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SUMMARY REPORT OF THE 1969 and 1970 BIKINI SURVEYS

This is a DRAFT REPORT -

INTRODUCTION

This report summarizes the results of radiological surveys of Bikini Atoll in 1969 and 1970 which are given in detail in "Report of the Radiological Cleanup of Bikini Atoll (SWRL #)" and "Radiological Resurvey of Animals, Soils and Groundwater at Bikini Atoll, 1969 (NVO-269-8)". Also included are results of selected samples from the 1967 survey. (Radiological Report on Bikini Atoll, P. F. Gustafson).

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I suggest that the report which is published outside the AEC be cleaned up to avoid local abbreviations etc

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BACKGROUND

Bikini Atoll was a site for atmospheric tests of nuclear devices from 1946 to 1958. The population of 166 Bikinians was moved from the atoll in March, 1946, first to Rongerik Atoll, then to Kwajalein Atoll; in November, 1948, a final move was made to Kili Island. The land area at Kili is about one-tenth that at Bikini Atoll and there is no lagoon. Therefore, access to Kili is difficult, often impossible, and sea foods are scarce.

The results of a radiological resurvey of Bikini in 1964 by the University of Washington's Laboratory of Radiation Biology indicated that Bikini might be radiologically safe for permanent habitation. A request from the High Commissioner of the Trust Territories of the Pacific to the Atomic Energy Commission in 1966 to rehabilitate Bikini resulted in an extensive survey of the atoll in the spring of 1967. This survey emphasized external radiation measurements, including *in situ* gamma-ray spectrometry, although some food items were collected to supplement data from the 1964 survey. The 1967 survey party included personnel from the Atomic Energy Commission's Health and Safety Laboratory, the Division of Biology and Medicine, the U. S. Naval Radiological Defense Laboratory, the Trust Territory, and the University of Washington.

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The data were summarized by DBM and were presented to a panel of experts assembled by DBM for evaluation of potential radiological hazards. Most of the participants in the 1967 survey attended the presentation to provide details not included in the summary.

The panel concluded that Bikini could be safely reoccupied, but recommended some simple measures that should be instituted to reduce exposure to radiation. These included reduction of the coconut crab population, because they contain high concentrations of ^{90}Sr, and covering the village area at Bikini Island with coral gravel from the beaches, as is the local custom. The panel also recommended that old structures and other such debris from the tests be removed from the islands and beaches and that the island be further monitored during the clean-up. Additional monitoring was necessary because dense vegetation on Bikini and Enyu Islets, especially, made it impractical to survey more than a few transects across the islands in 1967.

The panel's recommendations were made to the Chairman of the Atomic Energy Commission who informed the Secretary of the Interior, the administrator for the Trust Territory of the Pacific.

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CLEAN-UP OF BIKINI ATOLL

[redacted]

The clean-up phase of the rehabilitation of Bikini Atoll, a cooperative effort by AEC and Department of Defense, was begun in February, 1969, by Joint Task Force Eight. The AEC Nevada Operations Office was responsible for certification of the clean-up portion of the rehabilitation program. This was carried out under guidelines approved by the AEC Division of Operational Safety. At the request of NVOO, the U. S. Public Health Service took the responsibility for external radiation measurements, and for the collection and analysis of those land plants which are food items; the University of Washington Laboratory of Radiation Ecology was asked to sample and analyze other biological and environmental samples.

OBJECTIVE OF CLEAN-UP PHASE

The conclusions of the Ad Hoc Committee stated that the Bikini-Eneu complex of islands could be used for continuous occupancy and agricultural development sufficient to support the returning population. The clean-up of these islands called for:

1. The removal of all test related debris with disposal at sea of all radioactive debris.

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2. Stripping of the vegetation to permit planting of coconuts, pandanus, breadfruit, etc. This was accomplished by cutting swaths which were approximately 20 feet wide on 56-foot centers through the vegetative cover.

3. Determination of external background radiation levels at each step of the clearing and stripping operations.

4. Obtaining additional samples of available food items for laboratory analysis for comparison with previously collected data.

Although permanent occupancy was to be limited to the islands of Bikini and Eneu, the Ad Hoc Committee further concluded that "radioactive scrap should be removed from the islands adjacent to former shot sites." Since these islands may be used for the collection of birds, turtles, and their eggs for human consumption, removal of radioactive debris would make the scrap unavailable for collection by the natives.

The final objectives of the clean-up program, therefore, included the elimination of all physical hazards and the disposal of all radioactive scrap from each island of the atoll in addition to the specific measures cited for Bikini and Eneu.

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CRITERIA

Rather than establish firm, restrictive criteria for the removal of radioactive artifacts, or the elimination of high background areas from the islands of the atoll, each situation was viewed in terms of the potential exposure versus benefit. All debris or artifacts having little or no useful value were removed. All scrap metal or concrete with contact readings greater than 100 micro-Roentgen per hour (uR/hr) was treated as radioactive waste and buried at sea. Three specific locations were selected for this burial. In some cases, scrap reading less than 100 uR/hr was buried on land together with non-radioactive debris. This was only done on islands where areas exhibiting background levels in excess of 100 uR/hr were found. No radioactive debris at any level of activity was buried on the islands of Bikini, Eneu, or Aerokoj.

The exterior of several bunkers, located on the northern complex (Iroij, Odrik, Lomilik, and Aomen) and Nam, exhibited levels of radiation up to 7×10^3 uR per hour (uR/hr) (B+γ) at contact. The net gamma levels were 200 uR/Hr maximum. The levels inside the bunkers were less than 10 uR/hr. Since the potential for personnel exposure was negligible, and the bunkers were desired as typhoon shelters and storage buildings by the natives, the

The island was prepared for agricultural redevelopment by cutting parellel strips through the vegetation along the length of the island. The vegetative cover was knocked down and left in place to provide additional organic matter for the soil. The strips were surveyed and background gamma radiation levels recorded at 250-foot intervals along their length. Figure 1 illustrates the background variation by depicting the range and average of gamma radiation measurements taken at three feet above the ground for areas consisting of approximately four strips.

Although a large amount of debris was found on Bikini (from the testing program and World War II), with one exception none was radioactive. One pile of roofing paper scraps contaminated primarily with ^{137}Cs was located northwest of [redacted] center on the lagoon side of the island. This material which showed a contact reading of approximately 200 uR/hr was loaded into 55-gallon drums and disposed of in one of the disposal sites in the ocean south of Eneu.

The measured exposure rates were 10 uR/hr or less along the beaches, and ranged from 20-120 uR/hr inland. Soil samples taken at three locations in 1969 having measured backgrounds of 20, 70 and 100 uR/hr showed ^{137}Cs and ^{60}Co

to be the major gamma emitting contaminants. These were present in Cs/Co ratios of approximately 25/1, 50/1, and 30/1 respectively for the three samples, and thus the projected exposure rate decay will very closely approximate the decay of ^{137}Cs. In addition, ^{90}Sr was present in amounts ranging from 10-50% of the ^{137}Cs concentrations.

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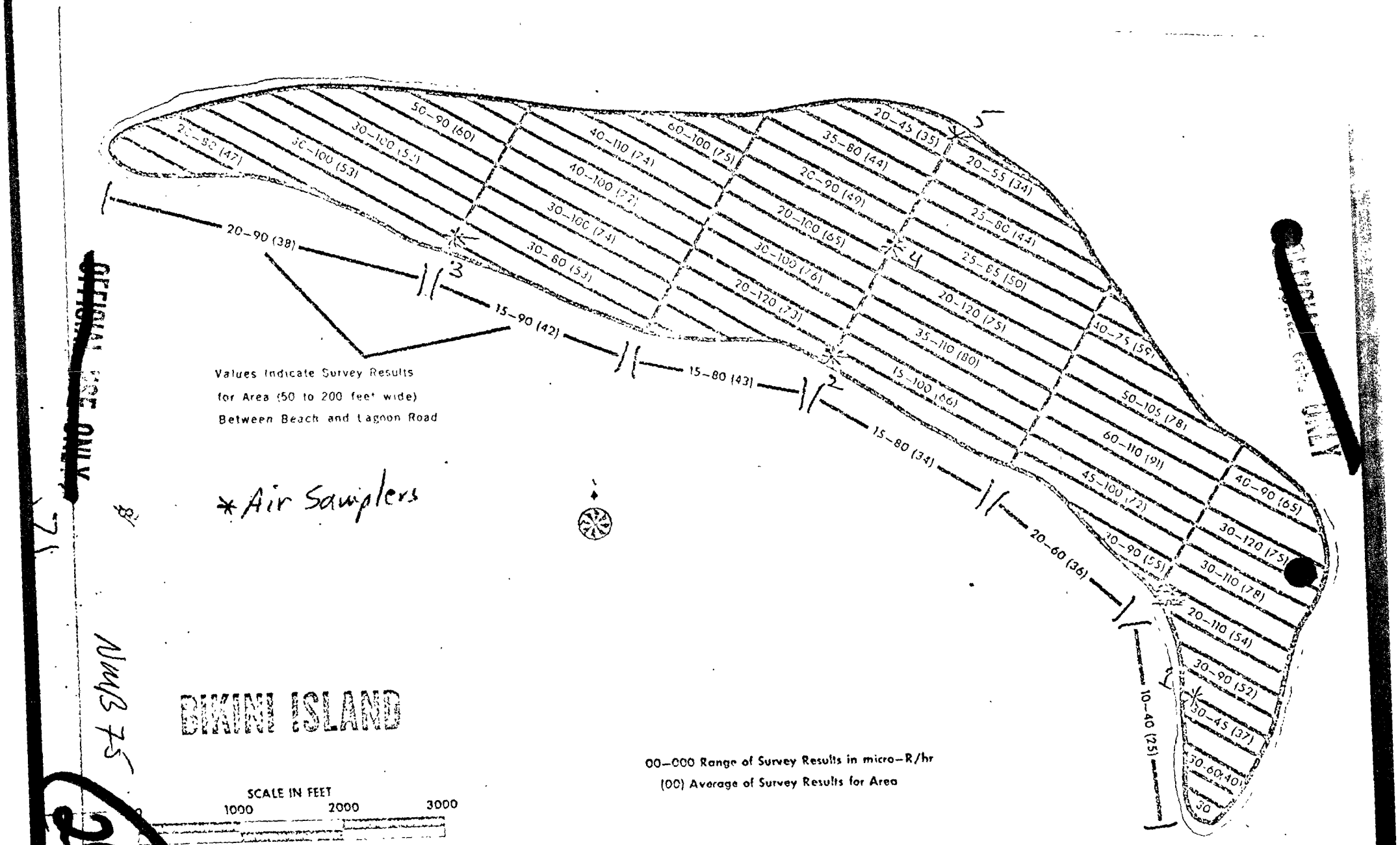

Figure 1. Bikini Island – Background Radiation Survey Results

ENEU ISLAND

The second largest island in the atoll and the site of the base camp for the clean-up operation, Eneu, was found to have external radiation levels considerably lower than Bikini, (Figure 2). Although an exposure rate of 50 uR/hr was obtained at one depressed location during the early stages of clean-up, filling of this "borrow pit" area reduced the level to approximately 10 uR/hr. The exposure rate generally ranged from less than 10 to 20 uR/hr.

00–000 Range of Survey Results in micro–R/hr

00 Survey Result in micro–R/hr at that Location

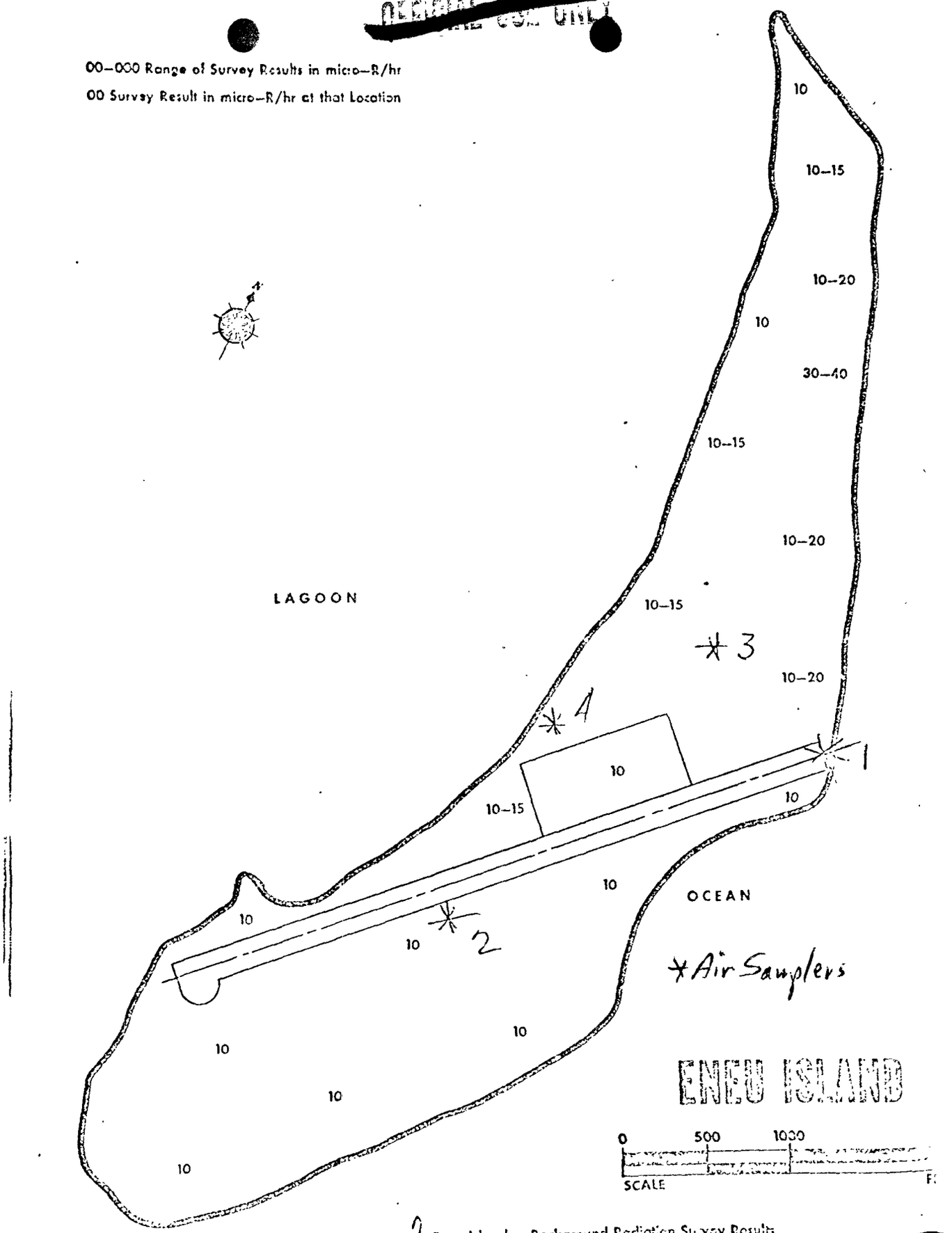

Figure 2 Eneu Island – Background Radiation Survey Results

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SIMULATED HOUSE EXPERIMENT

A simple experiment was conducted on Bikini Island to assess the potential exposure rate effect and reduction by concrete living quarters made from ? what is? aggregate obtained from the PETER-OBOE complex.

A concrete house was simulated by constructing a large square container with hollow walls six inches thick. The walls and the bottom six inches were eventually filled with aggregate (obtained from the PETER-OBOE complex) after the container was placed in an area of relatively high exposure rate (125 uR/hr). A compartment was located in the center of the structure in which a Ludlum scintillation survey meter was placed to measure exposure rates without aggregate, with six inches of aggregate on bottom, and with walls of aggregate.

Results of this experiment are as follows:

Background	125 uR/hr
Six inch aggregate bottom	75 uR/hr
Six inch aggregate bottom plus six inch walls	45 uR/hr

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Similar results were seen when exposure rates were measured inside and outside of a drained concrete cistern in the camp area, and which was constructed with

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the same aggregate. The average exposure rate of 10 mR/hr outside of the cistern was reduced to 3 uR/hr at waist height in the center of the cistern. From these observations it is expected that concrete houses made from this aggregate may reduce the exposure rates by a factor of approximately 3.

EDIBLE PLANTS

Coconut, arrowroot, and pandanus samples were collected in 1967 and 1969 and analyzed (Table 1). Coconut samples were collected from thirteen different locations on Bikini in 1969. Green coconuts were used for almost all samples and the meat and milk were analyzed separately. Only ^{137}Cs and ^{90}Sr were detectable in any of the samples. Tritium analyses were performed on the milk from selected coconuts but all results were below the lower limit of detection (0.4 pCi/ml).

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TABLE 1 - Mean ^{137}Cs and ^{90}Sr Concentration in Edible Plants Collected in 1967 and 1969 (pCi/g wet weight)

Location	Sample	1969 ^{137}Cs	1967 ^{137}Cs	1969 ^{90}Sr
Bikini	Coconut Meat	120	200	0.31
	Coconut Milk	130		
	Pandanus	130		28
	Arrowroot*	0.6		2.4
Eneu	Coconut Meat	21	28	.08
	Coconut Milk	23		
	Pandanus	87	14	
	Arrowroot*	0.7		0.4
Aerokoj	Coconut Meat	2.6		0.009
	Coconut Milk	3.0		

*Prepared by grinding, rinsing three times with salt water and once with fresh water (Marshallese method of preparation).

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FOOD ITEMS. OTHER THAN LAND PLANTS

The values of radionuclides observed in food items other than land plants are presented in Table 2. The fish collected and analyzed are in two main categories: the reef fish and the pelagic, or "troll-caught" fish. The reef fishes are usually collected by throw nets by the Marshallese and are important items in their diet.

Of the more than 700 species of reef fishes at Bikini Atoll, we selected three species commonly eaten by the Marshallese and representative of three feeding habits: the mullet, a plankton feeder; the convict surgeonfish, a grazing herbivore; and the goatfish, a bottom-feeding carnivore. The specific radionuclides found in fish and their concentrations are often associated with feeding habit, hence this was a necessary consideration in selecting samples representative of the kinds of fish which would be eaten when the Bikinians return. A fourth kind of reef fish, groupers, was also collected as representative of the higher order carnivores.

The troll-caught fishes are all high-order carnivores and fall into two broad subcategories: resident lagoon fish, ulua and dogtooth tuna; and migratory fish, yellowfin tuna. All were caught in or near Enu Pass.

The invertebrates sampled were the spiny lobsters (langouste), coconut crab and "giant" clams (Tridacna sp., and Hippopus hippopus).

Thousands of terns nest at Bikini Atoll, mostly on the western islets. Both the birds and their eggs will be used as food. The terns almost always feed at sea, outside the lagoon or reefs. On the other hand, the curlews and turnstones feed along the shores and on the reef, and the curlew also eats the seeds of an endemic shrub, Scaevola serica, or the beach magnolia. Although the curlews and turnstones are transients and are present in small numbers, at most a few hundred, they contain the higher levels of radionuclides among the birds.

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Table 2

Average Values of Radionuclides in Food Items Other Than Land Plants at Bikini Atoll, 1967[1] and 1969

pCi/g wet

Diet Item	^{55}Fe '67	^{55}Fe '69	^{60}Co '67	^{60}Co '69	^{90}Sr '67	^{90}Sr '69	^{137}Cs '67	^{137}Cs '69
Fish, muscle	100		3.7		.19		.32	
" eviscerated whole[2]		18		2.6		.08		.13
Fish, liver	9200*	382*	44.7				nd	
" viscera[2]		120		13				nd
Tuna, yellowfin								
light muscle		7.8		.02		<.03		.06
dark muscle		88		.26		<.03		.03
liver		120		.41				.02
Tuna, Dogtooth								
light muscle	484	31	.66	.30			.20	.19
dark muscle		241		1.1				.13
liver		478	15	7.1			.06	.17
Spiny lobster[3,4]		2.5	.11	.12	.04		.02	nd
Giant clams[5]		5.9		24				nd
Coconut crabs, muscle			10		19		72	
" " " (Bikini)		1.2		.65		12		181
" " " (Enyu)		.8		.14		.05		16
Coconut crabs, "liver" (Bikini)		41		7.8		62		170
" " " (Enyu)		16		1.5		5.1		16

Table 2 (con't)

Diet Item	pCi/g wet ^{55}Fe '67	^{55}Fe '69	^{60}Co '67	^{60}Co '69	^{90}Sr '67	^{90}Sr '69	^{137}Cs '67	^{137}Cs '69
Birds, muscle, all species	100	110	3.5		.13		26.5	
" " curlew		24	.94			nd		380
" " turnstone		105	7.7			nd		56
" " terns		155	1.1			nd		.08

(1) Radiological Report on Bikini Atoll. Philip F. Gustafson, Division of Biology and Medicine, USAEC, Washington, D. C., April 1968.
(2) Reef fish only.
(3) The heading, "Clams or Lobster" was used in the 1968 table, but it has been established that the values given are for spiny lobsters from Bikini I. only.
(4) The 1969 value includes spiny lobsters from Nam I. The average values for ^{60}Co for lobsters from Bikini I. is .07 pCi/g wet.
(5) Clams from near Bikini I. only. Only small clams, not usually eaten, were found off Nam. The maximum value for ^{60}Co was 29 pCi/g wet.
* Jacks (Ulua) only.
nd not detectable

AIR SAMPLES

During the 1970 re-survey 9 air samplers were operated, 4 on Eneu ~~and~~ and 5 on Bikini, for 14 days (See Figures 3 and 4 for locations). Results for those air samples are tabulated in the attached SWRHL Report.

Bikini No. 5 and Eneu No. 1 are considered to be background stations since they were located on the windward side of the respective islands, overhanging the beach.

Values for radionuclide concentrations in air were obtained by analyzing one half of the filter for each day composited by station over the total sampling period. For Bikini the ^{239}Pu results ranged from 0.6×10^{-4} pCi/m^3 to 5.4×10^{-4} pCi/m^3. All results for Eneu were 0.4×10^{-4} pCi/m^3. For comparison, the average value for ^{239}Pu background in the U. S. during 1968 was 0.4×10^{-4} pCi/m^3. The analytical error associated with these results is approximately $\pm$ 25% at the 2 sigma confidence level.

In order to assess the variation in air concentration, the remaining one half of the daily samples from Bikini No. 1 were analyzed individually. The range is from $<0.7 \times 10^{-4}$ pCi/m^3 to 7.9×10^{-4} pCi/m^3 for ^{239}Pu. The average for all samples at this station is approximately 4×10^{-4} pCi/m^3 which compares

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quite favorably with the value of 5.4×10^{-4} pCi/m^3 for the composite. Although some variation in daily levels is evident from these data, the distribution of results appear to be about what might be expected allowing for slight differences in wind conditions. In any event, it is extremely doubtful that significantly higher concentrations would be encountered under any weather conditions expected to occur in that area.

The results for Bikini #1 may be somewhat representative of highest levels to be expected when the island is reoccupied since this air sampler was located adjacent to and downwind of the road; being subjected to frequent dust clouds stirred up by a jeep.

SOIL SAMPLE RESULTS

Composite soil samples were taken in 1970 to a depth of one inch from undisturbed and disturbed areas along rows shown in figures 3 and 4 and from the area of air sampling stations. Soil profile samples were taken at well points shown in figure 3. The principal radionuclides in the soils are ^{137}Cs and ^{90}Sr. Average value of ^{137}Cs ~~values~~ on Bikini ranged from less than 1pCi/g dry to 470 pCi/g dry. The radionuclides are concentrated in the upper surface two inches of surface soil in undisturbed areas. An average having a range might be misleading.

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7 Oct. 1970
E.E.H.

TABLE 3
and Cesium-137
Plutonium/in the Surface One Inch
of Bikini Atoll Soils

pCi/g dry

		N	$^{239,240}Pu$	^{238}Pu	^{137}Cs
Bikini Island					
1967					
Soil Pit 1			5.1 ± 0.3	*	360 ± 6
" " 5			117 ± 7.4	*	1200 ± 18
" " 6			36 ± 2	*	49 ± 1
1969					
Well Point 1			130 ± 8	*	1220 ± 8
" " 2			27 ± 2	*	499 ± 3
" " 3			111 ± 5	*	1740 ± 15
1970					
1st BL** N to Centerline					
Row 24	Undisturbed	13	74 ± 9	*	299 ± 2
	Disturbed**	13	27 ± 3	*	156 ± 3
1st BL N to 2nd BL N					
Row 30	Undisturbed	20	65 ± 8	*	323 ± 5
	Disturbed	21	56 ± 8	*	170 ± 3
1st BL S to 2nd BL S					
Row 36	Undisturbed	18	87 ± 14	*	470 ± 9
	Disturbed	18	28 ± 4	*	228 ± 3
Camp area to Lagoon Rd.					
Row 66	Undisturbed	14	16 ± 2	*	175 ± 2
	Disturbed	14	6.2 ± 0.9	*	90 ± 1
Base Camp, Random Sample		16	3.9 ± 0.5	*	0.2 to 18
Eneu Island					
1969					
Camp Blandy			.71 ± 0.1	*	6.0 ± 0.3
1970					
North Central					
	Undisturbed	5	35 ± 4	*	156 ± 2
	Disturbed	4	3.0 ± 0.4	*	21 ± 0.5

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TABLE 3 (con't)

	N	$^{239,240}Pu$	^{238}Pu	^{137}Cs
Eneman Island				
1969				
SW Corner, 0-1" depth		79 ±3	49 ±2	19 ±6
8-9" depth		9.3±0.4	4.1±0.2	3.4±0.5
Bravo Crater				
1969		60 ±2	4.0±1	

N Number of subsamples in composite sample
* Not detectable
** BL = Baseline
*** Bulldozed planting strip

NOTE: Multiplication of the above values by 3×10^4 will give an approximate value in units of pCi/m^2.

Soil samples analyzed for plutonium (Table 3) were generally selected from areas with the highest levels of gamma radiation. Exceptions were the camp area at Bikini Island and along the runway at Eneu Island. ~~The~~ Soils were collected in 1967, 1969, and 1970 ~~were taken~~ from individual soil pits. ~~however,~~ In 1970 there was an additional collection of ~~most samples were~~ composite samples made up of 15 to 22 individual collections taken along ~~the~~ rows shown in figures 3 and 4. The area of higher radiation at Eneu Island was one of the few locations relatively undisturbed at Eneu and had an area of approximately fifty square feet; the sample from this area consisted of a composite of four collections. Seven soil samples were analyzed by both SWRL and ~~UW~~ University of Washington for an inter-laboratory check (Table 4).

TABLE 4

Plutonium - 239, 240 in the surface one inch of Bikini Soils Collected in 1967 and 1969, Inter-laboratory Checks

Picocuries per gram dry

Collection Site	Date	SWRL	UW
Bikini I.			
Pit 1	1967	5.1	5.1
Pit 5	"	130	117
Pit 6	"	40	34
Well Point 1	1969	190	129
Well Point 2	"	30	27

Collection Site	Date	SWRL	UW
Eneu I.			
Camp Blandy	1969	0.39	0.71

URINE SPECIMENS

A single urine specimen (24 hours) was collected from the Trust Territory resident at BIKINI. Another was obtained from a team member. These samples were analyzed and indicated no detectable plutonium activity.

TRITIUM GROUND WATER

Tritium in well water is present at low concentrations; the maximum value found was 14 pCi/ml, or 4300 tritium units, at Nam I., whereas at Bikini and Eneu Islands the concentration was 2 pCi/ml, or approximately 600 T.U. These values fall within the range of tritium concentrations in surface waters of the United States in 1966. It has been shown that there is approximately 10^4 times more tritium in bound water than in loose water in soils at Eniwetok Atoll. Since but that there is little exchange of the bound water with the loose water, Hence it is probable that there will be no major changes in the tritium concentration of well water at Bikini Atoll.

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SUMMARY AND RECOMMENDATIONS

The predominant radionuclides in the terrestrial organisms in Bikini Atoll are ^{137}Cs and ^{90}Sr, whereas the marine organisms contain mainly the ~~range~~ ^{60}Co and ^{55}Fe. The range in the amount of a radionuclide found in the same tissue from the same species at the same islet is wide. When detectable amounts of radionuclides are present, the minimum and ~~maximum~~ maximum values often differ by factors of four or five and sometimes by a factor of ten.

External radiation levels were measured on all islands of Bikini Atoll as part of the clean-up program. The highest exposure rate was measured on Tare (Eneman) where a low lying algae covered area showed 800 uR/hr. The maximum exposure rate encountered on the islands scheduled for rehabitation, Bikini and Eneu, was about 120 uR/hr in the interior of Bikini. Other islands exhibiting exposure rates greater than those found on Bikini were:

Uncle (Enidrik) - 300 uR/hr
Victor (Lukoj) - 180 uR/hr
William (Jelete) - 150 uR/hr
Charlie (Nam) - 500 uR/hr
Fox (Lomilik) - 500 uR/hr

Soil samples taken on Bikini showed greater than 95% of the exposure rate to be due to ^{137}Cs and thus the reduction in exposure rate can be assumed to closely follow the decay of ^{137}Cs. Turning of the soil as occurred during

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the stripping operations on Bikini accelerates this reduction. Soil samples from the other islands showed varying amounts of ^{60}Co and ^{102m}Rh in addition to the ^{137}Cs. The reduction in exposure rate due to radioactive decay on these islands should be much more rapid than for Bikini. Comparing the decay curves for these islands with that for Bikini, it can be seen that within approximately ten to fifteen years only Eneman will have an external background higher than that of Bikini. It is recommended that a re-survey to verify this projection be conducted in about ten years in anticipation of unrestricted use of these islands that now have higher radiation levels than Bikini. In the meantime, the recommendation of the Ad Hoc Committee should be followed.

The remaining islands of the atoll are lower in radiation levels than Bikini and it would appear that a restriction on continuous occupancy would not be needed. This is particularly true of the Oboe (Aerokoj), Peter (Aerokojlul), Roger (Bikdrin) complex where the lowest concentrations of radionuclides and lowest levels of radiation are found. Coconut samples from Aerokoj were lower in ^{137}Cs and ^{90}Sr content than those from Bikini or Eneu. Agricultural development of these islands should be considered. While the external level on Sugar (Lele) are as low as those on the other three islands, the fact that it

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is contiguous with Tare (Eneman).would make it advisable to restrict the use of this island at the present time. The causeway joining Lele to Bikdrin makes a logical dividing line for indicating this restriction.

Sampling of food items presently growing on the atoll ~~xdx~~ indicated mean concentrations of ^{137}Cs and ^{90}Sr which are essentially in agreement with those obtained in 1967. It should be pointed out that the planting of new species of foods on the islands will require additional sampling at the time of their reaching maturity in order to assess the potential internal dose. Internal dose estimates have been performed by Gustafson utilizing the 1967 data and would appear to be valid for the 1969-1970 survey data as well.

The concentrations of ^{90}Sr would seem to be of greatest concern with respect to internal dose. In this regard the recommendations of the Ad Hoc Committee for removal of top soil from the site of newly planted pandanus and possibly breadfruit trees, and the addition of a calcium supplement to the diet should be most effective in reducing the dose due to ^{90}Sr.

The results from Eneu air samples are comparable with 1968 air concentrations for ^{239}Pu in the United States. Bikini air sample results range from slightl

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higher than Eneu to approximately an order of magnitude higher (for the station exposed to the dust from the jeep on the lagoon road) even though the 239, 240Pu levels in the soils of Bikini Island are higher by approximately two orders of magnitude.