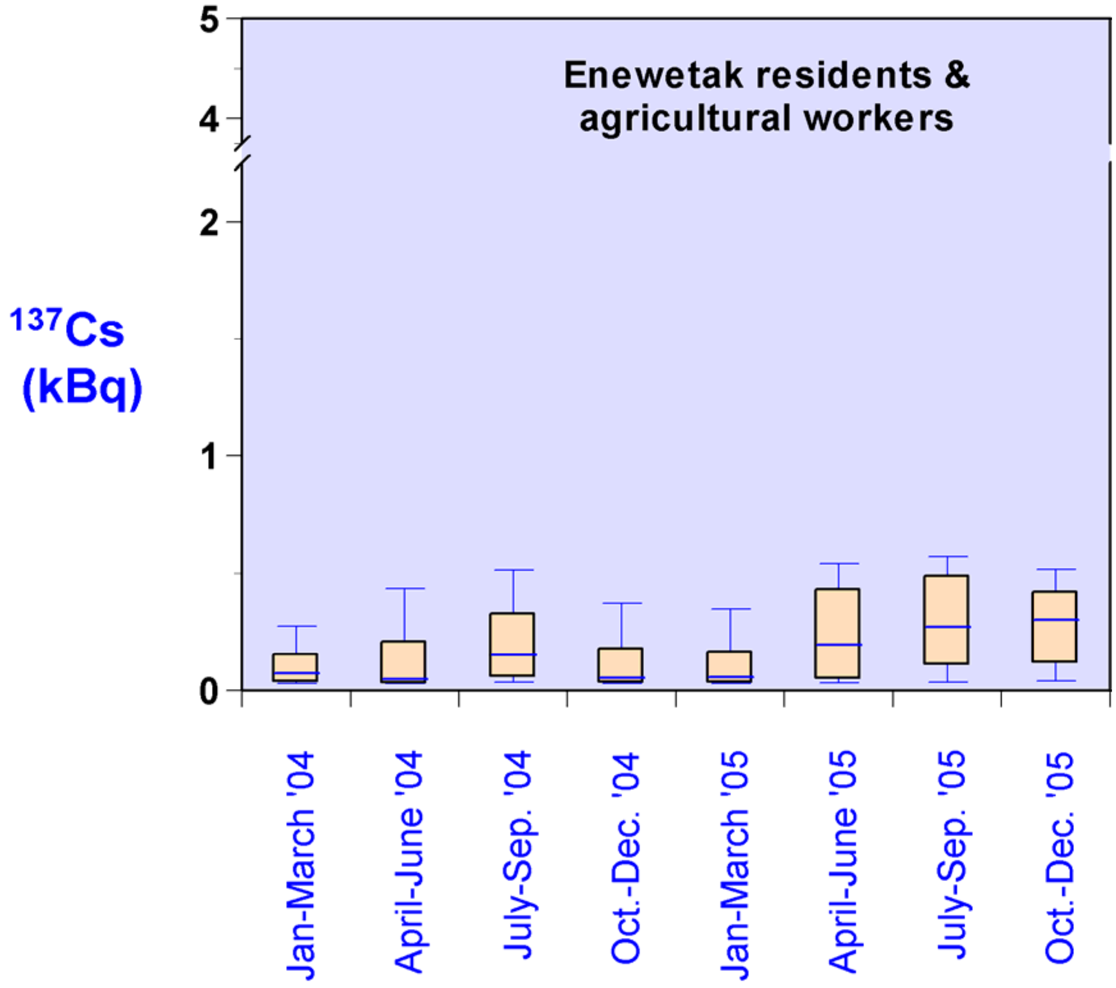
To summarize,

'Show you data from our whole body counting program' and simply say that there still is some interesting science to be done.

Volunteer database for the radiation protection surveillance program contains nearly 1800 personnel files

(or 3-4% of the Marshall Islands population)

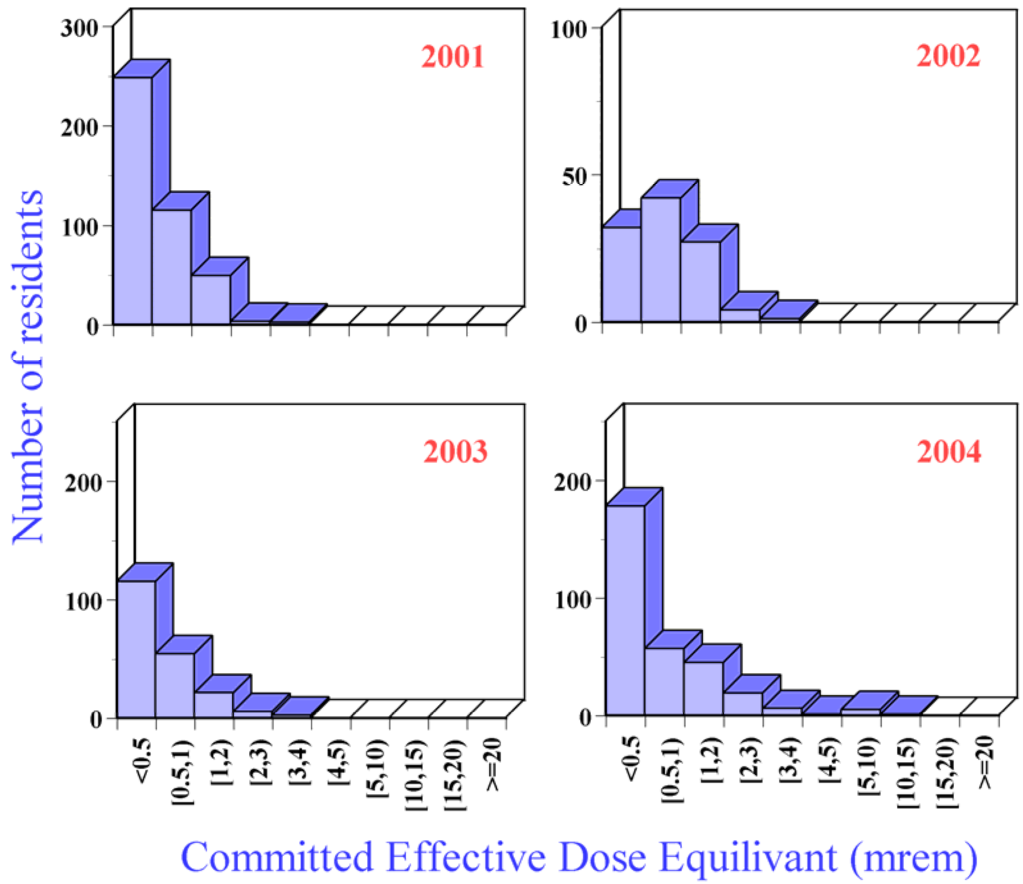
Whole Body Counting Measurement on Enewetak



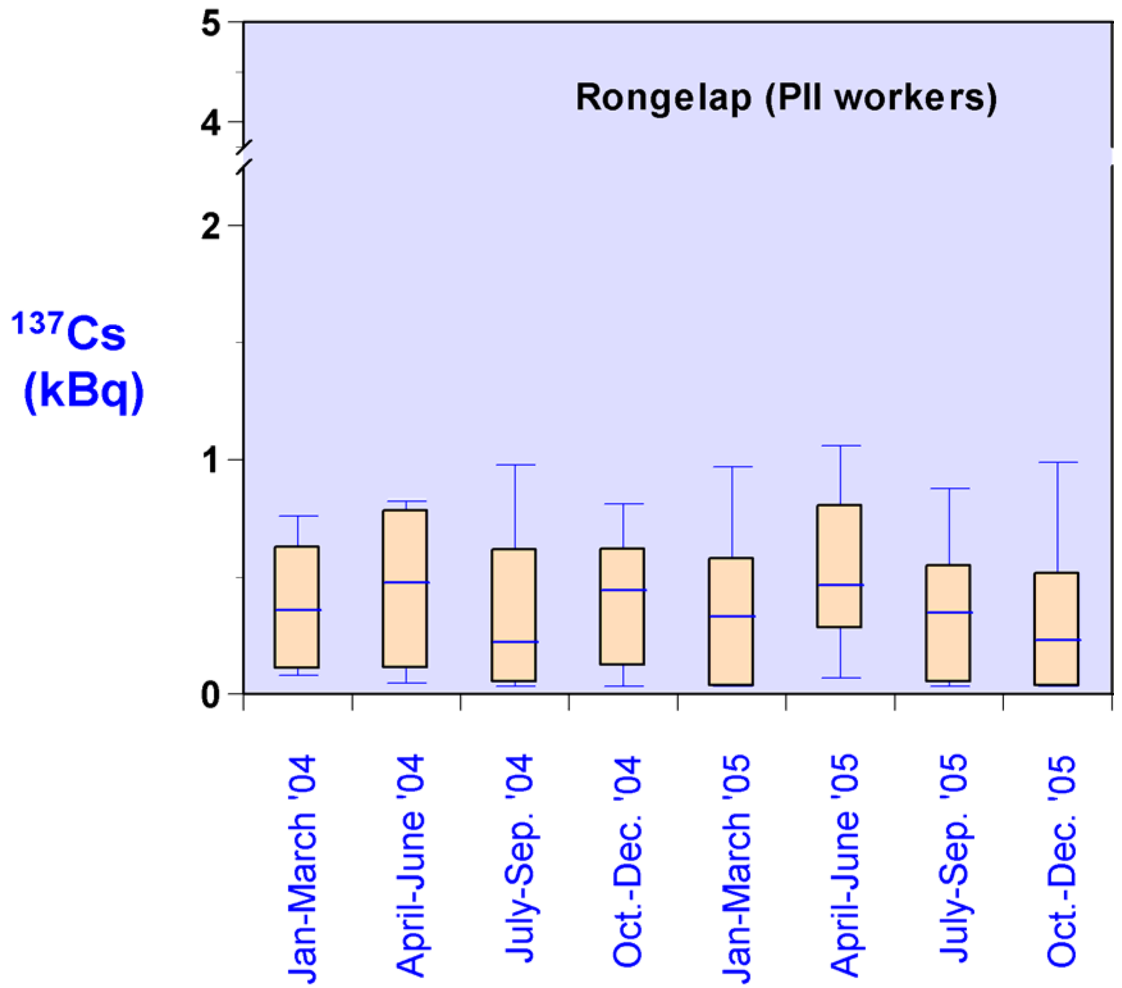
Committed effective dose equivalent from intakes of cesium-137 in the measurement year

Enewetak Atoll

- ➢No restriction on volunteer participation
- ➢Agricultural workers (originally identified as most critical group), monthly schedule
- ➢Those people showing elevated whole body burdens of cesium-137 we attempt to perform follow-up (place on monthly counts)
- ➢No person has exceeded cleanup criteria of 0.15 mSv (15 mrem) per year as adopted by the Marshall Islands Nuclear Claims tribunal



Whole Body Counting Measurements on Rongelap



Committed effective dose equivalent from intakes of cesium-137 in the measurement year

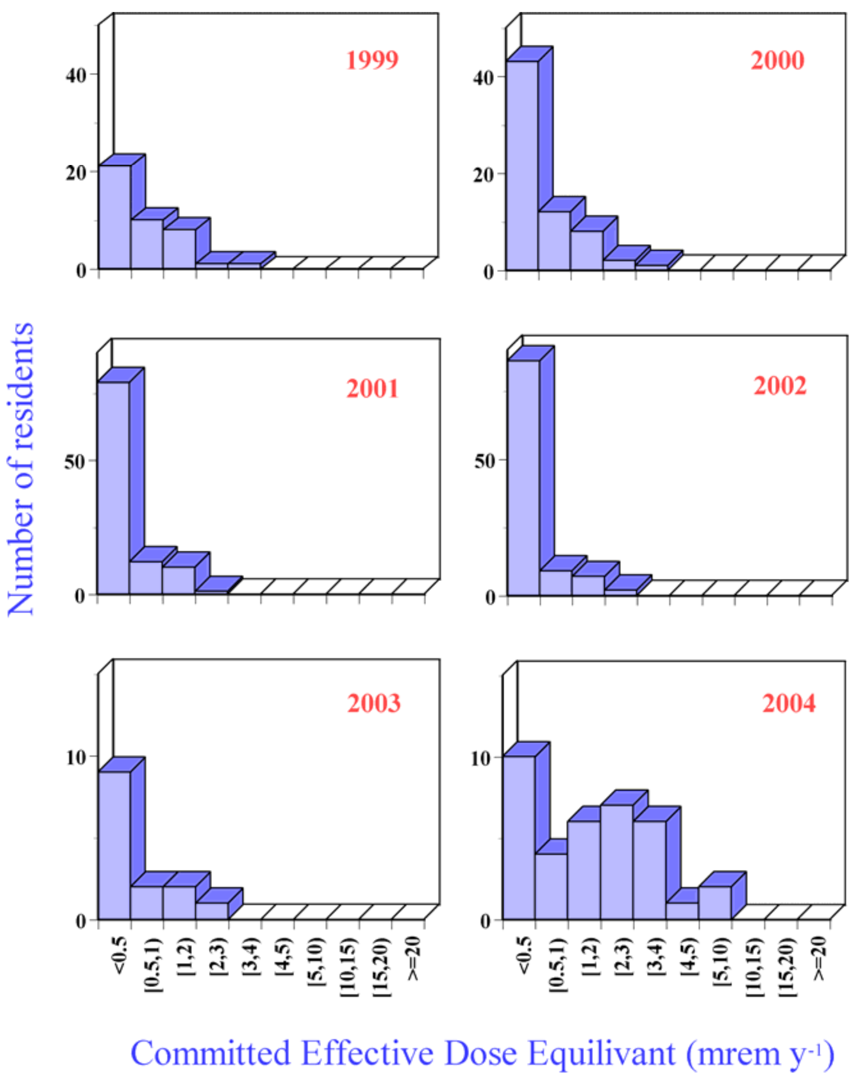
Rongelap Atoll (1999-2004)

➢**Initial focus on resettlement workers but include other volunteers visiting the island, workers on a monthly schedule.**

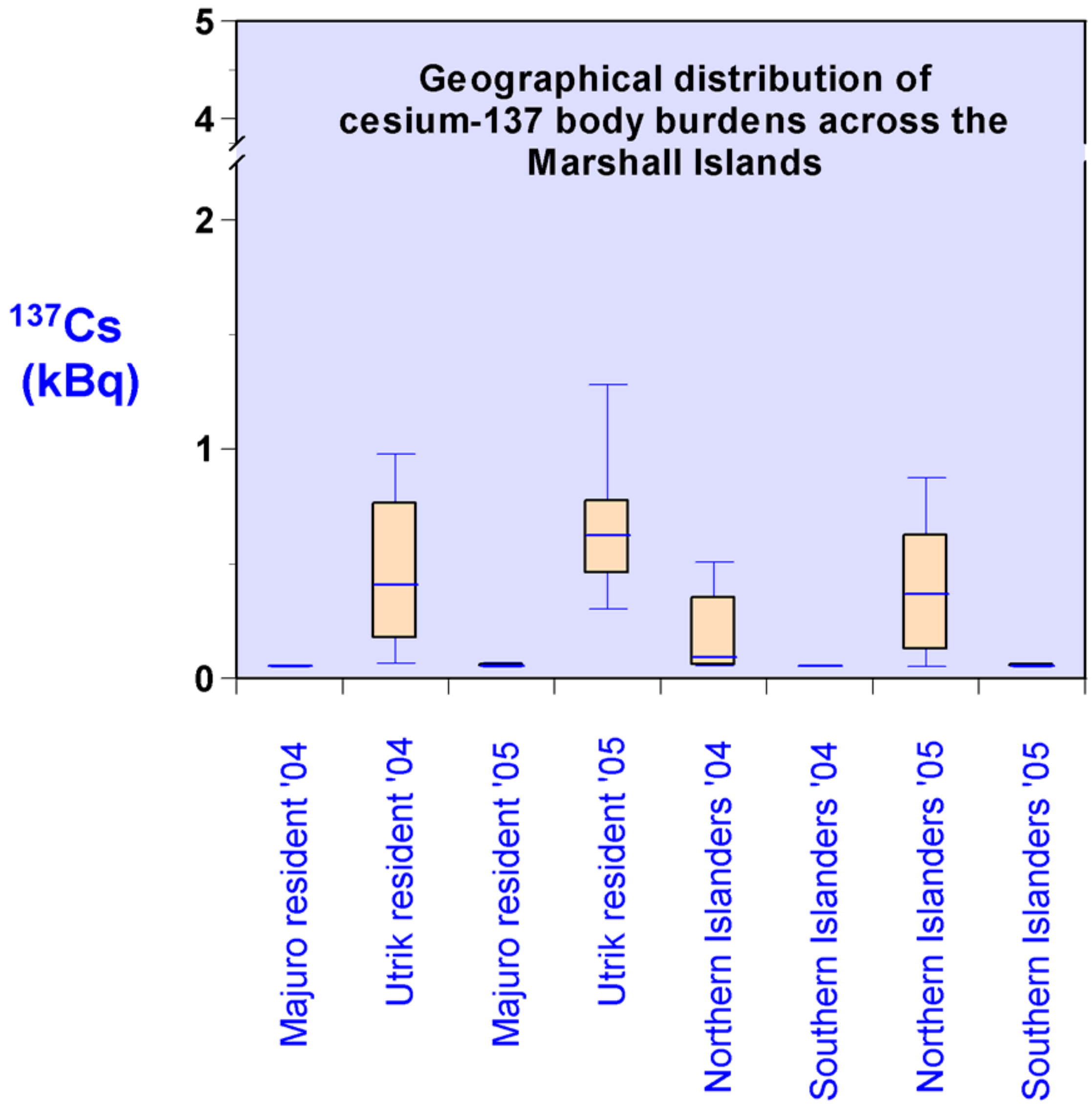
➢**Indication of higher cesium-137 intakes over the past 12-18 months (higher % of counts on maintenance staff who spend more time on island).**

"Perhaps more representative of what we might find in a resident population"

➢**No person has exceeded the 0.15 mSv (15 mrem) per year cleanup standard adopted by the Marshall Islands Nuclear Claims Tribunal**



Whole Body Counting Measurements of the Utrok Population Group as well as other Marshall Islanders



Committed effective dose equivalent from intakes of cesium-137 in the measurement year

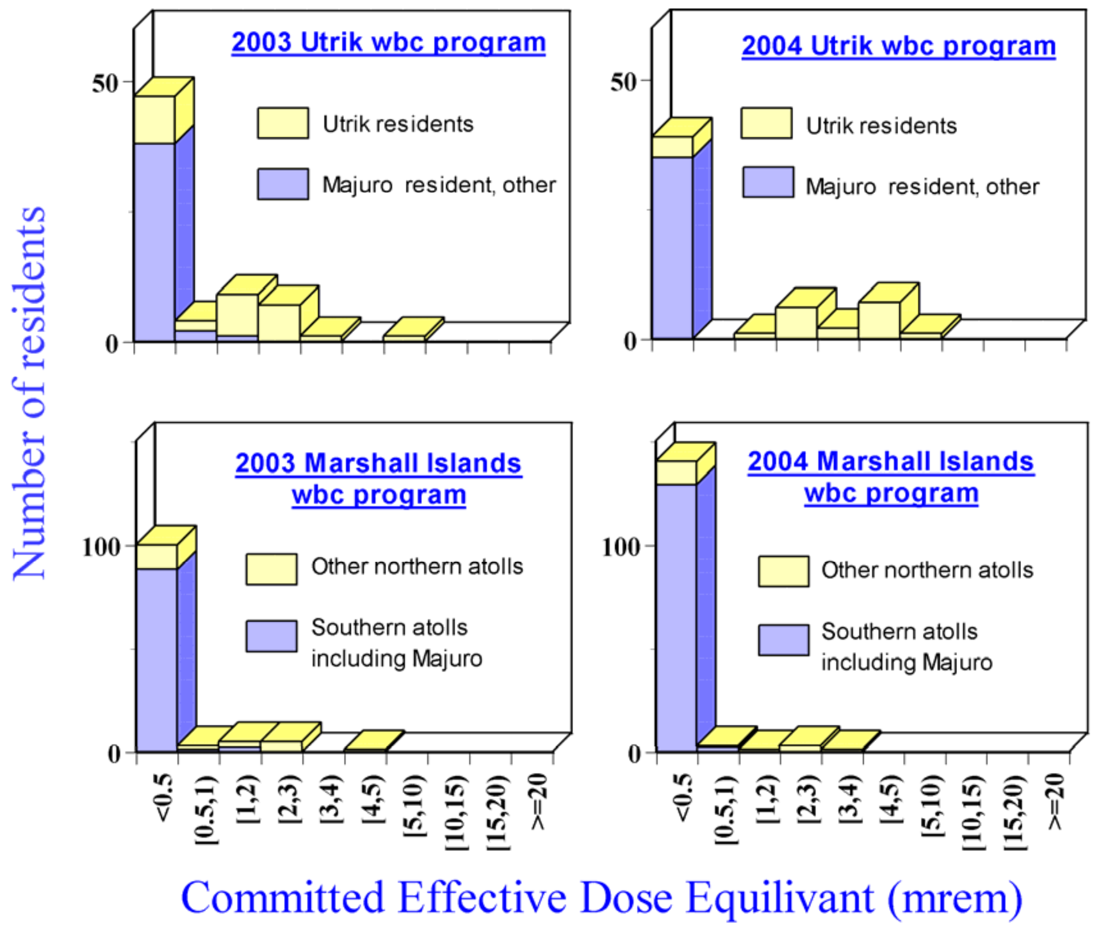
Utrok Atoll (2003-2004)

➢Facility established under the UALG MOU agreement but the local government has allowed the facility to be shared (national resource)

➢Clear indication of cesium-137 uptake into the majority of Utrok residents as compared with fellow citizens living on Majuro

➢Clear indication of cesium-137 uptake into majority of people living on other northern atolls (e.g., Ailuk Atoll).

➢Very low dose (risk) from exposure in residual fallout for people living elsewhere in the Marshall Island




THE END