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ANNUAL REPORT 1977-78

PACIFIC RADIOECOLOGICAL PROGRAM*

by

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Annual Report, 1977-78

Pacific Radioecological Program

The annual report is an account of work completed during the 1977-78 contract year for two projects: the Amchitka Long Term Effect and Monitoring Project and the Baseline Project. The latter project included the analyses of samples collected in the Central Pacific including the Marshall Islands and the preparation of reports. The Amchitka project was supported by the Division of Military Application ($[illegible]) and the Baseline project by the Division of Operational and Environmental Safety ($50,624).

The report consists of six sections. A summary comment and a report which is attached as an appendix is provided for each section.

1. Amchitka Radiobiological Program Progress Report, January 1977 to December 1977. This is the ninth in a series of progress reports that began in 1970, one year prior to the Cannikin event. This report appends the results of analyses of samples collected in September 1977 to the data in last year's report. The results of analyses of the 1977 samples leaves unchanged the conclusions of previous years, namely, that except for small quantities of tritium in the Long Shot mud pits and drainage basin there are no radionuclides of Amchitka origin in the water, plants, or animals of Amchitka Island. A copy of the report is attached and the report is in the process of publication by the Nevada Operations Office, U. S. Department of Energy, as report NVO-269-34.

2. The title of the second section of the annual report is, "Results of Plutonium and Gamma Spectrum Analyses of Enewetak Plant, Rat and Soil Samples Collected in March 1977." This is a table of the results of analyses of the samples collected and for use by Dr. William B. Jackson and associates of Bowling Green University in the preparation of a report on the rats of Enewetak Atoll. The analyses of these samples were not a part of the 1977-78 contract but the Laboratory agreed at a meeting at Lawrence Livermore Laboratory in June 1977 to do this work as a replacement of a Spring 1977 trip to [illegible] that was cancelled.

3. A report "Radiological Survey of Plants, Animals, and Soil in Micronesia, November 1975" was prepared by Dr. V. A. Nelson. Dr. Nelson was a former employee of the Laboratory and was retained as a consultant to prepare this report of the results of the analyses of samples he had collected while he was an employee of the Laboratory. The report has been submitted to the Nevada Operations Office of the U. S. Department of Energy and is expected to be published as report NVO-269-35.

4. Dr. Nelson also prepared a second report, "Radiological Survey of Plants, Animals and Soil at Five Atolls in the Marshall Islands, September-October 1976." He had collected the samples also while an employee of the Laboratory. This report has been submitted to the Nevada Operations Office as well and is expected to be published as report NVO-269-36.

5. Although the spring 1977 trip to Bikini was cancelled, some of the samples scheduled for collection at that time were collected in Ocotober 1977 when the laboratory had a field program at Bikini Atoll for another research contract. From this collection 14 coconut samples, 10 pandanus, 5 breadfruit and [illegible] papaya samples were analyzed for ^{137}Cs and 23 soil samples for ^{137}Cs, [illegible] Pu and ^{241}Am. Some samples were collected from the same areas in either 1974, 1975 or 1976 and the results of analysis of these samples are presented for the purpose of comparison. Usually the 1977 values were as great as or greater than values for earlier years and hence there is no strong evidence of a decrease in radionuclide concentration with time. For this period this observation indicates a long ecological half-life value for these radionuclides at [illegible]

6. The quality of our analytical work has been evaluated in two ways - first, by an interlaboratory comparison program and secondly by duplicate or replicate analyses of samples from our own collection. The interlaboratory comparison program, methods of analysis, and the limits of detection are reviewed in Section [illegible]

APPENDIX I

APPENDIX I

AMCHITKA RADIOBIOLOGICAL PROGRAM

PROGRESS REPORT

JANUARY 197[illegible] TO DECEMBER 197[illegible]

By

Allyn H. Seymour and Arthur F. Johnson

NVO-269-34

Environmental
and Earth Sciences

AMCHITKA RADIOBIOLOGICAL PROGRAM
PROGRESS REPORT
JANUARY 1977 TO DECEMBER 1977

BY

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JULY 1978

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ABSTRACT

The Amchitka Radioenvironmental Program began in 1970 and is a continuing program of collecting biological and environmental samples for radiometric analyses. The history of the program from July 1970 to October 1976 has been given in seven previous progress reports from the Laboratory of Radiation Ecology to the Nevada Operations Office of the U.S. Energy Research and Development Administration. This report is an account of the program for calendar year 1977.

Results of analyses for samples collected in September 1977 have been added to the tables in Nelson and Seymour (1977) that summarize the results of analyses on samples collected from 1970 to 1976, and include analyses for: (1) gamma-emitting radionuclides in soil, lichens, freshwater, birds, mammals, [illegible], marine invertebrates, fish, seaweeds, and freshwater mosses and plants; (2) strontium-90 (^{90}Sr) in fish, birds, and soil; (3) $^{239,240}Pu$ in soils, marine algae, and fish; and (4) tritium (^{3}H) in seawater, freshwater, and biological organisms. Monitoring of background radiation with [illegible] instruments was added to the Laboratory's program in 1974, and the results of the four annual surveys since that date are included in this report.

Conclusions from the results of the recent analyses are a reiteration of the results stated in Nelson and Seymour (1976a), namely: (1) no new radionuclides are present; (2) the most abundant radionuclides that are naturally occurring are beryllium-7 (^{7}Be) and potassium-40 (^{40}K); (3) the trace quantities of fission products and induced radionuclides are from world fallout; and (4) a few of the contamination readings in some [illegible] as previously reported. It is concluded from the results of analyses on samples collected between [illegible] 1970 and September 1977, as reported in this and the seven previous progress reports, that there were no radionuclides of Milrow or Cannikin origin in the water, plants, or animals of Amchitka Island.

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1. INTRODUCTION

The present Amchitka Radiobiological program began in 1970 but was preceded by the Long Shot radiobiological program in 1965. A complete description of the earlier programs is given in the 1972 Progress Report (Held et al., 1973), and relevant portions from that report follow.

> "The present Amchitka radiobiological program was initiated in July 1970, by the University of Washington's Laboratory of Radiation Ecology at the request of the U.S. Atomic Energy Commission, Nevada Operations Office. The program is designed to provide a periodic determination of radionuclides, both naturally occurring and fallout, in biological and environmental samples from habitats near Amchitka environs. Seafoods and organisms that are potentially available to man through the food web are emphasized. However, organisms other than food organisms are also collected and analyzed. These indicator organisms are used as they significantly concentrate one or more radionuclides. Comparing levels of radionuclides other than those potentially hazardous to man are useful as a means of providing clues to the origin of radionuclides at Amchitka. Unexpected radionuclides or concentrations of radionuclides would indicate the presence of newly added radionuclides to the environment, presumably from fresh fallout, nuclear-powered vessels, or from nuclear detonations at Amchitka Island."

The first two Amchitka Radiobiological Program Progress Reports covered the period July 1970 to January 1972. These reports have been summarized by [illegible] (1972), who concluded, "All of the man-made radionuclides found at Amchitka did not originate at Amchitka except for tritium, which has previously been reported to be present in pond water and mud samples from the Long Shot site."

The third to seventh progress reports reiterated the above conclusions and extended the records of the program through August 1976. Major conclusions of the seventh report, as stated by Nelson and Seymour (1977) were as follows:

a. "Naturally occurring ^{7}Be and ^{40}K were the most abundant radionuclides present in most sample types."

b. "Trace quantities of fission products, induced radionuclides and plutonium have been detected in amounts that would be expected from world fallout of such nuclides."

c. "No unexpected radionuclides or radionuclide ratios have been detected."

d. "Tritium values in seawater and freshwater are not significantly different than the values that would be expected at other stations at the same latitude in the northern hemisphere."

a. Some of the ponds and mud pits in the vicinity of the Long Shot surface ground zero may be contaminated with ^{3}H. The drainage from the mud pits is also contaminated. The concentration of ^{3}H [illegible] than the amount of ^{3}H in the rainfall at Vienna, Austria, in 1963, and about twice as great as the amount in freshwater samples [illegible] Island, in the same year."

b. "An extensive search with sensitive instruments for radionuclides in selected environmental samples, marine, terrestrial, and freshwater, collected during the first 20 months after the Cannikin detonation of November 6, 1971, indicates that no radionuclides from the Cannikin or Milrow events have escaped to the biotic environment."

In 1973, the field program proceeded the same as for the fourth progress report except that data only from the analyses of samples collected in September 1972 were added to the appropriate tables of the previous report. Figure 1 of this progress report shows the geographic location of Amchitka Island. Figure 2 shows general collection sites for the radiobiological program, while Figures 3 through 6 present the specific collection sites for the [illegible] area shown in Figure 2. Peak years of fallout radionuclides are shown in Figure 7.

B. METHODS

[illegible] samples collected prior to July 1972, and fresh, marine invertebrates, and [illegible] collected through 1972, were analyzed by gamma spectrometry with systems using 5x5 inch NaI (Tl) crystals and 200-channel [illegible] analyzers. Samples (except fresh marine invertebrates, and [illegible] as noted above) collected since July 1972, have been analyzed with a [illegible] Ge(Li) diode detector and 4096-channel pulse height analyzer. [illegible] the ashes of selected samples, ^{90}Y was chemically separated from ^{90}Sr, collected on filter paper and counted with a low-background beta counting system. Plutonium was extracted by ion exchange, electroplated on platinum discs, and analyzed by alpha spectrometry with silicon surface barrier alpha detectors and multichannel analyzers. [illegible] yield was determined by use of [illegible] as a tracer. Tritium in [illegible] and freshwater samples was determined by vacuum distillation of the [illegible] and liquid scintillation counting of the distillate, as described [illegible] et al. (1972). Free and bound ^{3}H in tissue samples from fish, [illegible] specific plant samples was determined by azeotropic distillation and [illegible] scintillation counting. A discussion of the procedure for processing [illegible] samples and analysis of ^{3}H in bound water was given in [illegible] (1974a and 1976).

Freshwater samples (4 liters or more) for analysis of radionuclides other than ^{3}H were collected from eight freshwater sites. The water was evaporated and the residue counted for gamma-emitting radionuclides.

All data presented in the tables have been corrected to the date of collection; this correction will introduce little or no error in the reported values except for ^{140}Ba if the [illegible] in the sample was [illegible] and is not in equilibrium with its daughter. In this case, an accurate decay correction cannot be made [illegible]

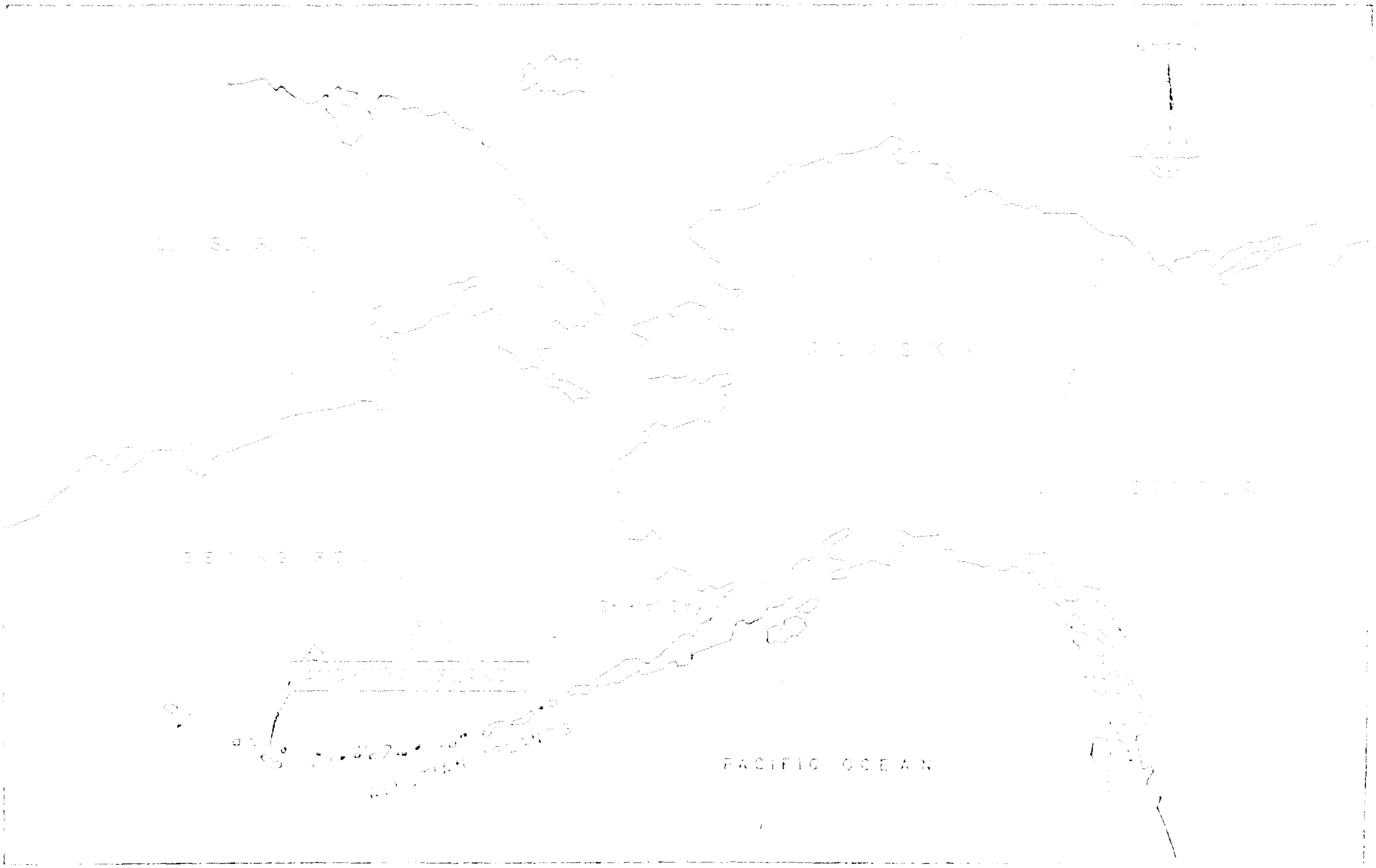

FIGURE 1. Location Map


BERING SEA
0
5
10
0
5
10
15

[illegible]

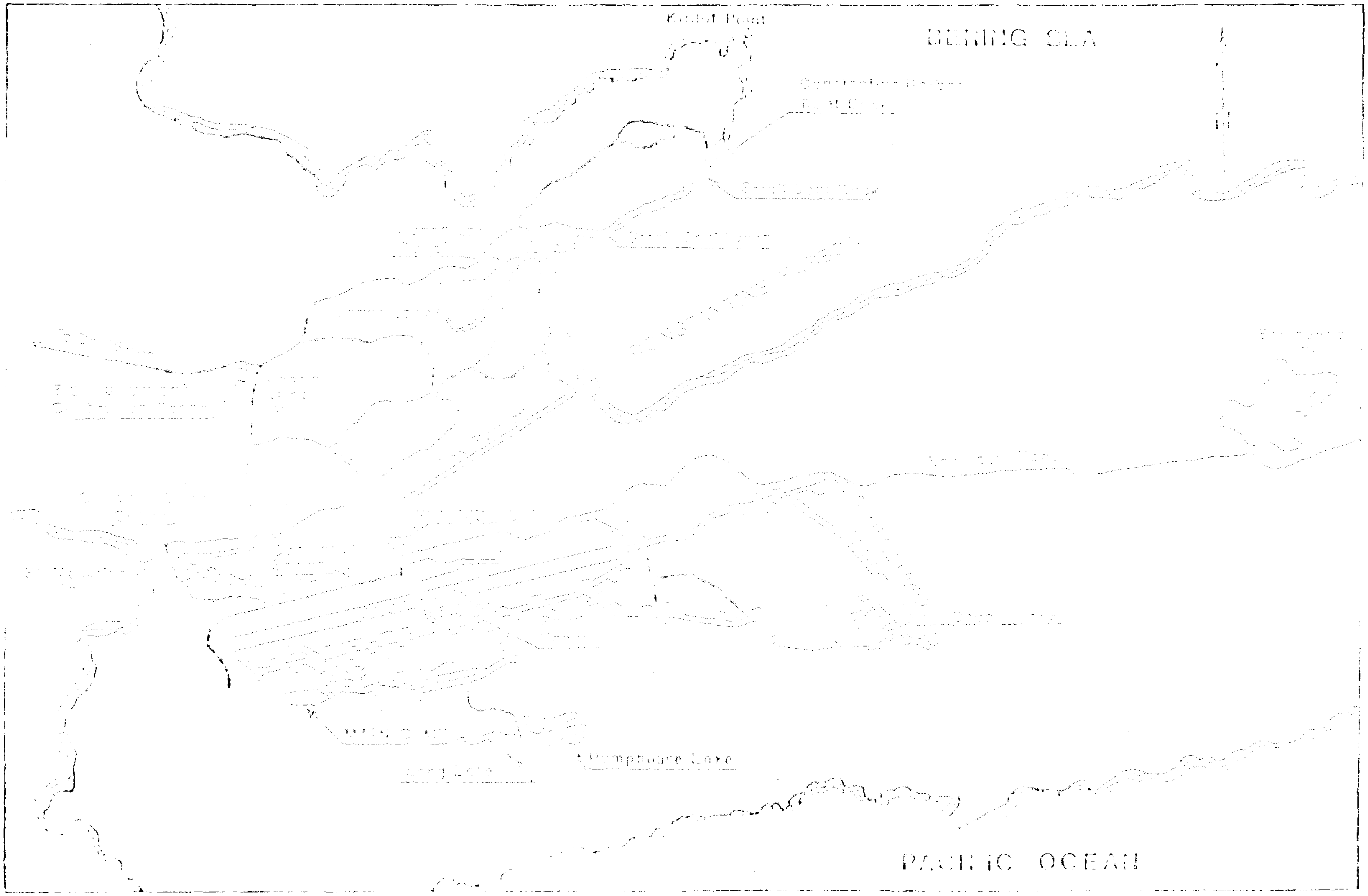

FIGURE 3. Collection Sites and Other Prominent Features in the Amchitka Island Base Camp Area

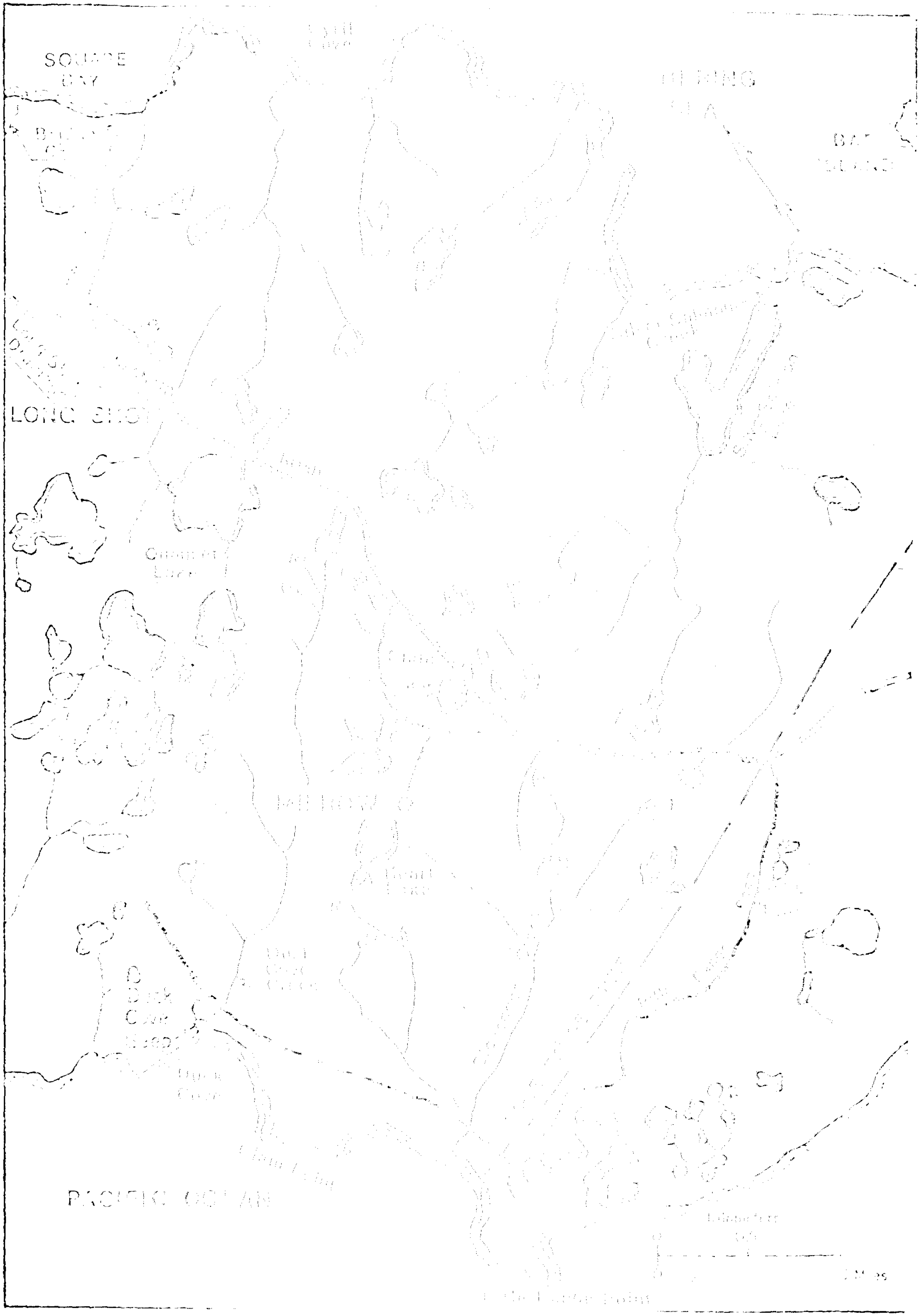

Figure 4. Collection Sites and Other [illegible] in the [illegible] Area.

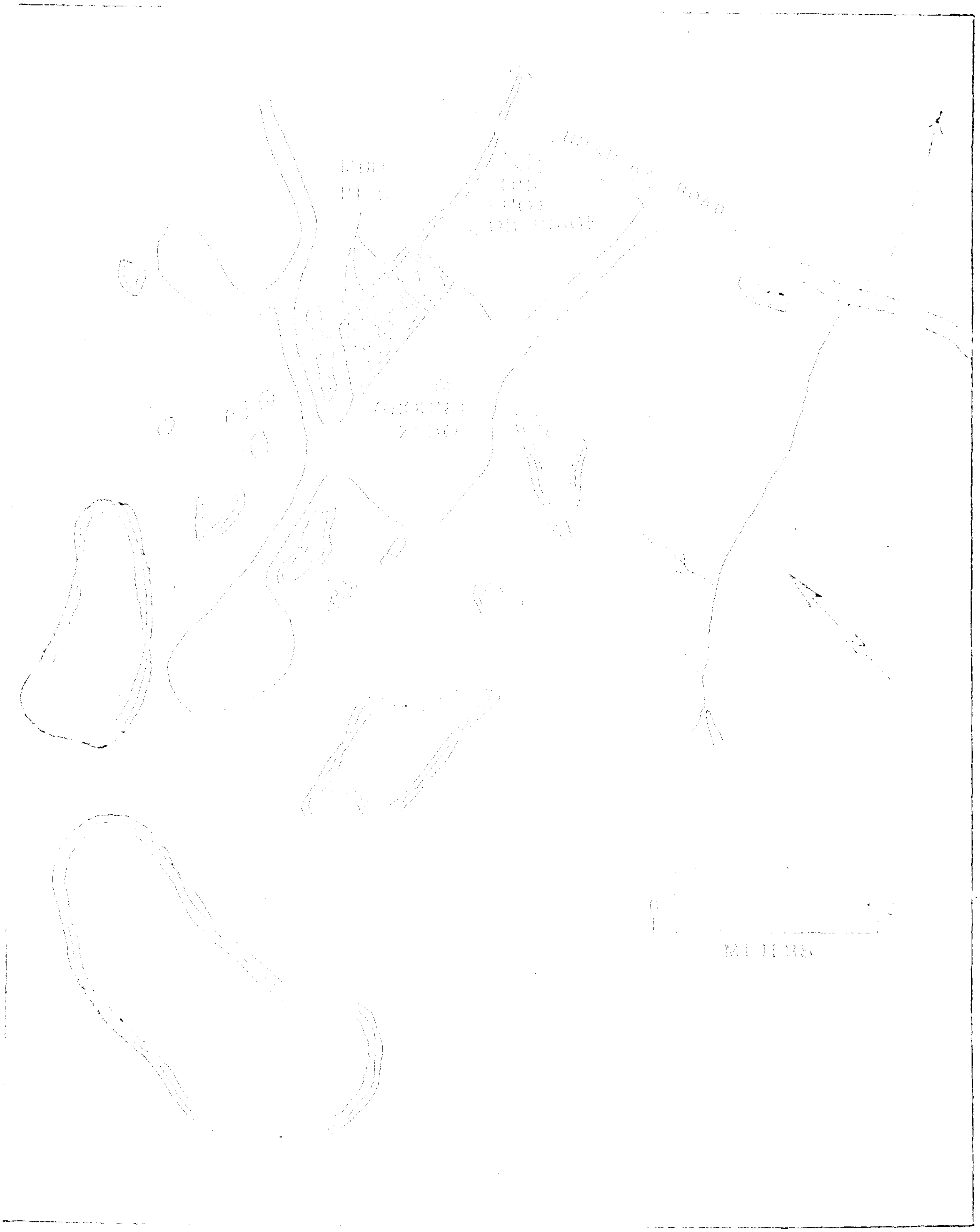

FIGURE 5. Collection Units, and Other Prominent Features at the Long Dot Mound Site, Indiana.

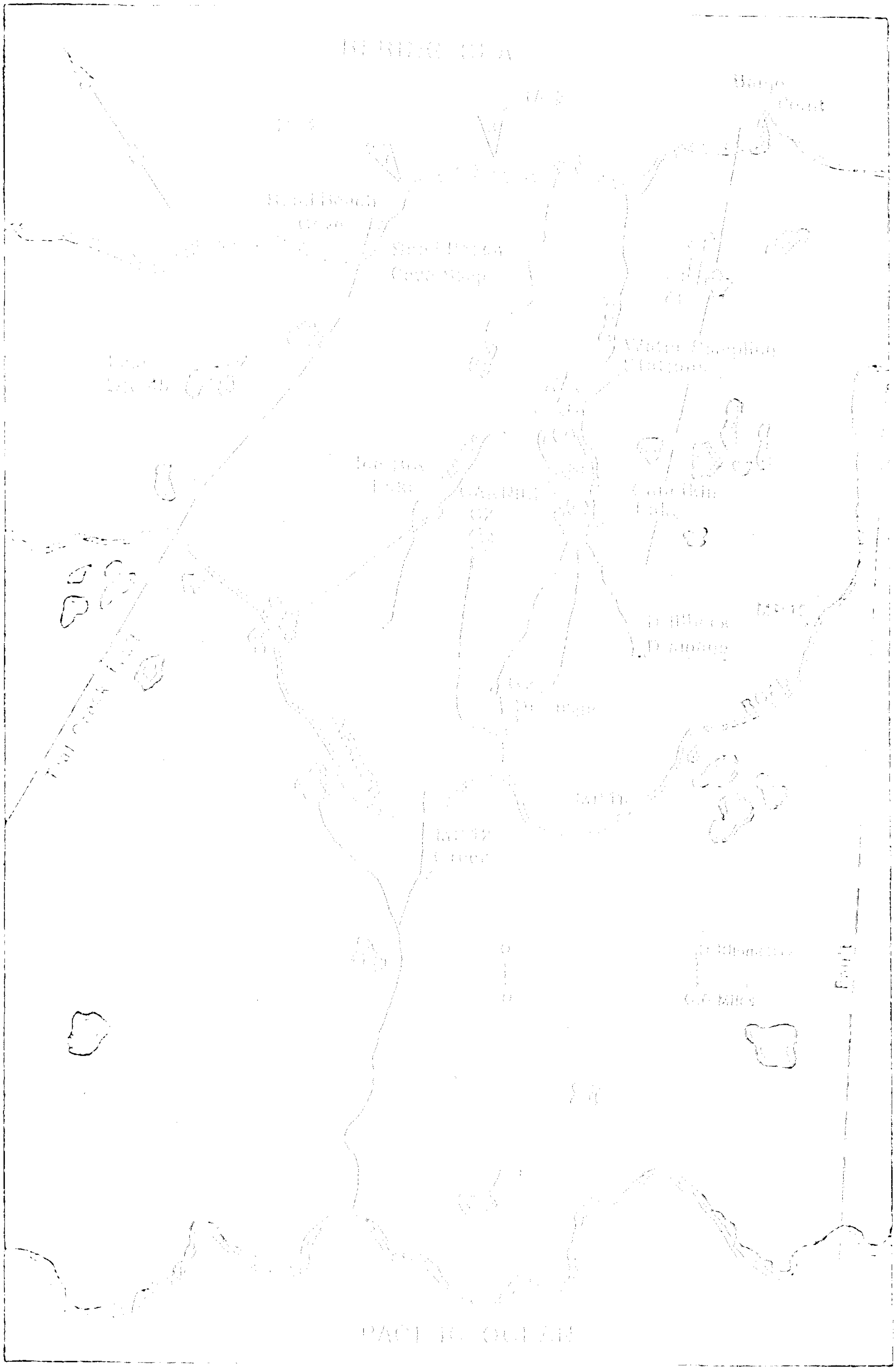

Figure 6. Collection Sites and Other Prominent Features in the Cold Bay Area

^{137}Cs, and the application of the standard decay correction factor for ^{65}Zn to the amount of ^{65}Zn present at the time of counting gives an estimate of the maximum possible amount of ^{65}Zn present at the time of collection. The problems of ^{65}Zn analyses have been discussed in [illegible] et al. (1978).

The error term in radionuclide concentrations for single samples is the combined counting error for the background, standard, and sample counts; the term "background" error [illegible] the error limit for the [illegible] resulting radionuclides in single samples are "two-sigma" or two standard deviation counting errors, while for the [illegible] data, error limits are [illegible] standard deviations [illegible] errors. Errors for ^{90}Sr in single samples collected before 1975 are one-sigma counting errors, while errors for 1975, 1976, and 1977 [illegible] for [illegible] and all [illegible] analyses are two-sigma counting errors. The error term for the mean of more than one [illegible] is one standard deviation of the mean.

Limits of detection are important since they govern the amount of a radionuclide that can be detected if it is present in a sample. Many factors influence the limit of detection, including the type of activity and yield, the presence of other radionuclides, the duration of counting, the specific activity of the sample, and the geometric relationship of the sample and detector. Hence, the actual limits of detection can vary considerably for various radionuclides and types of samples, but can be summarized by stating that the detection limits were approximately as follows:

By gamma detection	
^{40}K	2.5 pCi/g or less
^{7}Be, ^{106}Ru, ^{140}Ba, ^{144}Ce, ^{228}Th, ^{238}U	0.41 "
^{54}Mn, ^{65}Zn, ^{125}Sb, ^{137}Cs, ^{155}Eu, ^{226}Ra	0.17 "
By beta detection	
^{3}H	28 pCi/liter or less
^{90}Sr	0.2 pCi/g or less
By X-ray detection	
^{55}Fe	0.04 "
By alpha detection	
^{239,240}Pu	0.02 "

In addition to the radiochemical analyses made on the biological and environmental samples, environmental radiation surveys of selected sites on Amchitka Island were made in August 1974, 1975, 1976, and September 1977 with an Eberline survey meter, Model E-500, and a pancake probe with a 2 mg/cm² window.

2 RESULTS AND DISCUSSION

Since the completion of the 1976 Amchitka radiobiological program report, the book, "The Environment of Amchitka Island," has been published (Merritt and Fuller, ed. 1977). Chapter 24, "Radionuclides in Air, Water and Biota," (Seymour and Nelson, 1977) is a summary of the radiobiological studies at Amchitka from 1965 to 1976 including the studies presented in the 1970-71 to 1975 annual progress reports. Prior to 1970 there were radiobiological projects for the Long Shot event in 1965 and for the Milrow event in 1969 and the effort expended for these two projects was much less than for the Cannikin radiobiological project which began with a preevent study in 1970. Other chapters of the book provide additional information about the Amchitka environment based upon extensive studies by many investigators.

The samples collected in September 1977 were of the same type and from the same locations as in previous years and included biological specimens, water, soil, and sand from freshwater, terrestrial, and marine environments. The only changes in the 1977 schedule of sample collection and analyses were as follows:

1. A water sample was collected from Long Shot pond for the first time and was used for both ³H and gamma spectrum analyses.

2. Water samples from Constantine Springs and Sand Beach Cove seep and of rainwater from the Long Shot site were collected for gamma spectrum and ³H analyses, whereas only samples for ³H analysis were collected in previous years.

3. The sampling program which has been limited to one collection a year in recent years was supplemented by collections of foodstuffs and water from Bridge and Clevenger creeks and of rainwater from the Cannikin site in the spring and summer of 1977 by staff members of the U. S. Fish and Wildlife Service.*

Each of the samples were analyzed by gamma spectrometry for both natural and fission product radionuclides. In addition, selected samples were analyzed for tritium, strontium-90, and plutonium-239, 240. The results of radiological analyses are presented in Tables 1 to 18.

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*The assistance of James Coffey, Glen Elison, John Martin (Refuge Manager) and Robert Schulmeister (Biologist) of the Aleutian Canada Goose Restoration program is gratefully acknowledged.

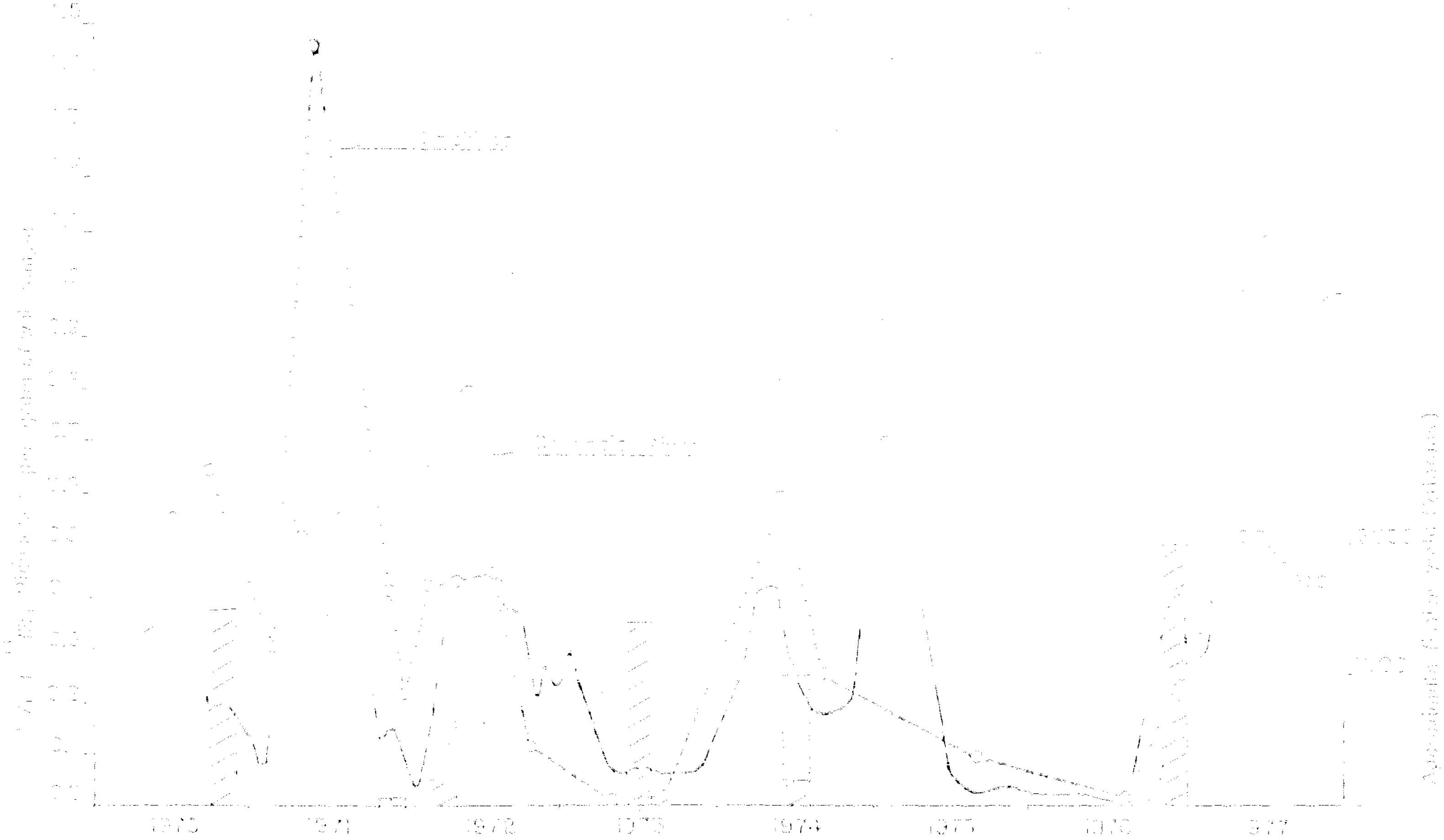
The results of gamma spectrum analysis for three types of biological samples collected on Amchitka are given in tables 3 to 5. The biota types were Dicranella (a moss), Ranunculus (a plant), and Aufwuchs (bottom-dwelling micro organisms) with filamentous algae. Samples were collected at [illegible] stations but only Dicranella was present at all locations. Inspection of the tables reveals that the values for the fallout radionuclides generally are greater than the values for the activation products and that there is a distinct "year of collection" effect with peak years in 1970-71, 1974, and 1977.

To further investigate the "year of collection" effect, the values for the amount of zirconium-95 (^{95}Zr) plus ruthenium-106 (^{106}Ru) in Dicranella from Amchitka were compared with the values of ^{95}Zr plus ^{106}Ru in [illegible] and algae samples from the Columbia River and with the schedule of atmospheric detonation of nuclear devices of 20 kilotons or greater fission yield by China. These data are presented in figure 7.

The variables in figure 7 were selected for the following reasons: ^{95}Zr and ^{106}Ru are indicators of fresh fallout radionuclides (two of the most abundant fission products in the Amchitka samples); Dicranella was selected as an excellent biological indicator species; [illegible] from the Columbia River were selected as comparable samples from a little contaminated area [illegible] samples from a location at approximately the same [illegible] as Amchitka; and the schedule of Chinese nuclear detonations was selected for comparison with the ^{95}Zr plus ^{106}Ru values because they are the probable source of fallout radionuclides in the samples from both areas. The results of one year of the Columbia River samples (a moss, Fontinalis [illegible] and/or an alga, Cladophora) were reported by [illegible] (1970). The Columbia River samples were collected monthly and it should be noted in figure 7 that the results of [illegible] have been smoothed by a moving average of three. Also, the Columbia River samples were reported in terms of dry weight and for this reason the Amchitka samples in figure 7 also are given in terms of dry weight. The dry weight values were calculated from the wet weight using a [illegible] ratio of [illegible] as determined from the mean [illegible] of [illegible] samples in [illegible].

The source of information about the Chinese nuclear detonations was [illegible] (1977). Inspection of figure 7 provides evidence for the following comments: (1) the trends for the Amchitka and Columbia River values are similar; (2) the peaks in the curves occur after Chinese nuclear detonations of 20 kilotons or greater fission yield; (3) there is a "year of collection" effect with peaks in 1970-71, 1974, and 1977; and (4) the collection and measurement systems are sensitive to small perturbations in the amounts of fallout radionuclides in the environment.

From comments (1) and (2) above, the obvious conclusion is that the source of radionuclides at Amchitka is world fallout, principally from the Chinese nuclear detonations. Another method of determining the source of the radionuclides is to determine the date of origin of the radionuclides and/or the presence of short half-lived fallout radionuclides in the samples. The date of origin of radionuclides can be determined from the ratio of fission product radionuclides of the parent radionuclide [illegible] [illegible] of any kind occurs, and [illegible] fission product radionuclide ratios can be calculated. For the Amchitka data, there is insufficient information to calculate date of origin by the [illegible] radionuclide ratio method. However, the presence of short half-life [illegible]



[illegible] than 20 kilotons [illegible]

^{95}Nb (65 and 35 days, respectively) as the dominant fission product radionuclides in the samples means that these radionuclides are of recent origin from the last nuclear detonation at [illegible] ([illegible] 1977) and hence from world fallout.

There has been no strong evidence from the radiological data for a [illegible] that the radioactivity of the [illegible] related to the [illegible] on Amchitka Island. However, in Table 3, the September 1977 values for [illegible] were [illegible] to three times greater for the Cannikin area than for samples from the Milrow and Long Shot areas [illegible] less than for natural radionuclides. This observation raised the question, "Were the differences statistically significant?" To answer the question, the mean radioactivity of seven lichen samples collected from the Cannikin area (Cannikin Lake, [illegible]) was compared with the mean [illegible] of the two samples from the Milrow area (Clevenger Creek, [illegible]) and the three samples from the Long Shot area ([illegible] Long Shot drainage stream). The radioactivity of each sample was additionally determined to be the sum of the radioactivity for the eight most abundant fission products radionuclides: ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{141}Ce, and ^{144}Ce. The mean values, and one standard deviation, for these [illegible] samples from the Cannikin, Long Shot, and Milrow areas, in terms of pCi/g of dry sample, were [illegible] ± [illegible], 7.8 ± 3.9 and 4.3 ± 0.5, respectively. To determine the significance of the mean differences, the "t" test was applied and the conclusion was that the differences were not statistically significant. Hence, even though the differences were two or three fold, the differences were not statistically significant because of the magnitude of the error term and the limited number of samples.

Radionuclide values for [illegible] are given in Table 4, for [illegible] in Table 5 and for lichens in Table 6. [illegible], a [illegible] and [illegible], hollow adhering micro-organism, are good biological indicator species but are not present at as many locations as lichens. The radionuclide values for [illegible], seaweeds, and [illegible] are similar. The lichens [illegible] for the collection and retention of fallout radionuclides [illegible] the [illegible] than for the [illegible]. The [illegible] values for ^{137}Cs and ^{90}Sr are greater than for the [illegible] indicator species [illegible] otherwise [illegible].

[illegible] of the marine alga, [illegible] (Table 7) had fresh fallout radionuclides present and at lower concentrations in 1977 than in other years from the [illegible] for vegetation types, [illegible] and [illegible]. The naturally occurring radionuclide, ^{40}K was present in concentrations that ranged from 2.[illegible] to 29 pCi/g of dry sample which is [illegible] times greater than [illegible] fission products. Also, ^{144}Ce was detected in [illegible] for the first time since 197[illegible].

[illegible] radionuclide values for the [illegible], a marine invertebrate, in terms of pCi/g of dry sample, as given in Table 8, were 6.2 for [illegible] and ranged from 0.01 to 1.2 for the [illegible] fission products.

Naturally occurring ^{40}K and fission product ^{137}Cs were the two radionuclides most commonly detected in fish (Tables 9-11). Of the [illegible] analyzed in 1977 [illegible], Dolly Varden, [illegible], ^{137}Cs was detectable in five samples and the maximum value was 0.4 pCi/g [illegible] fission. Potassium-40 was the predominant radionuclide in all fish samples in all years and the [illegible] isotope was usually present in concentrations 10 or more times greater than ^{137}Cs.

Potassium-40 and ^{137}Cs also were the predominant gamma-emitting radionuclides in [illegible] in previous [illegible] years (Table 12) and, as for [illegible] the 1977 values were significantly lower than the 1976 values. [illegible] values for both radionuclides in the 1977 [illegible] samples fell within the range of values for other years.

The samples analyzed for ^{90}Sr were soil and the bones of [illegible] and [illegible] (Table 13). In samples collected since 197[illegible], the ^{90}Sr [illegible] in terms of pCi/g dry sample ranged from [illegible] to 27 for [illegible] from the limits of detection to [illegible] in [illegible] bones. The [illegible] values were [illegible] less than the [illegible] values for these samples [illegible] previous years. Soil samples were collected in 1975, 1976, and [illegible] and in only one sample was the ^{90}Sr value greater than the limit of detection and this value was 0.0[illegible] pCi/g of dry sample. Soil, [illegible] and sand samples (0-2.5 cm) collected in the last three years were analyzed for gamma-emitting radionuclides. The soil samples were [illegible] at the Long Shot Site and in the Cannikin Area and the sand samples from [illegible] the Sand Beach Cove. The radionuclides [illegible] were ^{7}Be, ^{95}Zr, [illegible], ^{137}Cs, ^{226}Ra, ^{228}Th, and ^{232}Th. There were no [illegible] differences in radioactivity [illegible] in either year or [illegible] areas. The gamma-emitting fallout radionuclides present in these samples were ^{95}Zr, ^{106}Ru, and ^{137}Cs but the concentration of each in the samples was less than 1 pCi/g of dry sample. Similar types and levels of fallout radionuclides were seen in soil samples collected in Washington [illegible] during 1977 and 1978 (Nelson and [illegible], 197[illegible]).

Freshwater samples have been collected for gamma spectrum analysis [illegible] 1974-77 at four sites — Deep Lake, Heart Lake, Cannikin Lake, and Long Shot Mud Pit No. 1 — and in 1977 at three additional sites — Constantine Springs, [illegible] Lake, and Sand Beach Cove. In addition, a rainwater sample was collected for gamma spectrum analysis in 1977. The results of analyses on the residue from the evaporation of 3[illegible]-liter samples are presented in Table 14. The most abundant gamma-emitting fallout radionuclides in the 1977 freshwater samples were ^{95}Zr and ^{95}Nb in the Long Shot Mud Pit No. 1 sample, the values being 0.66 and [illegible] pCi/liter, respectively. These two radionuclides also were present in a [illegible] 1977 rainwater sample but at concentrations an order of magnitude greater than the values for the Long Shot Mud Pit No. 1 sample. [illegible] was the source of ^{95}Zr and ^{95}Nb [illegible] in the 1977 [illegible] detection at Long Shot Mud Pit No. 1 would be expected [illegible] in the lake samples because of [illegible] [illegible] in the lakes. [illegible] ^{95}Zr and ^{95}Nb observed in the 1977 samples [illegible] of relatively [illegible] because of the short half-lives of ^{95}Zr and ^{95}Nb (65 and 35 days, respectively) and, hence, the origin is presumed to be world fallout. Other significant observation from inspection of Table 14 is that the radioactivity for samples from the [illegible] sites in 1977 was within the range of values for samples from other locations.

The concentrations of tritium (^3H) in seawater and precipitation samples are recorded in Table 16. From 1970-71 to 1973 the ^3H values for seawater declined from 160 to 71 pCi/liter and since that time, including [illegible], the values have been at or below the limit of detection which is [illegible] 50 pCi/liter. The ^3H values for freshwater samples have been [illegible] larger than seawater samples, and like seawater, the values have constantly declined. The average value of 790 pCi/liter in 1970-71 for water samples other than those from the Long Shot area has declined to values that ranged from 92 to 140 pCi/liter in the period 1975-1977. The 1977 average of ^3H in freshwater samples (other than samples from Long Shot area) and in seawater samples was 95 and [illegible] pCi/liter respectively. Because of the relatively low and uncertain ^3H values, the difference between the freshwater and seawater values is not significant.

The water samples collected from the Long Shot Mud Pits [illegible] have always been considered separately from other samples because they were found to be slightly contaminated with ^3H a few months after the Long Shot nuclear detonation in 1965. The origin of this contamination has been well documented in previous Amchitka reports and in other publications (see Essington, 1975; Held and Allen, 1977; and Seymour and Nelson, 1977). In the period from 1970-71 to 1977, the average [illegible] for water samples from Long Shot Mud Pits have declined from [illegible] to 7.5 x 10^4 pCi per liter. These values are significantly less than the allowable concentration of ^3H in drinking water for the general public, which is 10^6 pCi of ^3H per liter. This value is 1/30 the [illegible] (maximum permissible concentration in drinking water) for continuous [illegible] by the occupational worker (ICRP, 1964). A more extensive discussion of this subject is given in Nelson and Seymour (1977) and Seymour and [illegible] (1977). Samples of water [illegible] from the Long Shot Mud Pits [illegible] were collected in 1975, 1976 and 1977 for ^3H analysis. [illegible] the course of the drainage stream, the ^3H values decreased [illegible] considerably as the Mud Pit values [illegible] and at the mouth of the [illegible] were comparable to ^3H values in freshwater samples from other areas of Amchitka Island. In 1977 the values in units of pCi per liter, [illegible] in regular order, from 7.5 x 10^4 near the Mud Pits to 52 at [illegible]. Hence the contribution of ^3H from the Long Shot Mud Pits to the [illegible] insignificant.

Table 16 also provides some information for evaluating of the effect of season of the year upon the amount of ^3H in the samples, but the data are insufficient for a positive conclusion. In 1977, water samples collected from Clevenger and [illegible] Creeks in May, August and September [illegible] a significantly greater amount of ^3H in the May sample from [illegible] [illegible] however, freshwater samples were collected in [illegible] July, August, and September and for these samples, no [illegible] effect is apparent although peak seasonal values in late spring [illegible] would not have been unexpected.

In Table 17, the results of ^3H analyses of free water extracted from biological samples are presented. The collections in 1977 included [illegible] from the marine environment ([illegible] and [illegible] of greenling and [illegible]), freshwater ([illegible] and Dolly Varden muscle) and from the [illegible] environment ([illegible]). The 1977 values, generally, were less than the 1976 values but the differences were not great. The concentrations were in the [illegible] samples and the average value [illegible] 1977 of [illegible] samples from the Long Shot Area was 120 pCi per liter [illegible] was not greatly different from the average value of 93 pCi per liter [illegible] of Amchitka freshwater samples exclusive of the Long Shot Area. [illegible] observation that the values for ^3H in rainfall from [illegible] Amchitka are about twice as great as ^3H values in water samples [illegible] the same location, was not verified by the 1977 data. However, as in previous years, the values for ^3H in Long Shot wells from the [illegible] Long Shot [illegible] were several times greater than in comparable [illegible] from other areas. Also, the ^3H values [illegible] were related [illegible] in the [illegible] in which the samples were collected [illegible] in the [illegible] of [illegible] samples [illegible] have not been [illegible]. [illegible] of a new sampling system may resolve some of the previous problems.

Some 1975, 1976, and 1977 samples [illegible] sand, [illegible] and [illegible] which were analyzed for [illegible] and the results of these analyses are given in Table 10. The general conclusion [illegible] of the table is that the maximum value was 0.035 pCi per gram (dry) [illegible] sample and that there were no obvious differences related to [illegible] classification. The [illegible]Pu values at Amchitka were compared with the results of analyses of comparable samples from the Atlantic Coast ([illegible] et al., 1973), California (Chang et al., 1977), and Washington ([illegible] and [illegible], 1976b) and were found to be similar, i.e., some of the Amchitka values were slightly less, some slightly greater than the values from other areas ([illegible] and [illegible], 1977). For this reason the source of [illegible] at Amchitka is believed to be the same as for other areas of the world, i.e., fallout.

A background radiation survey program with a Geiger-Mueller detector whose thickness is [illegible] mg/cm² was initiated in 1974 and the results of the survey for 1977 and the three previous years are presented in Table 11. Observations were made at 14 locations and in no instance was the [illegible] greater than 0.03 mR per hour, although occasionally pulses of radiation would temporarily deflect the needle on the dial to values of [illegible] 0.05 mR per hour. The survey meter readings for all areas [illegible] and [illegible] were essentially the same. Furthermore, the instrument which was operating near the lower limits of detection was insensitive to changes in background radiation.

4. SUMMARY AND CONCLUSIONS

The objective of the program is to determine the extent of radionuclide contamination on Amchitka Island. The objective is achieved, primarily, by the collection and radiological analysis of biological and environmental samples, and also by background radiation measurements. If the contamination was significantly greater than would be expected from world fallout, a [illegible] leakage of radionuclides from the underground sites of the Amchitka nuclear detonations would be suspected. The results of analyses of the samples collected in September 1977 and the background radiation measurements [illegible] lead to the same conclusion as in previous years, i.e., there is no evidence that the radionuclide contamination at Amchitka is greater than would be expected from world fallout except for a slight contamination of the Long Shot mud pit with tritium.

Findings are primary statements upon which the conclusions are made. [illegible] [illegible] radionuclide contamination of Amchitka Island and [illegible] is there, with the exception of tritium in samples from the Long Shot [illegible] [illegible] and [illegible], is of world fallout origin.

1. [illegible] radionuclides, [illegible] and [illegible], were the most abundant radionuclides in most samples.

2. Some fission products, induced radionuclides, and plutonium have been detected in samples. [illegible] range from the limits of detection to a few pCi/g of dry sample.

3. Values for [illegible] and [illegible] in [illegible] mosses and algae from Amchitka Island and the Columbia River were similar in [illegible] and peaks of abundance.

4. Peaks of abundance of fission product radionuclides occurred in 1970-71, 1974 and 1977 and followed major Chinese atmospheric detonations.

5. Two fission products of short half-lives, ^{95}Zr and ^{95}Nb, were the dominant fallout radionuclides in the samples and [illegible] of origin was [illegible] [illegible] from the last [illegible] [illegible] detonation.

6. The radioactivity from fallout radionuclides, generally was greater for freshwater than for marine organisms.

7. There has been no increase in the [illegible] or [illegible] values. [illegible] is a potential [illegible] indicator of radionuclide leakage from underground sites.

8. The background and other survey meter readings were at or near the lower limits of detection for the instrument.

9. The laboratory detection and measurement system for the radiological analyses of the samples was sensitive to small [illegible] in the amounts and species of radionuclides in the environment.

10. The results of analyses of the 1977 samples compared with the results of analyses of samples collected previously [illegible] reveal any unexpected information.

TABLE [illegible]

Scientific and Common Names and Wet Weight to Dry Weight Ratios of Some Amchitka Island Organisms

Name	Tissue	Wet/Dry Ratio	Standard Deviation
	VERTEBRATES		
[illegible]			
Rattus norvegicus			
Rat	Bone		
[illegible]			
Salvelinus [illegible]			
[illegible]	Muscle	3.62	0.70
	Viscera	4.20	0.42
Oncorhynchus gorbuscha			
Pink Salmon	Gonad	4.51	
	Muscle	4.33	
	Liver	4.02	0.65
[illegible]			
[illegible]	Muscle	4.03	0.58
	Liver	[illegible]	0.04
Hexagrammos lagocephalus			
Rock Greenling	Liver	[illegible]	0.41
	Muscle	[illegible]	0.14
	Viscera	2.13	0.07
Birds			
Lagopus mutus			
Rock Ptarmigan	Liver	3.57	0.37
	Muscle	[illegible]	[illegible]
	INVERTEBRATES		
Strongylocentrotus [illegible]			
[illegible] (green)	Entire	2.1	
	MARINE ALGAE		
[illegible]			
[illegible] algae	Entire	4.14	1.4
	FRESHWATER VEGETATION		
Cladophora sp.			
Filamentous algae	Entire	5.1	
Fontinalis sp.			
Moss	Entire	[illegible]	0.09
Ranunculus sp.			
Freshwater plant	Entire	12.2	[illegible]

TABLE 1 (Continued)

Species	Tissue	Wet/Dry Ratio	[illegible]
CRUSTACEA			
Amphipods & other crustaceans	Entire	7.27	2.80
[illegible]			
[illegible] sp. nymphs	Entire	3.75	0.57

---

a. Names are from "Common and Scientific Names of Fishes from the United States and Canada (Third Edition). 1970 American Fisheries Society Special Publ. 6.

b. Value calculated from [illegible] samples in 1977 is 8.1.

Table 2

[illegible] Radionuclides on Air Filters at Ground [illegible]
[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	—	—	—	—	—	—

a. [illegible]

b. [illegible]

Table 3

[illegible]-Emitting Radionuclides in the Freshwater Moss, [illegible]

[illegible]	[illegible]	Radionuclides [illegible]									
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	---	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	---
[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	---	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	---
[illegible]											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	---		---	---	[illegible]	[illegible]	---	---
Sept '77	1	---	3.6±2.1	---	1.1±0.4	---	---	---	1.0±0.2	[illegible]	---

3 (continued)

[illegible]

a [illegible] sample count of the [illegible] sample count is not [illegible]

b [illegible]

Table 4

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	---	---	---	---	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	---	---	---	---	---	[illegible]	[illegible]	---
[illegible]	[illegible]	---	[illegible]	---	---	---	---	---	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	---	---	[illegible]	---	---	[illegible]	---	---
[illegible]	[illegible]	---	[illegible]	---	[illegible]	---	---	---	[illegible]	[illegible]	---
[illegible]											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	---	---	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	---	[illegible]	---	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	---	---	---	---	[illegible]	[illegible]	[illegible]	---
[illegible]	[illegible]	---	[illegible]	---	[illegible]	---	[illegible]	---	[illegible]	[illegible]	---
[illegible]											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	---	---	---	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	---
[illegible]	[illegible]	---	[illegible]	---	[illegible]	---	---	---	[illegible]	[illegible]	---
[illegible]	[illegible]	---	[illegible]	---	---	---	[illegible]	---	[illegible]	[illegible]	---
[illegible]	[illegible]	[illegible]	[illegible]	---	---	---	---	---	[illegible]	[illegible]	---

[illegible]

[illegible] (Continued)

[illegible]

a. Tolerance limit values for a single sample (n = 1) are a single [illegible] figures in this table [illegible] are included in the analyses.

b. [illegible]

Table 5

[illegible]

Table 6

[illegible] Radionuclides in Lichens Collected at [illegible] Island

[illegible]

[illegible]

Table [illegible]

[illegible] in the Marine Algae [illegible]
[illegible] Island

[illegible]

[illegible] in the analyses.

[illegible]

Table 9

[illegible]

[illegible]	Tissue	n	[illegible]	[illegible]
[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]
[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
Second Day				
[illegible]	Muscle	[illegible]	[illegible]	[illegible]

a. Radionuclide values for a single sample (n = 1) are a single count of the sample ± [illegible] sigma, [illegible] counting error. The radionuclide value shown for more than one sample is the [illegible] [illegible]

Table 10

[illegible] Collected off [illegible]

Table [illegible] (Continued)

[illegible]

---

a. [illegible]

b. Number of samples [illegible] in all samples.

c. Nondetectable.

Table 11

[illegible] Potassium-40 and Cesium-137 in Muscle of Dolly Varden Collected at Amchitka [illegible]

[illegible] Date	Collection Location	n^b	Radionuclides, pCi/g [illegible]^a ^{40}K		[illegible]
[illegible]	Jones Lake	1/1	15 ± 0.5	0.[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	16 ± 1.0	[illegible].7	[illegible]
[illegible]	"	3/[illegible]	[illegible]6 ± 0.6	0.1	[illegible]
[illegible]	"	[illegible]	15 ± 1.7	0.[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	0.[illegible]	[illegible]
1976	Cannikin Lake	1/[illegible]	[illegible]	0.1	[illegible]
	[illegible]	1/[illegible]	15 ± 0.[illegible]	0.[illegible]	[illegible]
	Duck Cove	1/1	[illegible]	0.1	[illegible]
1977	Clevenger Lake Outlet	1/1	15 ± 2.5	0.[illegible]	[illegible]
	Jones Lake	1/[illegible]	12 ± 2.[illegible]	0.[illegible]	[illegible]
	Duck Cove	1/[illegible]	[illegible] ± 2.9	0.[illegible]	[illegible]

---

a. Radionuclide values for a single sample (n = 1) are a single count [illegible] the two-sigma propagated counting error [illegible] radionuclide values for more than one sample is the mean ± one standard deviation of the [illegible] single sample counts.

b. Number of samples/total number of [illegible] samples.

c. [illegible] Cannikin

d. [illegible] Lake, Bridge Creek, [illegible] Lake Outlet.

e. Jones Lake, Cannikin Lake, Duck Cove.

f. Jones Lake, Cannikin Lake, Bridge Creek, Duck Cove, Clevenger Creek.

Table 17

Potassium-40 and Cesium-137 in Land Plants[illegible]
[illegible] at Amchitka Island

[illegible] (pCi/g, [illegible])

[illegible]	Collection Site	[illegible]	Number of Plots	^{40}K	^{137}Cs
[illegible]	South Bight	Elymus	1	—	—
[illegible]	Cannikin	Mosses	1	13 ± 1.2	1.6 ± [illegible]
[illegible]	South Bight	[illegible]	2	1[illegible] ± 0.5	1.0 ± [illegible]
[illegible]	[illegible]	"	[illegible]	11 ± 1.6	0.76 ± [illegible]
[illegible]	[illegible]	"	[illegible]	1[illegible] ± 0.8	0.[illegible] ± [illegible]
May [illegible]	Cannikin	"	2	11 ± 1.2	0.67 ± [illegible]
Aug [illegible]	Cannikin	"	4	14 ± 1.5	0.90 ± [illegible]
Aug [illegible]	Cannikin	"	2	16 ± 2	3.6 ± [illegible]
[illegible]	Milrow [illegible]	"	2	11 ± 2	1.6 ± [illegible]
[illegible]	Milrow Area	"	2	[illegible]2 ± 2	1.6 ± [illegible]
[illegible]	Cannikin	"	2	12 ± 0.5	1.7 ± [illegible]
[illegible]	[illegible]/Long Shot	"	2	10 ± 4.1	0.[illegible]
[illegible]	Camp Area	"	[illegible]	10 ± 0.6	1.5 ± [illegible]
[illegible]	Milrow GZ	"	1	[illegible] ± 0.6	0.76 ± [illegible]
[illegible]	Cannikin	"	4	[illegible] ± 2.5	2.1 ± [illegible]
[illegible]	Long Shot	"	2	0.6[illegible] ± 1.0	0.57 ± [illegible]
[illegible]	Camp Area	"	5	[illegible] ± 2.3	0.66 ± [illegible]

a. [illegible] concentrations in samples collected from 1970 through 1977 are [illegible] [illegible] standard deviation of two or more single sample counts. [illegible] [illegible] collected from 1974 to 1977 are from a single count [illegible] [illegible] counting error. [illegible] [illegible] of the table indicate the sample counts were not significant.

b. [illegible]

c. [illegible] from [illegible] Lake, Cannikin, and Milrow [illegible] from [illegible] 5.

TABLE 13

[illegible] Bone and in Soil Samples Collected [illegible]

Collection Date	n[a]	Collection Location	Sample Type	pCi[b]	[illegible]
[illegible][d]	2	[illegible]	[illegible], Bone	1.6 ± [illegible]	
[illegible]	2	"	"	5.8 [illegible]	
[illegible]		"	"	1.9 [illegible]	
[illegible]		"	"	0.5 [illegible]	
[illegible]		"	"	<1.[illegible]	
197[illegible]	1	"	"	<0.[illegible]	
[illegible]	1	Other Sites[c]	[illegible], Bone	1.8 ± 0[illegible]	
197[illegible]	2	"	"	1.7 [illegible]	
[illegible]	2	"	"	1.4 [illegible]	
[illegible]	[illegible]	"	"	<1.[illegible]	
1977	[illegible]	"	"	0.[illegible]	
[illegible]	1	Cannikin Area	Ptarmigan, Bone	31 ± [illegible]	
[illegible]	1	"	"	1[illegible]	
[illegible]	1	"	"	1[illegible]	
[illegible]	[illegible]	"	"	17 ± 1.[illegible]	
[illegible][f]	1	Milrow/Long Shot	Ptarmigan, Bone	22 ± 1.[illegible]	
[illegible]	1	"	"	11 ± 0.7	
[illegible]	1	"		17 ± 1.2	
[illegible]	1	"	"	19 ± [illegible]	
[illegible]	[illegible]			15	1.[illegible]
[illegible]	2	Other Sites[c]	Ptarmigan, Bone	27 [illegible]	
[illegible]	[illegible]	"	"	14 [illegible]	
[illegible]	[illegible]			1[illegible] [illegible]	
[illegible]	1	"		19 [illegible]	
[illegible]	2	"	"	26 [illegible]	
[illegible]	1	"	"	15 [illegible]	
[illegible]	[illegible]	Rain Gage	Soil	0.03 [illegible]	
[illegible]	2	"		<0.[illegible]	
1977	1	"	"	<0.[illegible]	
[illegible]	[illegible]	Cannikin Zero	Soil	<0.[illegible]	
[illegible]	3	"	"	<0.[illegible]	
[illegible]	3	"	"	<0.[illegible]	

a. [illegible] 2 [illegible]

b. [illegible] values for [illegible] (4 [illegible]), collected before [illegible] of a [illegible] count of the sample [illegible], propagated, [illegible] figures for 197[illegible], 197[illegible], and 1977 [illegible] the [illegible] value for more than one sample is the mean [illegible] of these individual sample values. [illegible] 1976 and 1977 a [illegible] was made for [illegible] units and, in 1977, an additional [illegible] The maximum net effect of these [illegible] on sample values [illegible] of pCi [illegible] is about 0.5 for [illegible] (Sr), 0.3 for [illegible] (Pu) and [illegible] for soils ([illegible]).

c. [illegible]

d. Rain Gage, [illegible] Area, [illegible] Clevenger Creek ([illegible])

e. Rain Gage, [illegible] 12.

[illegible]le 14

[illegible]-Emitting Radionuclides in Sand and Soil Collected at [illegible] Island

Radionuclides, [illegible]

Type	Location	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]									
Soil	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]	---
Soil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	---
Sand	[illegible]	[illegible]	[illegible]	[illegible]	---	---	[illegible]	[illegible]	[illegible]
Sand	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]									
Soil	[illegible]	3	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]
Soil	[illegible]	3	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]
Sand	[illegible]	[illegible]	[illegible]	[illegible]	---	---	[illegible]	[illegible]	[illegible]
Sand	[illegible]	[illegible]	[illegible]	---	---	---	[illegible]	[illegible]	[illegible]
[illegible]									
Soil	[illegible]	[illegible]	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]
Soil	[illegible]	5	[illegible]	[illegible]	---	[illegible]	[illegible]	[illegible]	---
Sand	[illegible]	[illegible]	[illegible]	[illegible]	---	---	[illegible]	[illegible]	---
Sand	Sand Beach	1	[illegible]	---	---	---	[illegible]	[illegible]	---

[illegible] count of the sample [illegible]

[illegible] count is not significant.

Table [illegible]

Tritium Concentration in Water Samples Collected at Amchitka Island, 1970-1977

Collection Date	Collection Locality	Number of Samples	Tritium Units[a]	[illegible]
I. Seawater				
1970-71[c]	[illegible]	13	32 ± 19	[illegible]
1972	d	6	26 ± 25	[illegible]
1973	d	6	22 ± 12	[illegible]
1974	d	6	<10	[illegible]
1975	c	6	<10	[illegible]
1976	d	6	<15	[illegible]
September 1977	Constantine Harbor	1	<10	[illegible]
"	Square Bay	1	<15	[illegible]
"	Sand Beach Cove	1	<13	[illegible]
"	Duck Cove	1	13 ± 11	[illegible]
II. Freshwater, excepting Shot Areas				
1970-71[c]	d	17	92 ± 46	[illegible]
1972	c	62	49 ± 14	[illegible]
1973	d	46	50 ± 17	[illegible]
1974	c	24	32 ± 18	[illegible]
1975	d	29	24 ± 14	[illegible]
1976	d	50	30 ± 12	[illegible]
March 1977	Rain Gauge (rainfall)	2	34 ± 6	[illegible]
June "	"	2	<24	[illegible]
July "	"	2	34 ± 9	[illegible]
August "	"	2	46 ± 20	[illegible]
Sept. "	"	3	34 ± 9	[illegible]
May "	Clevenger Creek	1	17 ± 10	[illegible]
August "	"	1	22 ± 11	[illegible]
Sept. "	"	1	23 ± 11	[illegible]
May "	Bridge Creek	1	32 ± 21	[illegible]
August "	"	1	13 ± 11	[illegible]
Sept. "	"	1	41 ± 11	[illegible]
September 1977	[illegible] Spring	1	13 ± 12	[illegible]
"	[illegible] Lake	1	<10	[illegible]
"	Jones Lake Outlet	1	13 ± 11	[illegible]
"	Clevenger Lake Outlet	1	21 ± 12	[illegible]

Table 10 (Continued)

Collection Date	Collection Location	Number of Samples	Tritium Content[a]	[illegible]
II. Freshwater (cont.)				
September 1977	[illegible] Lake	1	16 ± 12	[illegible]
"	[illegible] Lake	1	35 ± 11	[illegible]
"	Duck Cove Creek (Mouth)	1	28 ± 11	[illegible]
"	[illegible]	1	20 ± 11	[illegible]
"	[illegible] Creek (at road)		31 ± 11	[illegible]
"	[illegible] Creek	1	25 ± 11	[illegible]
"	Cannikin Lake Inlet [illegible]		14 ± 11	[illegible]
"	Cannikin Lake Inlet near Drill [illegible]	1	47 ± 17	[illegible]
"	Cannikin Lake Middle [illegible]	1	20 ± 1[illegible]	[illegible]
"	Cannikin Lake Station #1 Surface	1	<15	
"	Cannikin Lake Station #1 Bottom		<15	[illegible]
"	Cannikin Lake Station #2 Surface		46 ± 12	[illegible]
"	Cannikin Lake Station #2 Bottom	1	27 ± 12	[illegible]
"	Cannikin Lake Station #3 Surface	1	36 ± 12	[illegible]
"	Cannikin Lake Station #3 Bottom		31 ± 12	[illegible]
"	Cannikin Lake Station #4 Surface		18 ± 12	[illegible]
"	Cannikin Lake Station #4 Bottom	1	20 ± 12	[illegible]
"	Cannikin Lake Outlet	2	20 ± 10	[illegible]
"	Ice Box Lake Inlet[c]		25 ± 11	[illegible]
"	Ice Box Lake Outlet[c]	1	<14	
"	DK 45 [illegible]	1	27 ± 11	[illegible]
	[illegible] Sand Beach Cove	2	32 ± 8	
III. Long Shot Mud Pits				
1970-1972[d]	Mud Pit #3	3	[illegible]000 ± 400	[illegible]
1973	"	4	2000 ± 400	[illegible]
1975	"	1	357 ± 15	[illegible]

Table 15 (Continued)

Collection Date	Collection Location	Number of Samples	[illegible]	[illegible]	[illegible]
III. Long Shot Mud Pits (cont.)					
1976	Mud Pit #3	1	1150 ± 28	[illegible]	[illegible]
1977	"	1	95[illegible] ± 2[illegible]	[illegible]	[illegible]
1976	Mud Pit #[illegible]	1	1140 ± 22	[illegible]	[illegible]
1977	"	1	751 ± 26	[illegible]	[illegible]
197[illegible]-71	Mud Pit #4	3	1000 ±150	[illegible]	
197[illegible]	"	4	2[illegible] ±240	[illegible]	[illegible]
1973	"	2	1950 ±420	[illegible]	
[illegible]	"	2	1360 ±240	[illegible]	
1975	"	1	192 ± 11	[illegible]	[illegible]
1976	"	2	726 ± 12	[illegible]	[illegible]
1977	"	2	681 ± 27	[illegible]	[illegible]
IV. Long Shot Mud Pit Drainage					
August 1975	3 meters below Mud Pit #[illegible]	1	872 ± 19	[illegible]	[illegible]
"	Infinity Road	1	666 ± 16	[illegible]	
"	100 meters below road	1	424 ± 15	[illegible]	[illegible]
"	500 meters below road	1	89 ± 1[illegible]	[illegible]	[illegible]
	200 meters above Sq. Bay	1	120 ± [illegible]	[illegible]	[illegible]
"	Mouth of creek	1	197 ± 13	[illegible]	
August 1976	3 meters below Mud Pit #4	1	739 ± 18	[illegible]	
"	Infinity Road	1	392 ± 14	[illegible]	
"	100 meters below road	1	278 ± 14	[illegible]	
"	200 meters below road[illegible]	1	25[illegible] ± 13	[illegible]	
"	400 meters below road[illegible]	1	103 ± 12	[illegible]	[illegible]
"	500 meters below road	1	53 ± 11	[illegible]	
"	200 meters above Sq. Bay	1	48 ± 11	[illegible]	[illegible]
"	20 meters above Sq. Bay	1	27 ± 11	[illegible]	
September 1977	Infinity Road	1	455 ± 16	14	[illegible]
"	100 meters below road	1	148 ± 5	[illegible]	[illegible]
"	200 meters below road	1	84 ± 12	[illegible]	
"	300 meters below road[illegible]	1	57 ± 12	[illegible]	

[illegible] (Continued)

Collection Date	Collection Location	Number of Samples	[illegible]	[illegible]
1. [illegible] (Cont.)				
October 1982	[illegible]	1	41 [illegible]	[illegible]
	[illegible]	1	[illegible]	[illegible]

a. Radiochemical values for single samples (n = 1) [illegible] mean of [illegible] [illegible] individual sample values.

b. One [illegible] equals [illegible].

c. Pre-Construction.

d. Mouth of [illegible].

e. A small lake formed in the north fork of [illegible] Creek after [illegible] at the [illegible] site.

f. Downstream of [illegible] site.

Table 17

Tritium in Free Water from Biological Samples Collected at Amchitka Island

[illegible] Type	Tissue	Collection Location	Collection Date	n	[illegible]		
[illegible]	Edible	Constantine Harbor	Aug '75	2	35±18	[illegible]	[illegible]
	"	"	Aug '76	1	38±11	[illegible]	[illegible]
	"	"	Sept '77	1	27±10	[illegible]	[illegible]
	"	[illegible] Bay	Aug '75	3	26±12	[illegible]	[illegible]
	"	"	Aug '76	2	25±[illegible]		[illegible]
	"	"	Sept '77	1	33±11		[illegible]
	"	Sand Beach Cove	Aug '75	[illegible]	27±[illegible]		[illegible]
	"	"	Aug '76	3	32±14		[illegible]
	"	"	Sept '77	[illegible]	28±11		[illegible]
	"	Duck Cove	Aug '76	3	35±13		[illegible]
	"	"	Sept '77	2	±13		
[illegible]	Muscle	Constantine Harbor	May '74	2	48±14		[illegible]
	"	"	Aug '75	1	±16	[illegible]	
	"	"	Aug '76	1	±21		
	"	"	Sept '77	2	±13		
	"	[illegible] Bay	Aug '75	4	±17		[illegible]
	"	"	Aug '76	1	±19	[illegible]	
	"	"	Sept '77	1	17±10	[illegible]	[illegible]
	"	Sand Beach Cove	May '74	3	94±30	[illegible]	[illegible]
	"	"	Aug '75	2	29±[illegible]	[illegible]	[illegible]
	"	"	Aug '76	3	29±7		[illegible]
	"	"	Sept '77	1	±12		
	"	Duck Cove	Aug '75	1	±15		
	"	"	Sept '77	1	±13		
[illegible] Varden	Muscle	Ice Box Lake	[illegible] '7[illegible]	3	65±9		
	"	White Alice Creek	Aug '7[illegible]	2	167±52		
	"	Bridge Creek	Aug '73	4	63±13		
	"	"	Aug '75	2	16±7		
	"	Duck Cove	Aug '76	2	42±9		
	"	"	Sept '77	1	±11		
	"	Jones Lake	May '74	3	62±14		
	"	"	Aug '75	4	[illegible]±16		
	"	"	Aug '76	1	58±13		
	"	"	Sept '77	1	[illegible]		
	"	Cannikin Lake	Aug '75	1	[illegible]		
	"	"	Aug '76	1	77±17		
[illegible]	Entire	Duck Cove Creek	Aug '73	[illegible]	68±15		
	"	White Alice Creek	Aug '73	2	89±28		
	"	Bridge Creek	Aug '73	2	67		
	"	Long Shot Pond[d]	Aug '76	1	120±17		
[illegible]	Entire	Clevenger Creek[c]	Aug '75	2	105±18		
	"	"	Sept '77	1	27±16		
	"	" [c]	Aug '75	2	97±14		
	"	White Alice Creek[c]	Aug '75	2	58±28		
	"	"	Aug '76	1	72±17		
	"	"	Sept '77	1	74±13		

Table 17 (Continued)

[illegible]	River	Collection Location	Collection Date	n[a]	Tritium [illegible]	±	[illegible][b]
[illegible]	[illegible]	[illegible]	Aug '76	2	[illegible]	[illegible]	[illegible]
	"	" [illegible]	Sept '77	1	36.[illegible]	[illegible]	[illegible]
	"	" [illegible]	Aug '76	2	56.[illegible]	[illegible]	[illegible]
	"	"	Sept '77	1	[illegible]	[illegible]	36
	"	[illegible]	Aug '76	1	[illegible]		
		"	Sept '77	1	47.[illegible]	[illegible]	[illegible]
	"	[illegible]	Aug '76	1	3[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]
	"		Sept '77	1	60.[illegible]	[illegible]	[illegible]
	"	Long Shot Creek [illegible]	Aug '76	2	36.[illegible]	[illegible]	[illegible]
	"	[illegible]	Sept '77		[illegible]	[illegible]	[illegible]
	"	[illegible]	Aug '76	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	Sept '77	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Camp Area	Aug '76	2	[illegible].21	[illegible]	
	"		Sept '77	[illegible]	21.10	[illegible]	32
	"	[illegible], Long Shot	Aug '76	2	60.17	[illegible]	[illegible]
	"		Sept '77	2	36.[illegible]	[illegible]	[illegible]
	"	[illegible] Area	Aug '76	[illegible]	36.[illegible]	[illegible]	[illegible]

---

a. n equals the number of free water samples used in a single tritium analysis.

b. [illegible] values for single samples [illegible] a [illegible] of [illegible] for the [illegible] one sigma, [illegible] counting error. The [illegible] value shown for [illegible] equal to the [illegible] of these individual sample values.

c. [illegible]

d. [illegible] meters below Industry Road.

e. [illegible] meters upstream from [illegible].

f. [illegible] meters upstream from [illegible].

Table 13

[illegible] Concentrations [illegible]
[illegible] Found in [illegible], Texas, [illegible]

Sample Type	Collection Location	August 1977		January 1978		September 1978	
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tank Liquid	[illegible]	0.001 ± 0.002	[illegible]	0.008 ± 0.003	[illegible]	[illegible]	[illegible]
Tank Liquid	Concentrating Tank	0.002 ± 0.002	[illegible]	<0.002	<0.2	[illegible]	[illegible]
Tank Liquid	[illegible]	ns	-	[illegible]	[illegible]	[illegible]	[illegible]
Tank Liquid	[illegible]	ns	-		-	[illegible]	[illegible]
[illegible]	Sand Batch Sump	<0.002	<0.1	<0.002	<0.2	[illegible]	[illegible]
[illegible]	Concentrating Tank	<0.002	<0.1	<0.002	<0.1	<0.002	<0.2
Soil Surface[b]	Sand Batch Sump	0.001 ± 0.002	-	<0.002	-	0.001 ± 0.002	-
Soil Surface	[illegible]	<0.002	-	0.002 ± 0.001	-	[illegible]	-
Soil Surface	[illegible]	[illegible]	-	0.002 ± 0.002	-	[illegible]	-
Soil Surface	[illegible]	ns	-	<0.002	-	0.003 ± 0.002	-
Soil Surface	[illegible]	ns	-	0.002 ± 0.001	-	[illegible]	-
Soil Surface	[illegible]	0.001 ± 0.002	-	<0.002	-	0.002 ± 0.002	-
Soil Surface	[illegible]	ns	-	0.003 ± 0.001	-	ns	
Soil Surface	[illegible] 13	ns	-	0.003 ± 0.001	-	ns	-

a. The analytical [illegible] for these samples [illegible] a sample [illegible] the sample [illegible]. Samples were analyzed for [illegible] and [illegible].

b. Surface samples were 0 to 2.5 cm deep.

Table 19

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	<0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<0.01	<0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<0.01	<0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<0.01	<0.01	0.01	0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	<0.01	0.01	0.01	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.01	<0.01	[illegible]	0.01	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

6. REFERENCES

[illegible], A. G. and G. A. [illegible] 1971. "[illegible] Tritium [illegible]." In The Physics of [illegible] Health Physics, [illegible]

[illegible], R. G. 1972. [illegible] of Tritium Through the Hydrosphere [illegible] In Tritium, A. A. Moghissi and M. W. Carter (Eds.). Messenger Graphics, Phoenix, Ariz.

[illegible], [illegible] and [illegible] 1973. Environmental [illegible] Studies, [illegible] In Tritium, A. A. Moghissi and M. W. Carter (Eds.). Messenger Graphics, Phoenix, Arizona.

Feinendegen, L. E. 1967. Tritium-Labeled Molecules in Biology and Medicine. Academic Press, New York.

[illegible], [illegible] and [illegible] 1973. Collection of Arctic Animals Near Experimental Marine Food [illegible] p. 253-[illegible] In Tritium, A. A. Moghissi and M. W. Carter (Eds.). Messenger Graphics, Phoenix, Ariz.

Held, E. E. 1971. Amchitka Radiobiological Program Progress Report, July 1970 to April 1971. NVO-269-11. University of Washington, College of Fisheries, Laboratory of Radiation Ecology. 36 p.

Held, E. E. 1972. Amchitka Radiobiological Program Progress Report, March 1971 to February 1972. NVO-269-17. University of Washington, College of Fisheries, Laboratory of Radiation Ecology. 30 p.

Held, E. E., V. A. Nelson, W. R. Schell, and A. H. Seymour. 1973. Amchitka Radiobiological Program Progress Report, March 1972 to December 1972. NVO-269-19. University of Washington, College of Fisheries, Laboratory of Radiation Ecology. [illegible] p.

International Atomic Energy Agency. 1971. Environmental Isotope Data No. 3: World Survey of Isotope Concentration in Precipitation (1966-1967). Technical Reports Series No. 129. IAEA, Vienna. 402 p.

International Commission on Radiological Protection. 1959. Recommendations of the International Commission on Radiological Protection (Adopted September 1958). ICRP Publication No. 1. Pergamon Press.

International Commission on Radiological Protection. 1964. Recommendations of the International Commission on Radiological Protection (as Amended 1959 and Revised 1962). ICRP Publication No. 6. Pergamon Press.

Merritt, M. L. and R. G. Fuller (Eds.) 1977. The Environment of Amchitka Island, Alaska. ERDA Book TID-26712.

National Committee on Radiation Protection. 1959. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure. National Bureau of Standards Handbook 69. 95 p.

Nelson, V. A. 1975. Groundwater and Lakes, Amchitka Island, Al[illegible] The [illegible] Final Report. University of Washington, College of Fish[illegible] Laboratory of Radiation Ecology. U. S. ERDA Report, NVO-269-26. [illegible]

Nelson, V. A. and A. H. Seymour. 1974. Amchitka Radiobiological Program Progress Report, January 1973 to December 1973. NVO-269-21. Univ. of Washington, College of Fisheries, Laboratory of Radiation Ecology. [illegible]

Nelson, V. A. and A. H. Seymour. 1975. Amchitka Radiobiological Program Progress Report, January 1974 to December 1974. NVO-269-23. Univ. of Washington, College of Fisheries, Laboratory of Radiation Ecology. [illegible]

Nelson, V. A. and A. H. Seymour. 1976a. [illegible] Radiological [illegible] Amchitka [illegible] University of Washington, College of Fis[illegible] Laboratory of Radiation Ecology. [illegible] p.

Nelson, V. A. and A. H. Seymour. 1976b. Amchitka Radiobiological Program Progress Report, January 1975 to December 1975. NVO-269-2[illegible]. Univ. of Washington, College of Fisheries, Laboratory of Radiation Ecology. [illegible] p.

Nelson, V. A. and A. H. Seymour. 1977. Amchitka Radiobiological Program Progress Report, January 1976 to December 1976. NVO-269-31. Univ. of Washington, College of Fisheries, Laboratory of Radiation Ecology. [illegible] p.

Noshkin, V. E., V. T. Bowen, K. M. Wong, and J. C. Burke. 1973. [illegible] in North Atlantic Ocean Organisms: Ecological Relationships. pp. [illegible] in Proc. Third National Symposium on Radioecology. D. J. Nelson (ed.). CONF-710501, p. 2. National Technical Information Service, Springfield, [illegible]

Robertson, D. S. 1976. [illegible] In [illegible] Hoffman, A. A. [illegible] and [illegible] (eds.). [illegible] Arizona.

Schell, W. R., G. Sauzay and B. R. Payne. 1974. World Distribution of [illegible] In Physical Behavior of Radioactive Contaminants in the [illegible] International Atomic Energy Agency, Vienna, Austria. IAEA-SM-181, [illegible] 375-400.

Seymour, A. H. and V. A. Nelson. 1977. Radionuclides in Air, Water [illegible] Biota. pp. 579-613 in "The Environment of Amchitka Island, Alaska." [illegible] Merritt and R. G. Fuller (eds.) USERDA TID-26712.

Stewart, G. L. and R. K. Farnsworth. 1968. United States Tritium [illegible] and its Hydrologic Implications. Water Resources Research 4 (2). [illegible]

Stewart, R. C., C. M. Rosenthal and J. R. Kline. 1973. [illegible] Tritium and Concentrations in [illegible] Ecosystems. pp. 466-[illegible] in D. J. Nelson (ed.) Radionuclides in Ecosystems. Proc. Third Nat. Symp. [illegible] May 10-12, 1971, Oak Ridge, Tenn. (CONF-710501).

[illegible], R. 1977. [illegible] of [illegible], Amchitka Radioactivity Concentrations [illegible], pp. II-39-II-66 in HASL Environmental Quarterly, Oct. 1, 1977. HASL-328.

[illegible], W. and W. C. Ballance. 1976. Radiohydrological Monitoring of Water after the Cannikin Event, Amchitka Island, Alaska, [illegible] 1975 to June 1976. U. S. Geological Survey Report, USGS-474-[illegible]. 15 p.

[illegible], W. and [illegible]. 1974. Radiochemical Monitoring of Water after the Cannikin Event, Amchitka Island, Alaska, July 1972. U. S. Geological Survey Report USGS-474-[illegible]. 13 p.

Toombs, G. 1975. Radiological Survey of the Columbia River in Oregon. Radiation Control Section, Oregon State Health Division, to be published.

United States Energy Research and Development Administration. 1977. Standards for Radiation Protection. ERDA Manual, Chapter 0524.

Wong, K. M., V. E. Noshkin and T. R. Folsom. 1972. Plutonium and Polonium Inside Giant Brown Algae. Nature, 237: 460-462.

Following is a list of previous Amchitka [illegible] reports.

Year	Report No.	Author
1970-71	NVO-269-11	[illegible] E.
1972	NVO-269-[illegible]	Held, E. E.
1972	NVO-269-19	Held, E. E., et al.
1973	NVO-269-[illegible]	Nelson, V. A., and A. H. Seymour
1974	NVO-269-23	Nelson, V. A., and A. H. Seymour
1975	NVO-269-27	Nelson, V. A., and A. H. Seymour
1976	NVO-269-[illegible]	Nelson, V. A., and A. H. Seymour

6. TABLE AND MAP [illegible]

Sampling Site	Figure No. (s)	Table No. (s)
[illegible] Runway	1	13
[illegible] Dump	2 & 3	2, 13, 19
[illegible]	1 & 7	9, 11
[illegible] Creek	4	3, 4, 11, 16, 17
[illegible] Lake [illegible] from [illegible]	6	16
[illegible] Lake	6	6, 11, 15, 16, 17
[illegible] Lake Outlet	6	3, 4, 16, 17
[illegible] Lake [illegible] from [illegible]	6	16
[illegible] Lake [illegible] from [illegible]	6	6, 16
[illegible] Site	1 & 6	12, 13, 14, 18, [illegible]
[illegible] Cove [illegible]	7	11
Cl[illegible]	4	6, 13, 16
Cl[illegible] Creek	4	3, 4, 11, 13, 16
Cl[illegible] Lake Outlet	3	7, 16
C[illegible] Harbor	2 & 3	7, 9, 10, [illegible], 14, [illegible], [illegible], 13
[illegible] Harbor	3	16
[illegible] Spring	3	15, 17
C[illegible] Point	2 & 4	7
D-[illegible]	2	19
[illegible]	3	19
D[illegible] Cove	3	7, 8, 10, 11, 12, 17
[illegible] Cove [illegible]	4	3, 4, 11, 16
[illegible] Cove [illegible]	4	16
E-[illegible]	2	19
E.C. [illegible]	3	19
[illegible] Lake	7	15, 16
[illegible] Dump	[illegible]	19
F[illegible]	6	None
F[illegible]	6	8
[illegible] Lake (Lake [illegible])	6	6, 16
[illegible] Lake Outlet	6	3, 16, 17
[illegible] Road	2 & 6	None
[illegible] Lake	3	13, 15, 16, 17, [illegible]
[illegible] Lake Outlet	3	16, 19
L[illegible]	6	11
L[illegible] Outlet	6	None
[illegible]	3	15, 16
L[illegible]	2, 7, & 5	5, 15, 16, 19
[illegible] Drainage	4 & 5	3, 4, 16, 17
[illegible] Dump	3	12, 13, 14, 18, [illegible]
[illegible] Cove	2	9
[illegible]	2	12, 13
[illegible]	2	12, 13
[illegible]	2 & 4	12, 19, 13, 17
[illegible] Creek	6	3, 16
[illegible] Creek	4	16
[illegible] Range Target Area	4	19
[illegible] Cove	6	7, 8, 10, 13, 15, [illegible]

[illegible] (Continued)

[illegible]	Figure No.(s)	Table No.(s)
[illegible]	9	16
[illegible]	2	5
[illegible] Lake	6	13
[illegible] Dock, [illegible] Harbor	3	None
[illegible]	2	12
[illegible]	1	16
[illegible] Bay	5	7, 8, 9, 10, 16, 17
[illegible] Creek	6	3, 4, 5, 16, 17

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[illegible], DOE/NV, Las Vegas, NV (2)
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[illegible], University of Arizona, Tucson, AZ

[illegible], Utah State University, Logan, UT

[illegible], University of Washington, Seattle, WA

[illegible], Ohio State University, Columbus, OH

[illegible], Battelle Columbus Laboratories, Columbus, OH

[illegible], Omaha, NE

[illegible], Las Vegas, NV

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[illegible], Division, NV (10)

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APPENDIX 2

RESULTS OF PLUTONIUM AND GAMMA SPECTRUM ANALYSES OF ENEWETAK PLANT, RAT AND SOIL SAMPLES COLLECTED IN MARCH 1976

UNIVERSITY OF WASHINGTON
LABORATORY OF RADIATION ECOLOGY

RESEARCH RESULTS

January 26, 1978
A. Nevissi

Principle Investigator: Dr. William [illegible]
Subject: Results of Plutonium and Gamma Spectrum Analyses of [illegible] Plant, Rat, and Soil Samples Collected in March, 1976

Rat, plant, and soil samples from [illegible] were sent to our laboratory by Dr. Jack [illegible] for gamma-counting and plutonium analysis. These samples had been [illegible], dried, and [illegible] by [illegible]'s group.

The soil samples were [illegible] in our [illegible] standard sample holders and counted for 400 minutes on a [illegible] detector system. The gamma-counting results for soil samples are given in Table 1. The quantity of the individual rat [illegible] samples was not sufficient to fill the standard sample holder. The samples were put in the standard sample holder in batches of [illegible] for gamma-counting. The results of analyses for gamma-emitting radionuclides in rat [illegible] samples are given in Table 2.

After gamma-counting, the samples [illegible] for plutonium analysis were spiked with [illegible] for chemical yield determination. The Laboratory's standard method was used for separation and purification of plutonium. Finally, plutonium was electroplated onto a stainless steel disc and measured with a surface barrier alpha-detector and pulse-height analyzer. The results of plutonium analysis are shown in Table [illegible].

cc: Seymour
Schell
Nevissi

Table [illegible]. Gamma-Emitting Radionuclides in Soil Samples Collected by Dr. William [illegible] at Enewetak in March, 1976. Values in pCi/g dry weight of sample.*

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	———	[illegible]	———	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	———	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	———	[illegible]	———	———	———
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	———	[illegible]	———	[illegible]	———	———	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	———	[illegible]	———	———	———
[illegible]	[illegible]	———	[illegible]	[illegible]	———	———	———	[illegible]	———	———	———
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	———	[illegible]	———	———	———	———	———
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	———	———	———	———	
[illegible]	[illegible]	[illegible]	———	———	———	[illegible]	———	———	———	———	———
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	———	———	———	———	———
[illegible]	[illegible]	[illegible]	[illegible]	———	———	[illegible]	———	———	———	———	———
[illegible]	[illegible]	[illegible]	[illegible]	———	———	———	———	———	———	———	———
[illegible]	[illegible]	———	0.7 ± 0.1	———	———	———	———	———	———	———	

---

* All counts are for single samples and the error term is the two sigma, propagated, counting errors; less than (<) values are blank. + The standard deviation divided by sample weight.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	± 1.7
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	± 3.3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	
[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	
[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	± 3.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	± 3.8
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

[illegible]

Table [illegible]. Plutonium-239,240 and Plutonium-238 in Rat, Plant, and Soil Samples Collected by Dr. [illegible] [illegible] of Enewetak in March 1972. Values in pCi/g Dry Weight of Sample.*

Sample	Sample Type	239,240Pu	238Pu
11	Rat Lung	[illegible] ± 0.03[illegible]	0.057 ± 0.023
12	Rat Bone	0.047 ± 0.016	0.043 ± 0.012
13	Rat Liver	[illegible] ± 0.007	0.024 ± 0.005
14	Rat Skin	[illegible] ± 0.06	0.37 ± 0.03
15	Rat Muscle	0.084 ± [illegible]	0.049 ± 0.020
16	Rat Lung	<0.00[illegible]	<0.007
17	Rat Bone	[illegible] ± 0.03	0.06 ± [illegible]
18	Rat Liver	[illegible] ± 0.006	0.012 ± 0.004
19	Rat Skin	[illegible] ± 0.28	0.51 ± 0.13
20	Rat Muscle	[illegible] ± 0.017	0.051 ± 0.010
22	Rat Bone	[illegible] ± 0.07	0.052 ± 0.011
23	Rat Liver	[illegible] ± 0.006	0.015 ± 0.003
24	Rat Skin	[illegible] ± [illegible]	0.75 ± 0.07
25	Rat Muscle	[illegible] ± [illegible]	0.032 ± 0.009
26	Rat Lung	<0.01[illegible]	<0.014
27	Rat Bone	0.0067	<0.0028
28	Rat Liver	[illegible] ± 0.003	0.001
29	Rat Skin	[illegible] ± 0.06	0.06 ± [illegible]
30	Rat Muscle	<0.0[illegible]	0.34 ± [illegible]
31	Rat Lung	[illegible] ± [illegible]	<0.005
32	Rat Bone	<0.003	<0.004
33	Rat Liver	[illegible]	<0.001
35	Rat Muscle	[illegible]	<0.003
36	Rat Lung	<0.00[illegible]	0.009
37	Rat Bone	<0.00[illegible]	0.005 ± [illegible]
38	Rat Liver	[illegible] ± 0.003	0.003 ± [illegible]
39	Rat Skin	[illegible] ± [illegible]	0.02 ± [illegible]
40	Rat Muscle	<0.00[illegible]	<0.002
41	Rat Lung	[illegible] ± [illegible]	0.03 ± [illegible]
SC-1	Scaevola Berries	[illegible] ± [illegible]	0.337 ± [illegible]
SC-2	"	[illegible] ± 0.07	0.29 ± [illegible]
SC-3	"	[illegible] ± [illegible]	0.04 ± [illegible]
SC-4	"	<0.00[illegible]	0.03 ± [illegible]
SC-5	"	[illegible] ± [illegible]	0.47 ± [illegible]
SC-6	"	[illegible]	0.21 ± [illegible]

Table 3. Continued

Sample#	Sample type	[illegible]	[illegible]
DS-1	Soil 0 m from crater	216 ± 27.7	134 ± 14.0
DS-2	Soil "	136 ± [illegible]	74.1 ± 8.8
DS-3	Soil "	130 ± 1.7	71.4 ± 6.46
DS-4	Soil 200m from crater	5.38 ± 0.28	0.77 ± [illegible]
DS-5	Soil "	4.08 ± 0.37	2.89 ± 0.2[illegible]
DS-6	Soil "	7.66 ± 0.34	3.84 ± 0.29

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* All counts are for a single sample and the error term is the one sigma, propagated counting error; less than (<) values are blank values and one standard deviation divided by sample weight.

APPENDIX 3

RADIOLOGICAL SURVEY OF PLANTS, ANIMALS AND SOIL IN MICRONESIA

NOVEMBER 1975

by

Victor A. Nelson

APPENDIX 3

NVO-269-35

RADIOLOGICAL SURVEY OF PLANTS, ANIMALS, AND SOIL IN MICRONESIA, NOVEMBER 1975

by

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28 April 1976

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INTRODUCTION

From 1946 to 1958 atomic devices were detonated under water, over water, on land or in the atmosphere over the water of the central Pacific. Most of these tests took place at Bikini and Enewetak atolls in the Marshall Islands and some at Johnston, Christmas and Malden Islands further east. The distribution of radionuclides produced by these tests has been studied extensively, especially at Bikini and Enewetak atolls. The present study is part of a Laboratory of Radiation Ecology program begun in 1974 and described in a previous report (Nelson, 1977). The purpose of this study was to determine qualitatively and quantitatively radionuclides presently found in certain foods and soils in areas of Micronesia other than those areas receiving local fallout during the test periods. Areas sampled were Majuro Atoll in the Marshall Islands, Truk and Ponape in the Caroline Islands, Guam in the Mariana Islands and Koror and Babelthuap in the Palau Islands. Data on samples collected in these areas will provide a comparison with the amounts and kinds of radionuclides found in similar samples from Bikini and Enewetak atolls.

SAMPLING PROGRAM

The areas mentioned above were visited in November 1975. In Figure 1 these areas are shown in relationship to the test sites at Bikini and Enewetak atolls, while in Figures 2 and 3 the collection sites within these areas are shown. The trip was a joint survey with personnel from Brookhaven National Laboratory (BNL) who took radiation survey readings with sodium iodide (Tl) scintillation detectors and a pressurized ion chamber. The results of the survey readings will be given in a separate BNL report. Personnel from

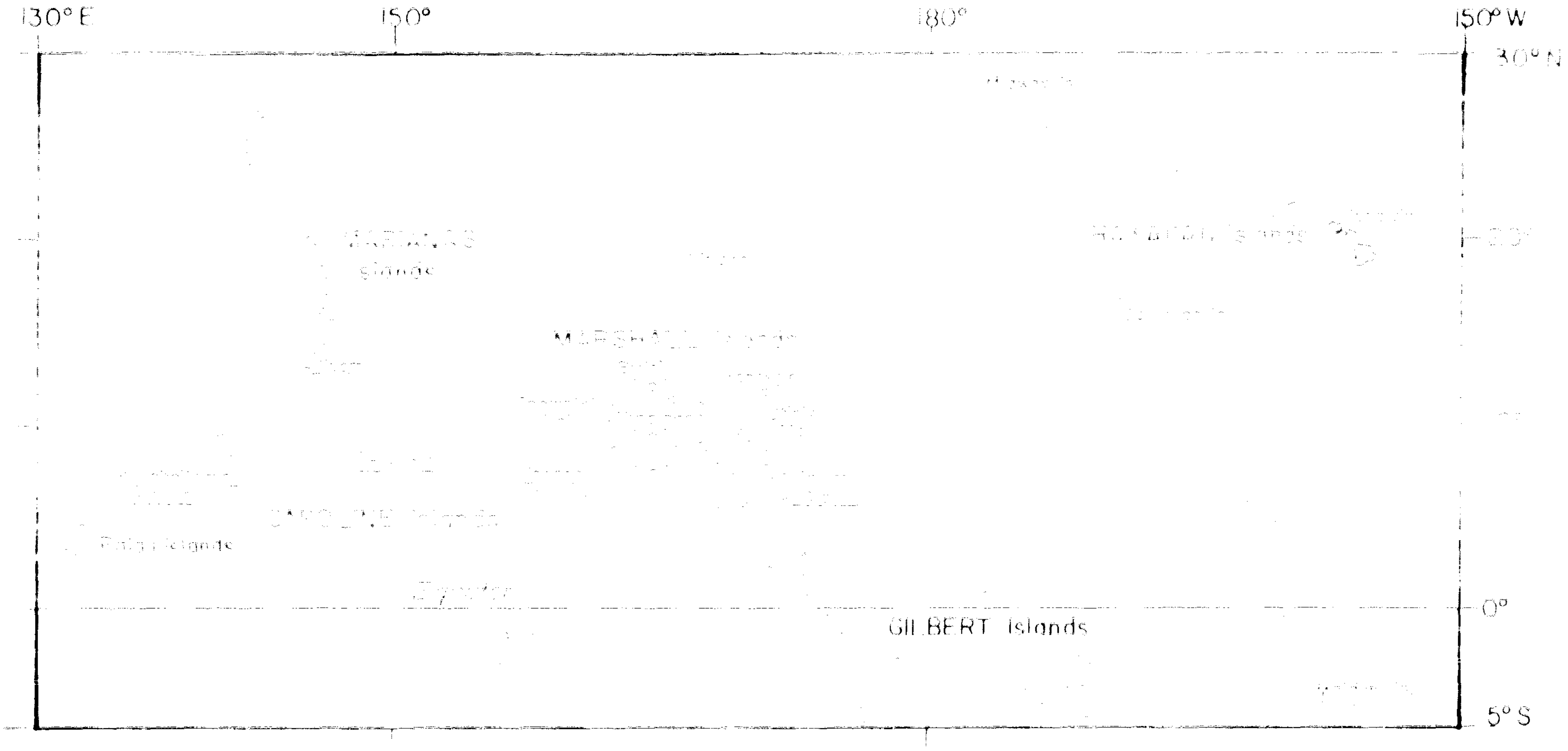

Figure 1. Sampling locations (underlined) in Micronesia, November 1976.

Figure 2. Locations sampled at Ponape, Truk, Guam and Palau in [illegible]

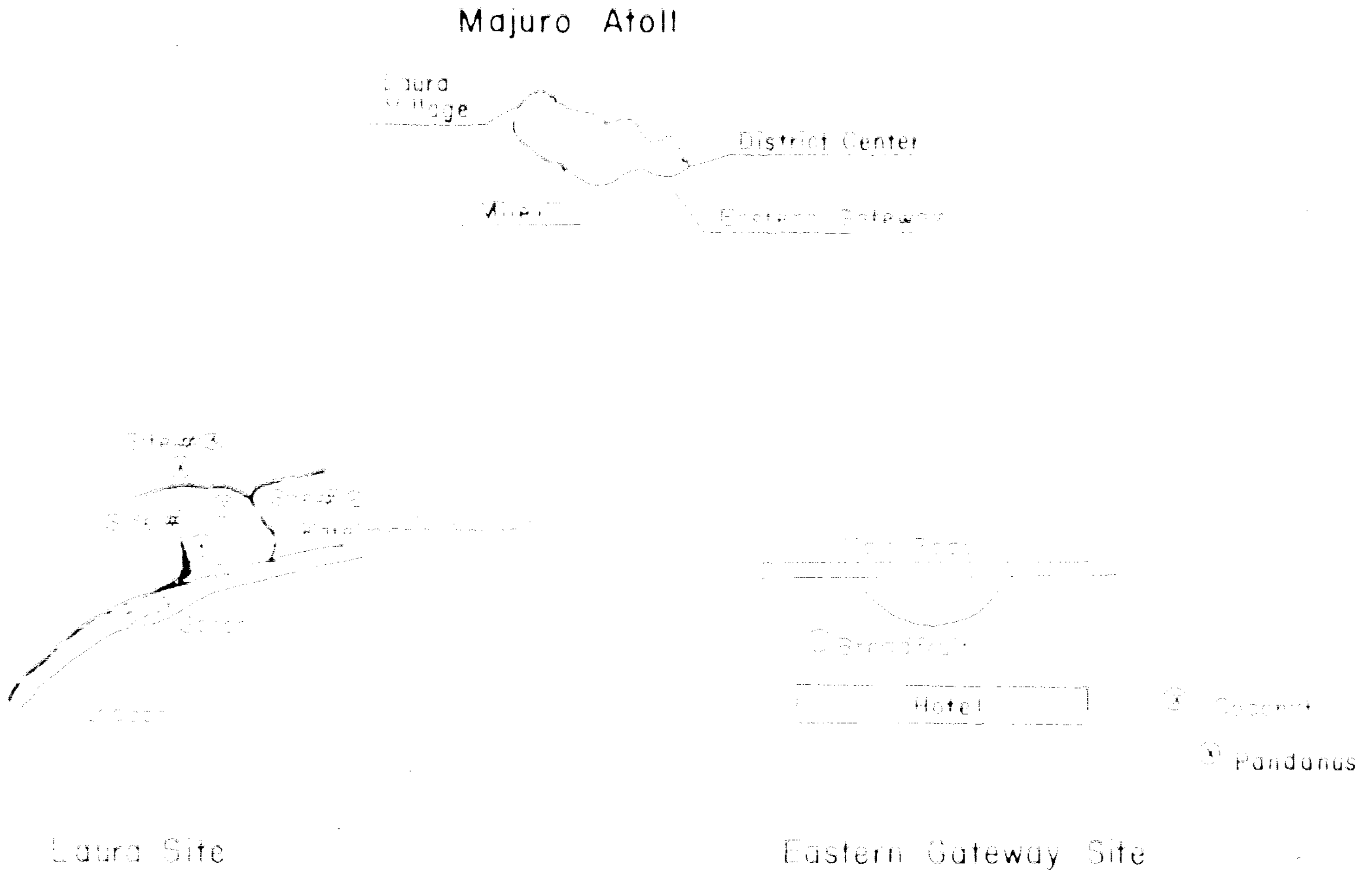

Figure 3. Locations sampled at Majuro Atoll in November 1975.

Laboratory collected representative biological and soil samples with emphasis on food items common to the diet of the Marshallese people (i.e., fish, coconut, pandanus, breadfruit, coconut crabs, etc.) although nonedible portions of these items were also collected and analyzed. Soils were collected to provide data for estimation of future distribution and quantities of radionuclides in the environment and biota.

The number of samples, after division into tissues or soil fractions, is shown in Table 1. Seventy percent of the samples were biological - plants, fish, and animals (rats) - and thirty percent were soils - surface (0-2.5cm) and profile (0-100cm). Approximately equal numbers of samples came from each of five major collection areas.

ANALYTICAL METHODS

Gamma-Ray Spectrometry

All of the samples were analyzed by gamma-ray spectrometry either with a 9" X 5" sodium iodide (thallium-drifted) crystal and 200-channel pulse-height analyzer or with a germanium (lithium-drifted) diode detector and 4,096-channel, pulse-height analyzer. Soil samples were analyzed on the Ge(Li) system, and the biological samples were analyzed on both systems.

All samples were oven dried, ground and a portion compressed into sample holders of polyvinyl chloride (PVC) pipe 2 inches in diameter and either 1/2 or 1 inch for radionuclide measurement. Fifty grams of tissue or 80 grams of soil could be compressed into the 2" X 1" holder. The densities of the biological and soil samples were 1.0 and 1.25, respectively. These samples were then analyzed for gamma-emitting radionuclides.

The gamma-emitting radionuclides in the samples counted on the NaI crystal were determined by a method of least squares. The radionuclide values for samples counted on the Ge(Li) detector were calculated either manually or with

Table I. Disposition of Samples Collected on the November 1974 Trip to Micronesia.

Sampling Location	Samples Processed[a]			Samples Analyzed		
	Foods	Soil	Fish	γ	^{90}Sr	$^{239,240}Pu$
Majuro	29	12	8	47	26	18
Ponape	22	13	14	50	30	17
Truk	31	14	1	46	14	12
Guam	12	13	5	79	16	7
Palau[b]	25	15	3	43	23	13
Total	119	67	31	265	109	67

a. The number given is the total after the samples have been divided into tissues or fractions of soft organs.

b. Three coconut crabs were also collected on an island south of Koror. The muscle, hepatopancreas, and exoskeletons from these crabs were ashed and analyzed for gamma-emitting radionuclides plus ^{90}Sr and $^{239,240}Pu$.

calculated by adding the counts in an energy range of five channels around a peak in the spectrum, subtracting the appropriate background counts, and applying correction factors to convert counts to picocuries (pCi). A set of previously recorded reference spectra for the type of sample holder and radionuclide was used. All values were corrected for decay to the date of collection.

Strontium-90 and Plutonium Analyses

To measure ^{90}Sr content, ^{90}Y was chemically separated from ^{90}Sr, collected on filter paper and counted with a low-level beta counting system. Plutonium was extracted by ion exchange, electroplated on platinum discs, and measured by alpha spectrometry with systems using surface barrier alpha detectors and pulse-height analyzers. Chemical yield was determined by use of [illegible]Pu tracer).

Error Limits

For a single sample, the errors given for all radionuclides listed are two-sigma, propagated, counting errors. The error term for the mean of more than one sample is one standard deviation and disregards counting errors.

Limits of Detection

Many factors influence the limit of detection, including the type of detector and analyzer, the presence of other radionuclides, the duration of the counting period, the size and density of the sample, and the geometric relationship of the sample and detector. Hence, the limits of detection varied considerably for various radionuclides and types of samples, but can be summarized by stating that detection limits were approximately as follows:

By gamma detection

^{40}K	2.1 pCi/g or less
^{238}U	0.41
^{110m}Ag, ^{125}Sb, ^{137}Cs, ^{207}Bi, ^{155}Eu, ^{241}Am, ^{228}Th	0.12 pCi/g or less

By beta detection

^{90}Sr	0.2 pCi/g or less

By alpha detection

$^{239+240}$Pu	0.02 pCi/g or less

RESULTS AND DISCUSSION

Data are presented in Appendix Tables 1 through 11 for the results of the analyses of the samples collected by us in Micronesia in 1975. All values are given as picocuries per gram of dry weight (pCi/g, dry), except where specifically noted. Table 2 gives the mean wet weight to dry weight ratios of the biological samples. Thus the pCi/g, dry values may be converted to pCi/g, wet for purposes of computing dietary intake of the measured radionuclides. Since there are greater differences in the radioactivity values between sample types than area of collection, other than soil, the results will be discussed by sample type.

Fish

Seven species of fish were collected from one or more of the five districts. Goatfish, mullet and surgeonfish were the most common fish available and were collected at three sites each. As shown in Appendix Table 1, naturally occurring ^{40}K was the only radionuclide measured in fish tissues at a concentration greater than 0.6 pCi/g, dry and the average value was 4.6 pCi/g, dry tissue. Cesium-137 was detected in only 6 of 31 samples. The maximum concentration of ^{137}Cs measured was 0.19 pCi/g, dry in the viscera of [illegible] from Ponape. Strontium-90 was detected in 1 of 15 tissue samples analyzed.

Table 2. Mean Wet and Wet Weight to Dry Weight Ratios of Some Micronesian Organisms

Species	Number of Samples	Part	Mean Wet/Dry Ratio	Deviation
		FISH		
Mullet	(4)	Eviscerated Whole	3.[illegible]	± .[illegible]
"	(4)	Viscera	4.66	± .[illegible]
"	(1)	Entire	[illegible].56	
Parrotfish	(2)	Muscle	4.30	± .1[illegible]
"	(2)	Viscera	4.95	± .[illegible]7
"	(2)	Residue	3.65	± .1[illegible]
Goatfish	(6)	Eviscerated Whole	3.[illegible]7	± .1[illegible]
"	([illegible])	Viscera	4.[illegible]	± .[illegible]
Snapper	([illegible])	Viscera	6.25	
"	(1)	Eviscerated Whole	3.76	
Flagtail	(1)	Viscera	3.72	
"	(1)	Eviscerated Whole	3.09	
Convict surgeon	(1)	Viscera	[illegible].94	
" "	(1)	Eviscerated Whole	3.50	
Jack	(1)	Entire	3.92	
		PLANTS		
Breadfruit	(12)	Edible	6.12	± 1.17
"	(12)	Inedible	6.24	± 1.1[illegible]
	(13)	Leaves	4.28	± .62
Pandanus	(12)	Edible	7.28	± 1.13
	(13)	Inedible	4.22	± .[illegible]
	(36)	Leaves	3.56	± .37
Coconut	(11)	Meat	2.60	± .37
	(3)	Leaves	2.27	± .2[illegible]
"	(7)	Copra	1.12	± .[illegible]
Taro	(5)	Edible	2.71	± .5[illegible]
"	(2)	Leaves	7.90	± .2[illegible]
"	(2)	Stem	14.70	± 1.5[illegible]
Papaya	(7)	Edible	12.19	± 3.[illegible]
"	(7)	Inedible	10.49	± 2.14
"	(7)	Seeds	4.5[illegible]	± 1.3[illegible]
Cassava	(1)	Root	2.18	
Banana	(1)	Edible	4.07	

Table 2 (continued)

Species	Number of Samples	Tissue	Mean Wet/Dry Ratio	Deviation
		INVERTEBRATES		
Coconut crab	(1)	Exoskeleton	1.53	
" "	(1)	Hepatopancreas	2.86	
" "	(1)	Muscle	4.51	

while ^{239,240}Pu was not above the limits of detection in any of the other samples analyzed.

The amount of ^{137}Cs in these fish was less than the amount present (Nelson, 1977) in fish from Utirik, Rongelap, and Ailinginae atolls in the northern Marshall Islands which have low radiation levels, but which did receive some local fallout during the testing at Bikini and Enewetak atolls. The amount of ^{137}Cs in the few (6 of 25) fish samples which contained ^{137}Cs in quantities greater than our limits of detection was similar to ^{137}Cs concentrations in fish from Amchitka Island in the Aleutians (Nelson and Seymour, 1977), and in fish collected from Japanese coastal waters in 1973 and 1975 (NIRS, 1976).

The concentrations of ^{90}Sr and ^{239,240}Pu are less than or near the limits of detection in fish samples from the three atolls noted above and in the fish samples analyzed for this report.

Coconut Crabs

Three coconut crabs from Palau were dissected and the tissues pooled for analysis. Results of these analyses are shown below in pCi/g, dry.

Tissue	^{40}K	^{60}Co	^{137}Cs	^{90}Sr	^{239,240}Pu
Exoskeleton	17.0 ± [illegible]	2.2 ± 0.86	1.5 ± 0.09	1.7 ± [illegible]	[illegible]
Hepatopancreas	NS^{a}	NS	0.17 ± 0.09	<0.25	[illegible]
Muscle	[illegible]	NS	0.20 ± 0.09	<0.23	[illegible]

a. NS = not significant

The values for ^{90}Sr and ^{137}Cs in these crabs are less by a factor of [illegible] than amounts in coconut crabs from Rongelap and Ailinginae atolls and are similar to amounts found in crabs from Kwajalein Atoll, which did not receive any appreciable local fallout from the testing at the Pacific Test Sites.

Plants

Four species of plants, pandanus, coconut, breadfruit and papaya, were collected from one to three sites within each of the five major collection locations. In addition bananas, taro and cassava were collected at some sites. Results of the analysis of these samples are given in Appendix Tables 2 through 6.

Naturally occurring ^{40}K was the most abundant radionuclide measured in the plant samples. Of the fallout radionuclides only ^{137}Cs was detected in more than 50 percent of the samples. Most values of ^{137}Cs were less than 1 pCi/g, but a value of 48 pCi/g was measured in the edible portion of a pandanus fruit from Guam. The inedible portion of this fruit also had a high ^{137}Cs value, 16 pCi/g. If these high unexplained values of ^{137}Cs are excluded, the ^{137}Cs values in plants from Guam are similar to values in plants from Palau and Truk where the lowest values were measured. Ponape had slightly higher amounts of ^{137}Cs in the plants, while plants from Majuro had the highest average amount of ^{137}Cs. About 50 percent of the ^{137}Cs values in the plants from Majuro were above 1 pCi/g. Strontium-90 values in plants followed a similar pattern, while $^{239,240}Pu$ values were above the limits of detection in one sample of copra from Majuro and in two samples of breadfruit from Ponape.

The values for ^{137}Cs and ^{90}Sr in plants from Guam, Palau, Ponape, and Truk were less than values for the same plants from the Marshall Islands ([illegible] et al., 1977) but were similar to values found in food plants from Japan (NIRS, 1976) and Washington State (Nelson and Seymour, 1975).

Soil

Surface (0-5 cm) soil samples and shallow soil profiles were collected from several sites in each district. Results of the analysis of these samples are presented in Appendix Tables 7 through [illegible]. Soil from the atolls [illegible], Majuro, generally contained small (< 1 pCi/g) amounts of ^{90}Sr, ^{137}Cs, [illegible] and ^{239,240}Pu, as did soils from the volcanic islands of Ponape, Truk, [illegible], and Palau. In addition to these radionuclides, these contained naturally occurring isotopes of radium and thorium. The soil from Guam also contained ^{40}K and ^{238}U in addition to ^{137}Cs, ^{226}Ra, ^{232}Th, and ^{239,240}Pu (no [illegible] for ^{90}Sr were made on the soils from Guam). No major differences in the amount of ^{137}Cs, ^{90}Sr or ^{239,240}Pu found in the soil samples were noted [illegible] the five districts.

Soil from the northern stations on Guam had much higher values of [illegible], ^{226}Ra, ^{232}Th and ^{238}U than did the soil samples from the other stations [illegible] or from the other districts. For instance, the ^{226}Ra values from the [illegible] sites were two orders of magnitude higher than ^{226}Ra from other districts [illegible] the ^{232}Th values were one order of magnitude higher. Also ^{40}K and ^{238}U were not detected in soils from any district other than Guam. The range of [illegible] for the radionuclides in the soils from Guam were as follows: ^{137}Cs [illegible], ^{40}K ([illegible] to 22), ^{226}Ra ([illegible] to 26), ^{232}Th ([illegible]) and ^{238}U ([illegible]).

Results of the analyses of the soil profiles indicated that the concentration of the fallout radionuclides ^{137}Cs and ^{90}Sr decreased with depth, while the concentration of the naturally occurring radionuclides remained relatively constant up to the depth of our deepest samples. Most of the ^{137}Cs and ^{90}Sr was present in the top 5 cm of the soil profile.

Considering only the fallout radionuclides, the values for ^{90}Sr, [illegible] and ^{239,240}Pu in soils from Palau, Guam, Truk, Ponape and Majuro are less than values for these radionuclides in soils from atolls in the northern Marshall Islands such as Utirik, Rongerik, and Ailinginae, and are much less than the soils from Bikini and Rongelap atolls ([illegible], 1977).

SUMMARY AND CONCLUSIONS

This study of radionuclides in plants, fish, and soil from five districts in Micronesia was one part of LRL's Pacific Radioecology Program. The general purpose of this part of the program is to determine the kinds and amounts of radionuclides in biological and environmental samples from the Central Pacific. The specific purpose of this study was to measure the radionuclides presently found in common foods and soil from areas of Micronesia which did not receive appreciable local fallout from the tests at Bikini and Enewetak atolls. Approximately [illegible] samples for this study were collected during November [illegible], and [illegible] γ-spectrum, 169 strontium-90, and 67 plutonium-239,240 analyses were performed.

Results of the analyses indicate that naturally occurring ^{40}K is the predominant radionuclide in the biological samples. Cesium-137 was the main fallout radionuclide detected in most of the biological samples. Amounts of ^{137}Cs present in the biota were usually less than 1 pCi/g of dry tissue, although plants from Majuro had slightly greater amounts of ^{137}Cs than did plants from the other districts.

Soil samples from all districts usually contained less than 1 pCi/g of ^{90}Sr, ^{137}Cs, ^{60}Co, and $^{239,240}Pu$, while soil from Truk, Palau, and Ponape also contained less than 2 pCi/g naturally occurring isotopes of radium and thorium. Soil from Guam contained the above fallout and naturally occurring radionuclides and in addition contained [illegible] and [illegible]. Amounts of the naturally occurring radionuclides in the Guam soils were much higher than amounts of fallout or naturally occurring radionuclides from the other districts.

Considering only the fallout radionuclides, the values for ^{90}Sr, [illegible], and $^{239,240}Pu$ in fish, plants and soils from Palau, Guam, Truk, Ponape and Majuro are less than values for these radionuclides in similar samples from atolls such as Utirik, Rongelap and Ailinginae in the northern Marshall Islands.

and is much less than values of these radionuclides in samples from Florida and Georgia states.

REFERENCES

National Institute of Radiological Sciences. 1976. Radioactivity survey data in Japan. NIRS-RDA-40. Chiba, Japan.

__________. 1976. Radioactivity survey data in Japan. NIRS-RDA-41. Chiba, Japan.

Nelson, V. A. 1977. Radiological survey of plants, animals, and soil at Christmas Island and seven atolls in the Marshall Islands. NVO-269-32. University of Washington, College of Fisheries, Laboratory of Radiation Ecology. 69 p.

Nelson, V. A., and Seymour, A. H. 1976. Preliminary Radiological Surveillance Program, Washington Public Power Supply System Nuclear Site 2B, Annual Report to UNICO Services, Inc. University of Washington, College of Fisheries, Laboratory of Radiation Ecology. 44 p.

__________. 1977. Amchitka radiobiological program progress report January 1976 to December 1976. NVO-269-31. University of Washington, College of Fisheries, Laboratory of Radiation Ecology. 49 p.

Appendix Table I. Predominant Radionuclides in Fish Collected in Micronesia in November, 1975.

Collection Site	Species	Tissue	Radionuclide concentration in pCi/g, dry[a] ^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Majuro Atoll Majuro I.	Mullet	Viscera	[illegible] ± 1.6	ns[c]	ns[c]	na
"	"	Evisc. whole[b]	[illegible]	ns	< 0.07	na
	Goatfish	Viscera	[illegible]	ns	< [illegible]	ns
		Evisc. whole	[illegible] ± 1.3	ns	< 0.13	< [illegible]
"	[illegible]	Viscera	ns	ns	ns	ns
"	"	Evisc. whole	5.0 ± [illegible]	ns	ns	ns
	Tilapia	Viscera	5.5 ± 2.0	ns	ns	ns
	"	Evisc. whole	4.2 ± [illegible]	ns	ns	ns
[illegible]	[illegible]	Evisc. whole	5.6 ± 2.0	ns	ns	ns
[illegible]	Goatfish	Viscera	3.7 ± [illegible]	ns	< [illegible]	ns
"	"	Evisc. whole	[illegible]	ns	< [illegible]	ns
"	"	Viscera	[illegible]	[illegible]	ns	ns
"	"	Evisc. whole	[illegible]	[illegible]	< [illegible]	ns
"	"	Viscera	ns	ns	ns	ns
"	"	Evisc. whole	2.3 ± 1.1	ns	< 0.03	< [illegible]
"	Mullet	Entire	[illegible] ± 1.7	ns	< 0.05	< [illegible]
"	"	Viscera	1.2 ± 8.0	ns	< 0.45	na
"	"	Evisc. whole	2.8 ± 3.2	ns	< 0.15	< 0.002
"	Convict Surgeon	Viscera	9.3 ± [illegible]	ns	< 0.43	na
"	"	Evisc. whole	ns	ns	0.05 ± .02	< .04
"	Parrotfish	Muscle	4.0 ± 1.2	0.07 ± 0.05	na	< 0.03
"	"	Viscera	3.4 ± 2.3	ns	[illegible]	na
"	"	Remainder	3.2 ± 1.7	ns	na	na

Table 1. (Continued)

Collection Site	Species	Tissue	Radionuclide concentration in pCi/g, dry[d] ^{40}K	^{137}Cs	^{90}Sr	^{239,240}Pu
Palau/Malakal I.	Jack	Entire	8.3 ± 1.1	0.20 ± 0.9	< 0.3	< 0.004
	Goatfish	Evisc. whole	5.5 ± 0.[illegible]	0.06 ± 0.04	< 0.23	< 0.003
	"	Evisc. whole	3.3 ± [illegible]	0.04 ± 0.0[illegible]	ns	ns
[illegible]	Surgeonfish	Muscle	[illegible]	ns	ns	ns
"	"	Viscera	[illegible]	ns	ns	ns
"	"	Remainder	[illegible]	ns	ns	ns
"	[illegible]	Viscera	[illegible]	ns	ns	ns
	"	Evisc. whole	[illegible]	ns	ns	ns

d. The errors are two-sigma propagated counting errors for a single sample.

e. [illegible]

f. ns = not significant; the net sample count is less than the two-sigma propagated counting error; na = not analyzed.

Appendix Table 2 Some Radionuclides in Plants Collected on Majuro Atoll in November 1975.

Collection Site	Sample Type		Radionuclide concentration in pCi/g, dry[a]			
			^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Eastern Gateway	Pandanus,	edible fruit	4.0 ± 1.6	1.9 ± 0.1	<0.0[illegible]	na[b]
"	"	inedible fruit	[illegible] ± 1.6	2.0 ± 0.[illegible]	na	na
"	"	[illegible]	[illegible]	0.51 ± 0.15	na	na
[illegible] Village	"	edible fruit	[illegible]	[illegible]	na	<.001
"	"	inedible fruit	ngt	[illegible]	<.[illegible]	<.002
"	"	[illegible]	[illegible]	[illegible]	<.[illegible]	<.[illegible]
[illegible]	"	edible fruit	[illegible]	[illegible]	[illegible]	<.[illegible]
"	"	inedible fruit	[illegible]	[illegible]	[illegible]	na
"	"	leaves	[illegible]	[illegible]	na	[illegible]
[illegible]	Coconut,	meat	[illegible]	[illegible]	<.[illegible]	na
"	"	milk	[illegible]	[illegible]	<.[illegible]	na
"	"	leaves	[illegible]	[illegible]	na	na
[illegible] Village	"	meat	na	[illegible]	na	na
"	"	milk	[illegible]	na	na	na
"	"	leaves	[illegible]	[illegible]	<.[illegible]	<.[illegible]
[illegible]	"	meat	[illegible]	[illegible]	<.[illegible]	[illegible]
"	"	milk	[illegible]	[illegible]	<.[illegible]	na
"	"	leaves	[illegible]	[illegible]	na	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	<.[illegible]	[illegible]
[illegible]	Breadfruit,	edible portion	[illegible]	[illegible]	[illegible]	na
"	"	inedible portion	[illegible]	[illegible]	na	na
"	"	leaves	[illegible]	[illegible]	na	na
[illegible] Village	"	edible portion	[illegible]	[illegible]	<.[illegible]	<.[illegible]
"	"	inedible portion	[illegible]	[illegible]	[illegible]	[illegible]
"	"	leaves	[illegible]	[illegible] ± 0.13	[illegible]	<.001
"	Papaya,	edible fruit	[illegible] ± 1.9	[illegible]	[illegible]	<.001
"	"	inedible fruit	[illegible] ± 2.6	2.3 ± 0.17	na	na
"	"	seeds	22.[illegible]	[illegible] ± 0.10	na	na
"	Banana,	edible fruit	[illegible] ± 2.0	[illegible]	<.[illegible]	<.001

---

a. The error values are two-sigma, propagated, counting errors for a single sample.

b. ngt- not significant; the net sample count is less than the two-sigma counting error. na- not analyzed.

Appendix Table 3. Some Radionuclides in Plants Collected in Ponape District in November 1975.

Collection site	Sample type	^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
		Radionuclide concentration in pCi/g, dry[a]			
Kolonia	Pandanus, edible fruit	9.6 ± 1.6	[illegible] ± 0.13	[illegible] ± 0.02	na[b]
	inedible fruit	[illegible] ± 3.6	1.2 ± 0.6	[illegible]	na
	leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	edible fruit	[illegible]	[illegible]	[illegible]	na
	inedible fruit	[illegible]	[illegible]	[illegible]	[illegible]
	leaves	[illegible]	[illegible]	ns	[illegible]
[illegible]	[illegible], edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
	inedible fruit	[illegible]	2.8 ± [illegible]	<.05	na
	leaves	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	leaves	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Coconut, meat	[illegible]	[illegible]	[illegible]	[illegible]
	milk	[illegible]	2.6 ± [illegible]	[illegible]	[illegible]
	leaves	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	leaves	ns	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Banana, edible fruit	[illegible]	[illegible]	[illegible]	na
	Taro, root	[illegible]	[illegible]	[illegible]	[illegible]

---

a. The error values are two-sigma, propagated, counting errors for a single sample.

b. ns= not significant; the net sample count is less than the two-sigma counting error. na= not analyzed.

Appendix Table 4. Some Radionuclides in Plants Collected in Truk District in November 1975.

Collection site	Sample Type		Radionuclide concentration in pCi/g, dry[a] ^{40}K	^{137}Cs	^{90}Sr	^{239,240}Pu
Tefan I.	Pandanus,	edible fruit	[illegible] ± 1.0	0.15 ± 0.05	0.06 ± 0.03	na[b]
"		inedible fruit	[illegible]	[illegible]	na	na
"		leaves	[illegible]	0.06 ± 0.03	na	na
Moen I.	"	edible fruit	[illegible]	0.25 ± 0.03	<.11	na
"	"	inedible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"		[illegible]	[illegible]	ns	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tefan I.	[illegible]	[illegible]	[illegible]	ns	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	ns	[illegible]	[illegible]
	"	[illegible]	[illegible]	ns	[illegible]	[illegible]
		[illegible]	[illegible]	ns	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible] ± 0.2	ns	[illegible]	[illegible]
Tefan I.	Papaya,	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"		inedible fruit	15.0 ± 1.0	[illegible] ± 0.07	na	na
"		seeds	[illegible] ± 1.0	[illegible] ± 0.07	na	na
Dublon	"	edible fruit	[illegible] ± 0.4	[illegible] ± 0.03	[illegible]	[illegible]
"		inedible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"	"	seeds	15.0 ± 0.6	3.0 ± 0.1	na	na
"	Coconut	copra	[illegible] ± 0.7	ns	[illegible]	na

a. The error values are two-sigma, propagated, counting errors for a single sample.

b. [illegible] significant, the sample count is less than the two sigma counting error. [illegible] not analyzed.

Appendix Table 5. Some Radionuclides in Plants Collected in the Palau Islands in November 1975.

Collection Site	Sample Type	Radionuclide concentration in pCi/g, dry[a]			
		^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Babelthuap I.	Pandanus, edible fruit	[illegible]	0.67 ± 0.07	<0.14	<0.001
"	" inedible fruit	[illegible]	[illegible]	[illegible]	ns[b]
"	" leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	" edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"	" inedible fruit	[illegible]	[illegible]	na	na
"	" leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible], edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"	" inedible fruit	[illegible]	[illegible]	[illegible]	na
"	" leaves	[illegible]	ns	na	na
[illegible]	" edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"	" inedible fruit	[illegible]	[illegible]	na	na
"	" leaves	[illegible]	ns	na	na
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	[illegible]	[illegible]	na	na
"	[illegible]	[illegible]	ns	na	na
"	[illegible]	[illegible]	ns	na	na
[illegible]	" [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	" [illegible]	[illegible]	ns	[illegible]	na
[illegible]	[illegible], edible fruit	[illegible]	[illegible]	<0.02	[illegible]
"	" inedible fruit	[illegible]	[illegible]	na	na
"	seeds	[illegible]	ns	na	na
"	Taro, root	3.4 ± [illegible]	ns	[illegible]	<0.002
"	" stem	23.0 ± 0.9	0.24 ± 0.05	<0.18	na
"	leaves	28.0 ± 3.3	0.76 ± 0.23	<0.20	na
"	Cassava, root	[illegible]	ns	[illegible]	na

---

a The error values are two-sigma, propagated, counting errors for a single sample.

b. ns = not significant; the sample count is less than the two sigma counting error. na = not analyzed.

Appendix Table 6. Some Radionuclides in Plants Collected on Guam in November 1975.

Collection Site	Sample Type	Radionuclide concentration in pCi/g, dry[a] ^{40}K	^{137}Cs	^{90}Sr	^{239,240}Pu
Agat	Pandanus, edible fruit	[illegible]	1.1 ± 0.04	<0.03	<0.001
"	inedible fruit	[illegible] ± 1.8	[illegible] ± 0.10	na	na
"	" leaves	[illegible] ± 0.5	1.3 ± 0.10	na	na
[illegible]	" edible fruit	22.[illegible]	ns[b]	<0.03	<0.001
"	" inedible fruit	[illegible]	ns	na	na
"	leaves	[illegible]	[illegible]	na	na
[illegible]	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
"	inedible fruit	[illegible]	[illegible]	[illegible]	na
"	leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible], edible fruit	[illegible]	ns	[illegible]	na
	inedible fruit	[illegible]	ns	na	na
	" leaves	[illegible]	ns	na	na
[illegible]	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
	inedible fruit	[illegible]	[illegible]	[illegible]	na
	leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	edible fruit	[illegible]	ns	[illegible]	na
	inedible fruit	[illegible]	ns	na	na
	leaves	[illegible]	ns	na	na
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
	[illegible]	[illegible]	ns	na	na
	leaves	ns	[illegible]	na	na
[illegible]	Papaya, edible fruit	[illegible]	[illegible]	[illegible]	na
	inedible fruit	[illegible]	ns	na	na
Inarajan	" edible fruit	10.0 ± [illegible]	ns	[illegible]	[illegible]
"	" inedible fruit	[illegible] ± 1.6	0.12 ± 0.10	na	na
"	" seeds	26.0 ± [illegible]	ns	na	na
Dededo	Taro, root	5.8 ± 0.3	0.06 ± 0.02	<0.13	<0.001
"	" stem	33.0 ± 1.1	ns	na	na
"	" leaves	[illegible] ± 1.1	0.31 ± 0.08	na	na

---

a. The error values are two sigma, propagated, counting errors for a single [illegible].

[illegible] significant; the sample count is less than the two sigma counting error. na = not analyzed.

Appendix Table 7. Some Radionuclides in Soil Collected on Majuro Atoll in November 1975.

Collection Site	Sample Depth in cm.	Radionuclide concentration in pCi/g, dry[a]			
		^{90}Sr	^{137}Cs	^{238}U	$^{239,240}Pu$
Eastern Gateway	Surface composite	1.5 ± 0.33	0.11 ± 0.03	ns[b]	0.022 ± 0.020
"	0 - 2.5	[illegible] ± 0.10	0.07 ± 0.04	ns	0.11 ± 0.09
"	2.5 - 5	<0.25	[illegible]	[illegible]	ns[b]
"	5 - 10	[illegible]	ns	[illegible]	[illegible]
"	[illegible]	ns	ns	[illegible]	ns
"	[illegible]	ns	ns	ns	ns
"	[illegible]	ns	ns	[illegible]	ns
[illegible]	0 - 2.5	[illegible]	[illegible]	[illegible]	[illegible]
"	2.5 - 5	ns	ns	[illegible]	ns
"	5 - 10	ns	ns	ns	ns
"	Surface composite	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

---

a. The [illegible] are [illegible] counting errors for a single sample.

b. ns = not significant; the net sample count is less than the two-sigma counting error. [illegible] = not analyzed.

Appendix Table 8. Some Radionuclides in Soil Collected in the Ponape District in November 1975.

Collection Site	Sample Depth in cm	Radionuclide concentration in pCi/g, dry[a] ^{90}Sr	^{137}Cs	^{226}Ra	^{228}Th	^{232}Th	^{238}U	^{239,240}Pu
Nand	Surface composite	<0.19	0.49 ± 0.05	0.56 ± 0.06	1.6 ± 0.12	0.31 ± 0.26	0.54 ± 0.30	na[b]
[illegible]	0 - 2.5	[illegible]	0.09 ± 0.03	ns[b]	ns	ns	ns	0.03 ± 0.02
"	2.5 - 5	<0.19	0.19 ± 0.11	0.73 ± 0.06	ns	ns	1.2 ± 0.6	0.008 ± 0.014
"	5 - 10	ns	0.16 ± 0.05	0.09 ± 0.06	ns	0.17 ± 0.19	1.02 ± 0.28	na
[illegible]	0 - 2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	2.5 - 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	5 - 10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
[illegible]	0 - 2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	2.5 - 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
"	5 - 10	ns	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na

---

a. [illegible] two-sigma [illegible] for a single sample.

b. ns= not significant; the net sample count is less than the two-sigma counting error. na= not analyzed.

Appendix Table 9. Some Radionuclides in Soil Collected at Truk in November 1975.

Collection Site	Sample Depth in cm	Radionuclide concentration in pCi/g, dry[a]						
		^{90}Sr	^{137}Cs	^{226}Ra	^{228}Th	^{232}Th	^{238}U	^{239,240}Pu
[illegible]	0 - 2.5	0.16 ± 0.16	0.41 ± 0.06	0.41 ± 0.06	0.49 ± 0.11	[illegible]	ns[b]	0.092 ± 0.009
"	2.5 - 5	0.20 ± 0.2[illegible]	[illegible]	[illegible] ± 0.06	0.62 ± 0.09	[illegible]	[illegible]	0.007 ± 0.001
"	5 - [illegible]	na	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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a. The error values are the two-sigma counting errors for a single sample.

b. ns= not significant; the net sample count is less than the two-sigma counting error. na= not analyzed.

Appendix Table 10. Some Radionuclides in Soil Collected in the Palau Islands in November 1975.

Collection Site	Sample Depth in cm	Radionuclide concentration in pCi/g, dry[a]				
		^{90}Sr	^{137}Cs	^{226}Ra	^{232}Th	$^{239,240}Pu$
[illegible]	Surface composite	[illegible]	[illegible] ± 0.01	0.24 ± 0.05	0.60 ± [illegible]	na[b]
	0 - 2.5	ns	[illegible]	ns	ns	na
	2.5 - 5	ns	[illegible]	ns	ns	na
	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
[illegible]	Surface composite	[illegible]	[illegible]	[illegible]	ns	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2.5 - 5	[illegible]	[illegible]	[illegible]	ns	[illegible]
	[illegible]	ns	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns	[illegible][c]
	2.5 - 5	ns	[illegible]	[illegible]	ns	ns
	[illegible]	ns	[illegible]	[illegible]	[illegible]	ns
	[illegible]	ns	[illegible]	[illegible]	ns	ns
	[illegible]	ns	[illegible]	[illegible]	[illegible]	ns
	[illegible]	ns	ns	[illegible]	ns	ns
	[illegible]	ns	ns	ns	ns	ns

---

a. [illegible]

b. ns = not significant; the net sample count is less than the two-sigma counting error. na = not analyzed.

c. These two samples were pooled for the $^{239,240}Pu$ analysis.

Appendix Table 11. Some Radionuclides in Soil Collected on Guam in November 1975.

Collection Site	Sample Depth in cm	Radionuclide concentration in pCi/g, dry[a]					
		^{137}Cs	^{210}Pb	^{210}Ra	^{232}Th	^{235}U	$^{239,240}Pu$
Agana	0 - 2.5	0.24 ± 0.06	20.0 ± 7.2	79.0 ± 0.4	4.4 ± 0.8	5.6 ± 0.1	0.010 ± .004
"	2.5 - 5	1.0 ± 0.2	22.0 ± 5.7	ns	ns	ns	0.003 ± .002
"	[illegible]	ns[b]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dededo	0 - 2.5	ns	[illegible] ± 3.3	42.0 ± 0.3	4.5 ± 1.6	[illegible] ± 0.6	na
"	2.5 - 5	ns	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	na
"	[illegible]	ns	[illegible]	[illegible]	[illegible]	[illegible]	na
Talofofo	0 - 2.5	[illegible]	ns	[illegible]	[illegible]	[illegible]	na
"	2.5 - 5	[illegible]	ns	[illegible]	[illegible]	[illegible]	na
"	[illegible]	[illegible]	ns	[illegible]	[illegible]	[illegible] ± 0.04	[illegible] ± .004

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a. The error reflects a one-sigma, propagated counting error for a single sample.

b. ns = not significant, the net sample count is less than the two-sigma counting error; na = not analyzed.

APPENDIX 4

RADIOLOGICAL SURVEY OF PLANTS, ANIMALS AND SOIL AT FIVE ATOLLS IN THE MARSHALL ISLANDS

SEPTEMBER - OCTOBER 1974

by

Victor A. Nelson

APPENDIX 4

NVO-269-36

RADIOLOGICAL SURVEY OF PLANTS, ANIMALS AND SOIL AT FIVE ATOLLS IN THE MARSHALL ISLANDS SEPTEMBER-OCTOBER 1976

By

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2 May 1978

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Prepared for the U. S. Department of Energy
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INTRODUCTION

As stated in a previous progress report (Nelson 1977),

> "The Division of Operational Safety of ERDA (now Safety Standards and Compliance) portion of the Laboratory of Radiation Ecology (LRE) Pacific Radioecology Program (formerly [illegible] Atoll Program) began on 1 July 1974 and is continuing. The purpose of this program is to determine the kinds and amounts of radionuclides distributed in the foods, plants, animals, and soils of the Central Pacific, especially the Marshall Islands, and to transmit these data to DOS/ERDA and other appropriate agencies (Lawrence Livermore Laboratory, Nevada Operations Office ERDA) so that they may make an evaluation of the dose of ionizing radiation received by the people living throughout the Central Pacific."

Here we report the results of the analyses of samples collected on a field trip conducted in September-October 1976.

SAMPLING PROGRAM

Atolls visited in the Marshall Islands are shown in Figure 1. This trip was a joint survey with personnel from Brookhaven National Laboratory. Representative biological and soil samples were collected with emphasis on food items common to the diet of the Marshallese people (i.e., fish, coconut, pandanus, breadfruit, coconut crabs, etc.) although nonedible portions of these items were also collected and analyzed. Soils were collected to provide data for estimating future distributions and quantities of radionuclides in the environment and biota. Sampling sites are shown in Figures 2 through [illegible].

The number of samples collected, after division into tissues or soil fractions, is shown in Table 1. Slightly less than half the samples were land plants, fish, clams, and coconut crabs; and the rest were soils — surface (0-2.5cm) and profile (0-100cm).

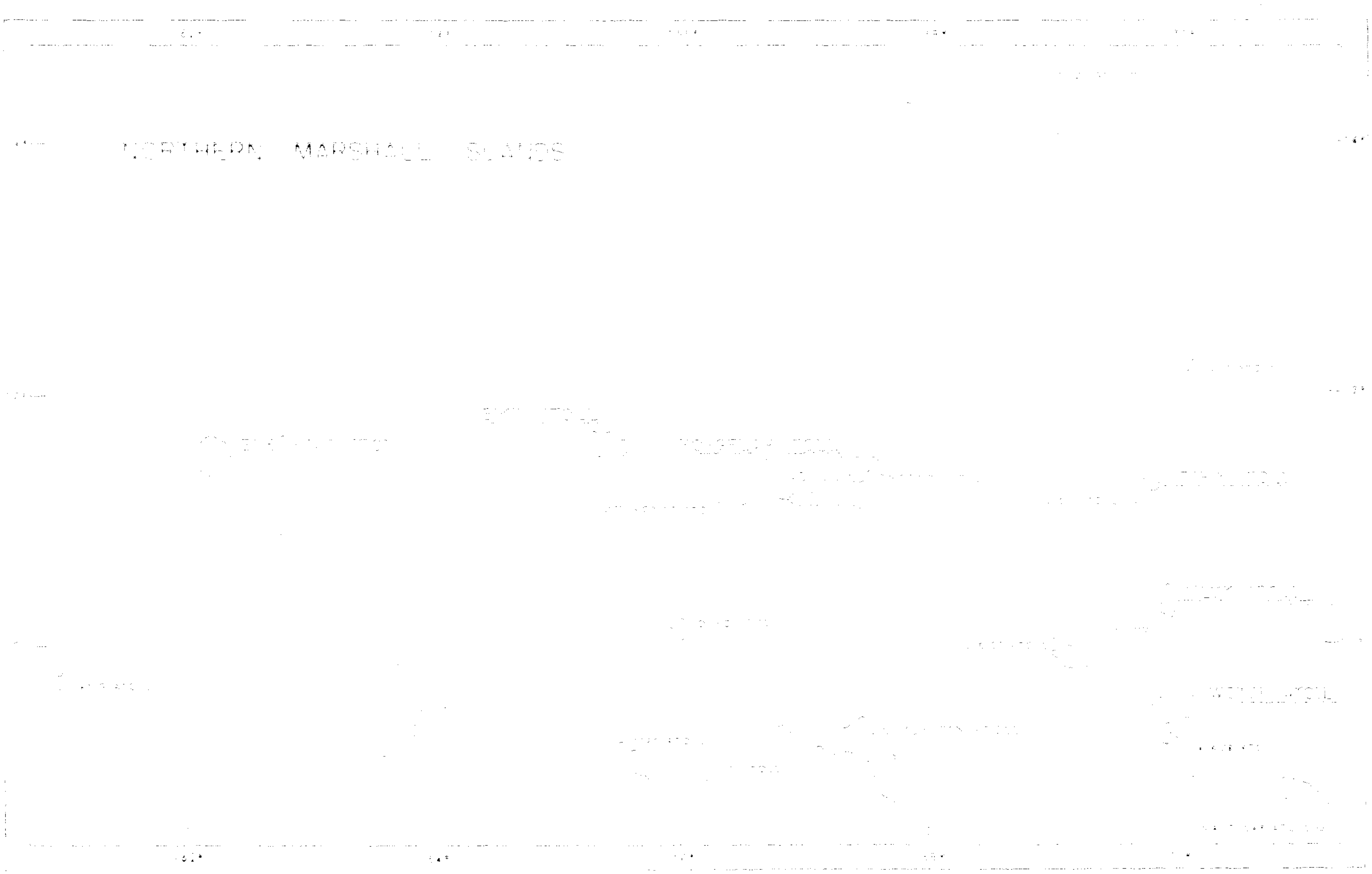

Figure 1. Five atolls (underlined) in the northern Marshall Islands where samples were collected September-October 1976.

Figure 9. Sampling sites on Bikini Island, Bikini Atoll, October 1976.

Figure 3. Sampling Sites on Wormej and Wotje Islands, Wotje Atoll and on Ailuk and Bigen Islands, Ailuk Atoll, September 1976.

Figure 4. Sampling Sites on Utirik and Aon Islands, Utirik Atoll and on Naen Island, Rongelap Atoll, September 1976.

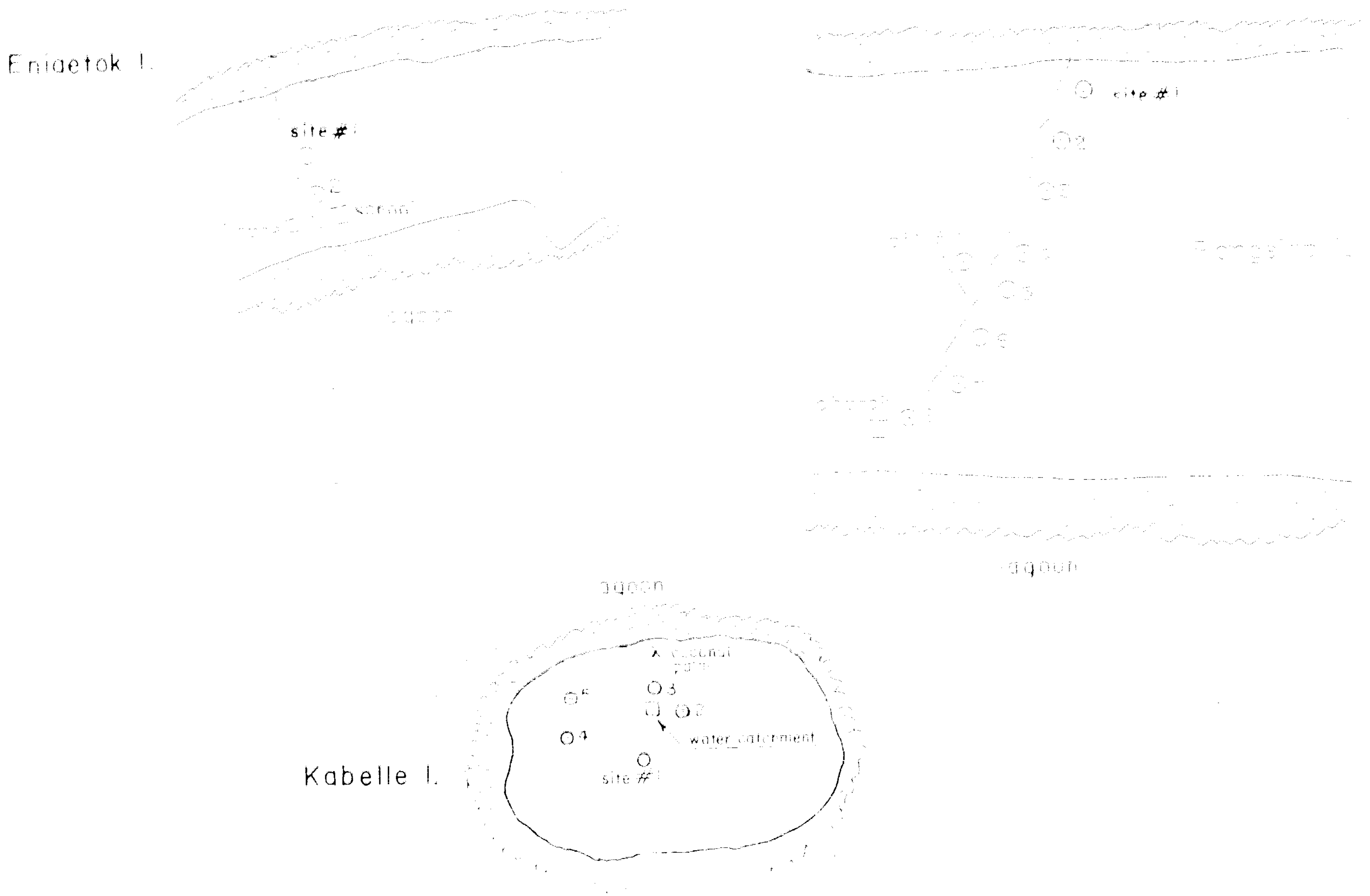

Figure 5. Sampling Sites on Eniaetok, Rongelap, and Kabelle Islands, Rongelap Atoll, September 1976.

TABLE 1. Number of samples processed and analyzed that were collected during the September-October 1976 field trip to the Marshall Islands

	SAMPLES PROCESSED					SAMPLES ANALYZED		
[illegible]	[illegible]	Soil	[illegible]	Coconut Crab	Total	[illegible]	^{90}Sr	^{239,240}Pu
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

In addition to the samples the Laboratory collected, personnel from Brookhaven National Laboratory collected samples, made in situ measurements and took radiation survey readings with sodium iodide (NaI) scintillation detectors and a pressurized ion chamber. The results of the Brookhaven analyses and measurements may be combined with the LRL results in a series of joint reports to the open literature.

ANALYTICAL METHODS

Gamma-Ray Spectrometry

All of the samples were analyzed by gamma-ray spectrometry, either with a 3 x 3 inch sodium iodide (thallium activated) crystal and 200-channel pulse-height analyzer or with a germanium (lithium-drifted) diode detector and 4096-channel pulse height analyzer. Soil samples were analyzed on the Ge(Li) system and the biological samples were analyzed on both systems.

All samples were oven dried, ground and a portion compressed in polyvinyl chloride (PVC) pipe 2 inches in diameter and either ½ or 1 inch deep that served as a sample holder for radionuclide measurement. Fifty grams of biota or 100 grams of soil could be compressed into the 2 x 1 inch container. The densities of the biological and soil samples were 1.0 and 1.35, respectively. These samples were then analyzed for gamma emitting radionuclides.

The gamma-emitting radionuclides in samples counted on the NaI counter were determined by the method of least squares. The radionuclides values in samples counted on the Ge(Li) detector were calculated manually or with a computer by adding the counts in an energy range of five channels under a peak in the spectrum, subtracting the appropriate background counts, and applying correction factors to convert counts to picocuries (pCi). A set of previously recorded reference spectra for the different geometries and radionuclides are used. All values were corrected for decay to the date of collection.

Strontium-90 and Plutonium Analyses

To measure ^{90}Sr content, ^{90}Y was chemically separated from ^{90}Sr, collected on a filter paper and counted with a low level beta counting system. Plutonium isotopes were extracted by ion exchange, electroplated on platinum discs, and analyzed by alpha spectrometry with systems using surface barrier alpha detectors and multichannel analyzers. Chemical yield was determined by use of ^{236}Pu as a tracer.

Error Limits

For a single sample, the errors given for all radionuclides listed are two-sigma, propagated, counting errors. The error term for more than one sample is one standard deviation and disregards counting error.

Limits of Detection

Many factors influence the limits of detection, including the type of detector and analyzer, the presence of other radionuclides, the duration of the counting period, the size and density of the sample, and the geometric relationship of the sample and detector. Hence, the limits of detection vary considerably for various radionuclides and types of samples, but can be generalized by stating that the detection limits were approximately as follows:

By gamma detection	
^{40}K	2.1 pCi/g or less
^{137}Cs	0.41 " "
^{60}Co, ^{207}Bi, ^{125}Sb, ^{155}Eu, ^{241}Am	0.02 pCi/g or less
By beta detection	
^{90}Sr	0.2 pCi/g or less
By alpha detection	
$^{239,240}Pu$	0.02 pCi/g or less

RESULTS

Data are presented for the results of the analyses of the samples collected by UW in the Marshall Islands in 1976. Appendix Tables 1 through 38 give the data for single samples. The data are first presented atoll by atoll and then summarized by comparisons between atolls for selected sample types. All data are given as picocuries per gram of dry weight except where expressly noted.

Ailuk and Wotje Atolls

Samples from Biken and Ailuk Islands at Ailuk Atoll and from Wotje and Ormed Islands at Wotje Atoll were collected during the September-October 1976 field trip. Results of the analyses on these samples of fish, plants and soil for gamma emitting radionuclides, ^{90}Sr and $^{239,240}Pu$ are given in Appendix Tables 1 (fish), 2 and 3 (plants) and 4 through 7 (soil).

In the fish, naturally occurring ^{40}K was the most abundant radionuclide. Except for a small amount of ^{137}Cs in one fish sample, no fallout radionuclides were detected in any of the other fish samples. In plants ^{40}K was also the predominant radionuclide, however ^{137}Cs was above the limits of detection in all plant samples and ^{90}Sr was measurable in about one third of the samples analyzed. Of the plants sampled, pandanus fruit had the most ^{137}Cs and unprocessed arrowroot tubers had the most ^{90}Sr. Processing the arrowroot tubers for food removes most of the ^{90}Sr.

Cesium-137 was the predominant radionuclide in the soil samples from Wotje and Ailuk atolls, but the amount measured was less than 1 pCi/g in all samples except four from Biken Island, the northernmost sampling location on these two atolls. Concentrations of ^{137}Cs in these four samples ranged from 1.3 to 1.6 pCi/g. Strontium-90 and ^{239,240}Pu were not measurable in the samples analyzed. Concentrations were less than a picocurie in all samples but one, the [illegible] soil from 0-10 cm on [illegible] Island. Soil at this site contained 3.8 pCi of ^{239,240}Pu per gram. Americium-241 was detected in only a few of the soil samples.

Utirik Atoll

The two predominant radionuclides in plant samples from Utirik Atoll were ^{90}Sr and ^{137}Cs (Appendix Table 8). Of the [illegible] samples analyzed, the edible portion of the three pandanus fruit samples contained the greatest amounts of ^{137}Cs (average 14 pCi/g). Values of ^{90}Sr in the plants ranged up to 2. [illegible]. Plutonium-239, 240 values were below the limits of detection in the five [illegible] samples analyzed.

Soil samples from Utirik Atoll contained ^{137}Cs, ^{90}Sr and ^{239,240}Pu in most of the samples analyzed for these radionuclides (Appendix Tables [illegible]). Americium-241 and ^{60}Co were also detected in many of the surface soil samples. Cesium-137 values ranged up to 5.8 pCi/g and averaged about 3 pCi/g in the [illegible] surface soil samples. Soil samples from 5-10 cm below the surface contained [illegible] than 0.5 pCi of ^{137}Cs per gram. In the surface samples analyzed, ^{90}Sr values ranged from 0.6 to 3.2 pCi/g while ^{239,240}Pu values ranged from 0.08 to [illegible]. Americium-241 and ^{60}Co values were less than a pCi/g.

Rongelap Atoll

Most samples of marine organisms from Rongelap contained ^{60}Co and [illegible] as the predominant radionuclides (Appendix Tables [illegible] and 11). Cobalt-60 was present in less than pCi/g amounts, except in the [illegible] of one clam kidney which contained 7.8 ± [illegible] pCi/g. Samples of terrestrial organisms also contained [illegible] with [illegible] as the predominant radionuclide in the plants (Appendix Table [illegible]) [illegible] ^{90}Sr in the coconut crabs (Appendix Table [illegible]). Most plant samples contained [illegible] to 100 pCi of ^{137}Cs per gram of dry tissue. However, coconut milk sample contained up to 355 pCi/g. The exoskeleton of the coconut crabs contained 15 to 360 pCi of ^{90}Sr per gram. The other tissues contained 1 to 20 pCi/g.

The results of the analyses of the soil samples are given in Appendix Tables 14 through 17. Cesium-137 and ^{90}Sr are the predominant radionuclides and ^{60}Co, ^{238}Pu, ^{241}Am, and ^{239,240}Pu were also detected in most of the samples analyzed for these specific radionuclides. Antimony-125 was also detected in the soils from Naen Island. Radionuclide values were lowest on Rongelap and Eniaetok Islands and highest on Naen. Cesium-137 and ^{90}Sr values in surface soils from Naen averaged several hundred pCi/g and ranged up to 900 and 622 pCi/g for ^{137}Cs and ^{90}Sr, respectively. Cesium-137 values in soil from Rongelap Island were less than a hundred pCi/g. Plutonium-239 and 240 values in Rongelap and Eniaetok Island soils were commonly 1 to [illegible] pCi/g, while in Naen soils values for these radionuclides ranged to 65 pCi/g.

Bikini Atoll

Plants were the only sample type collected at Bikini Atoll. Results of the analyses of these samples are in Appendix Table 18. Cesium-137 and ^{90}Sr are the predominant radionuclides. The greatest ^{137}Cs and ^{90}Sr values were in the leaves of the pandanus. Leaves from a pandanus plant near [illegible] (see Figure 2) contained 2360 pCi of ^{137}Cs per gram, while leaves from a plant near House 25 contained 483 pCi of ^{90}Sr per gram. Plutonium-239,240 values were mostly less than the limits of detection.

DISCUSSION AND CONCLUSIONS

Comparison Between Atolls

Moving in a northerly direction, radioactivity values were least in the samples from Mejit Atoll, increased slightly at Ailuk Atoll and increased significantly at Utirik. From Utirik, radioactivity values increased to the west.

Thus, Rongelap Atoll had higher values than Utirik and Bikini had the highest values of any atoll sampled during this survey. This pattern has been noted previously (Nelson, 1977) and is a result of the fallout distribution from the 1 March 1954 Bravo test on Bikini Atoll. The south to north increase in radioactivity is also apparent at Rongelap Atoll where the southern islands have radioactivity levels about a factor of ten lower than the northern islands.

Differences Due to Sample Type

As noted previously (Nelson, 1977) ^{90}Sr and ^{137}Cs are the predominant radionuclides in biological and soil samples from the terrestrial environment. In addition, ^{241}Am and ^{239,240}Pu are important in soils from Rongelap Atoll and Bikini Atoll (Nelson, 1977) because of the quantity of these radionuclides and because they are alpha-emitters, which have a higher potential health hazard than most of the gamma-emitters. Pandanus leaves continue to be the best indicator species for ^{137}Cs because they concentrate ^{137}Cs and are abundant and available throughout the year. These leaves may also be used as indicator for ^{90}Sr if coconut crabs are not available. The exoskeletons of these crabs contain more ^{90}Sr than any other biological sample analyzed. However these crabs are often scarce or absent on the most populated islands.

In the marine environment ^{40}K is the predominant radionuclide. Cobalt-60 was the only fallout radionuclide present in a significant number of the marine samples and the values for this radionuclide were usually less than 5 pCi/g. The viscera of the Tridacna had the greatest amounts of ^{60}Co of the marine samples analyzed.

SUMMARY

The current portion of the Pacific Radioecology Program began on 1 July 1974. The purpose of this program is to determine the types and amounts of radionuclides in biological and environmental samples from the Central Pacific especially the Marshall Islands. A field trip was conducted for this purpose in September-October 1976. About 300 samples were collected and about 217 spectrum, 130 strontium-90 and 76 plutonium-239, 240 analyses were performed.

Results of the analyses indicate that ^{90}Sr and ^{137}Cs are predominant in the terrestrial environment and, in addition, ^{241}Am and ^{239,240}Pu are also important in the soil from Rongelap Atoll. Potassium-40 is the predominant radionuclide in the marine organisms, while ^{60}Co is important in the kidney of the *Tridacna* clam.

Amounts of radioactivity between atolls and between islands within Rongelap Atoll vary with distance from the test site at Bikini Atoll and in relation to the fallout pattern from the March 1954 Bravo test. Plants from Bikini Island had the highest amounts of radioactivity, primarily ^{137}Cs, while plants from Naen Island of Rongelap Atoll had slightly lower amounts. The southern islands of Rongelap Atoll and Utirik Atoll had intermediate amounts of radioactivity, while Ailuk and Likiep Atolls had the lowest amounts of radioactivity of the atolls visited during this field trip.

REFERENCES CITED

Nelson, V. A. 1977. Radiological survey of plants, animals, and soil at Christmas Island and Seven Atolls in the Marshall Islands. U. S. ERDA Report NVO-269-32. College of Fisheries, University of Washington, Seattle.

APPENDIX TABLE 1

Some Radionuclides in Fish Collected at Rongelap,
Ailuk, and Wotje Atolls in September 1976

Atoll/Island	Species	Tissue	Radionuclide Concentration in pCi/g, dry[a] ^{40}K	 ^{60}Co	 ^{137}Cs	 ^{90}Sr
Rongelap/Rongelap	Yellowfin Tuna	Liver	ns[b]	0.10±0.03	0.01±0.03	na[b]
[illegible]	Goatfish	Evisc. whole[c]	[illegible]	[illegible]	ns	na
		Viscera	[illegible]±7.3	[illegible]	ns	na
Rongelap/Eniaetok	Goatfish	Evisc. whole	[illegible]	[illegible]	ns	<0.13
"	"	Viscera	ns	ns	ns	na
"	Mullet	Evisc. whole	[illegible]	[illegible]	[illegible]	<0.10
"	"	Viscera	[illegible]	ns	ns	na
[illegible]	[illegible]	Evisc. whole	[illegible]	ns	[illegible]	[illegible]
"	"	Viscera	[illegible]	ns	[illegible]	na
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	ns	ns	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	ns	ns	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	ns	ns	[illegible]
[illegible]	[illegible]	Evisc. whole	[illegible]	ns	[illegible]	na
		Viscera	[illegible]	ns	ns	na

---

a. [illegible]

b. ns = not significant; [illegible]; na = not analyzed.

c. Evisc. whole = eviscerated whole fish, i.e., the entire fish less the viscera.

APPENDIX TABLE 2

Predominant Radionuclides in Plants Collected at Wotje Atoll in September 1976

Island	Site	Sample Type		^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
				Radionuclide Concentration in pCi/gm dry[a]			
[illegible]	[illegible]	Coconut,	[illegible]	[illegible]	[illegible]	[illegible]	<0.001
			[illegible]	na[b]	na	[illegible]	na
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]				[illegible]	[illegible]	na	na
	[illegible]			[illegible]	0.22±0.05	[illegible]	na
	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Pandanus,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	na	na
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	na	na
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	na	na
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	na	na
			seeds	[illegible]	[illegible]	na	na
[illegible]	[illegible]		edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			skin	[illegible]	[illegible]	na	na
			seeds	[illegible]	[illegible]	na	na
Wotje	Village	Taro,	root	6.5±1.5	[illegible]	[illegible]	<0.001
		Yam,	edible	[illegible]	[illegible]	[illegible]	<0.001
		Squash,	edible	[illegible]	[illegible]	[illegible]	<0.001

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a. The error values for all radionuclides are two-sigma, propagated, counting errors for a single sample.

b. na = not analyzed

APPENDIX TABLE 3

Predominant Radionuclides in Plants Collected
on Ailuk Atoll in September 1976

Island	Site	Sample Type		Radionuclide Concentration in pCi/g, dry[a] ^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			Leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]		Leaves	[illegible]	[illegible]	[illegible]	na
	[illegible]			[illegible]	[illegible]	na	na
[illegible]	[illegible]	[illegible]	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			inedible fruit	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		inedible fruit	[illegible]	[illegible]	[illegible]	na
			Leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]		edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			inedible fruit	[illegible]	[illegible]	[illegible]	na
	[illegible]		edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			inedible fruit	[illegible]	[illegible]	[illegible]	na
			Leaves	[illegible]	[illegible]	[illegible]	na
	[illegible]	[illegible]	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			inedible fruit	[illegible]	[illegible]	[illegible]	na
			edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			inedible fruit	[illegible]	[illegible]	[illegible]	na
			Leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]		Leaves	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]	[illegible]	edible fruit	[illegible]	[illegible]	[illegible]	[illegible]
			inedible fruit	[illegible]	[illegible]	[illegible]	na
	[illegible]	[illegible]	Whole	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	Whole	[illegible]	[illegible]	[illegible]	[illegible]

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a. The error values for all radionuclides are one sigma, propagated, counting errors for a single sample.

b. na = not analyzed

c. [illegible]

A P P E N D I X   T A B L E   4

Predominant Radionuclides in Soil Collected on
Wormei Island, Wotje Atoll, September 1976

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[1] ^{137}Cs	^{60}Co	^{241}Am	^{239,240}Pu	^{90}Sr
Site #1	0-2.5	0.59±[illegible]	0.63±0.07	[illegible]	[illegible]	[illegible]
"	2.5-5	[illegible]	[illegible]	ns[2]	[illegible]	[illegible]
"	5-[illegible]	0.26±0.11	ns	ns	ns[3]	ns
Site #2	0-2.5	[illegible]	[illegible]	ns	ns	[illegible]
"	2.5-5	[illegible]	ns	ns	ns	ns
"	5-10	[illegible]	ns	[illegible]	ns	ns
"	10-15	[illegible]	[illegible]	ns	ns	ns
"	[illegible]	ns	ns	ns	ns	ns
"	[illegible]	ns	[illegible]	ns	ns	ns
"	[illegible]	ns	[illegible]	ns	ns	ns
"	[illegible]	ns	[illegible]	ns	ns	ns
"	[illegible]	ns	[illegible]	ns	ns	[illegible]
Site [illegible]	0-2.5	[illegible]	[illegible]	ns	[illegible]	[illegible]
"	2.5-5	[illegible]	ns	ns	ns	ns
"	5-[illegible]	[illegible]	[illegible]	ns	ns	ns
Site #6	0-2.5	[illegible]	ns	ns	ns	[illegible]
"	2.5-5	0.38±0.05	ns	ns	ns	ns
Site #7	0-2.5	[illegible]	ns	ns	ns	ns
"	2.5-5	0.25±0.12	ns	0.20±0.14	[illegible]±0.02	ns

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[1] The error [illegible] for all radionuclides are two-sigma, propagated, counting errors for a single sample.

[illegible] counting error [illegible] not

A P P E N D I X   T A B L E   5

Some Radionuclides in Soil Collected on
Wotje Island, Wotje Atoll, September 1978

Collection Location	Soil Depth (cm)	^{137}Cs	^{60}Co	^{241}Am	^{239,240}Pu	^{90}Sr
		Radionuclide Concentration in pCi/g, dry[a]				
Site #1	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2.5-5	[illegible]	ns[b]	ns	ns	ns
	5-10	[illegible]	[illegible]	ns	ns	ns
Site #2	0-2.5	[illegible]	ns	ns	ns	[illegible]
	2.5-5	[illegible]	ns	ns	ns	ns
	5-10	[illegible]	ns	[illegible]	ns	ns
Site #3	0-2.5	[illegible]	ns	ns	ns	ns
	2.5-5	[illegible]	[illegible]	ns	ns	ns
	5-10	ns	ns	ns	ns	ns
	10-15	[illegible]	ns	ns	ns	ns
	15-25	ns	ns	ns	ns	ns
	25-35	ns	ns	ns	ns	ns
	35-45	ns	[illegible]	ns	ns	ns

a. The error is two sigma for all radionuclides.

b. ns - not significant; the net sample count is less than the two-sigma, propagated counting error.
na - not analyzed.

APPENDIX TABLE 6

Some Radionuclides in Soil Collected on Ailuk Island, Ailuk Atoll, September 1978

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[a] ^{137}Cs	[illegible]	Other
Site #1	0-2.5	0.48±0.05	1.1±0.14	[illegible] 0.77±0.27
	2.5-5	0.28±0.03	0.62±0.24	
	5-10	0.23±0.08	1.4±0.36	
	10-15	0.16±0.07	ns[b]	
	15-25	0.07±0.03	ns	
	25-35	0.05±0.01	ns	
	35-50	ns	ns	
	50-75	ns	ns	
	75-100	ns	0.44±0.24	
Site #2	0-2.5	0.78±0.12	0.36±0.39	
	2.5-5	0.32±0.05	ns	
	5-10	0.15±0.05	0.52±0.32	
Site #3	0-2.5	ns	ns	
	2.5-5	0.07±0.02	0.45±0.28	
	5-10	0.18±0.07	ns	
Site #4	0-2.5	0.09±0.12	0.65±0.29	
	2.5-5	0.12±0.05	0.72±0.31	
	5-10	ns	ns	
Site #5	0-2.5	0.61±0.11	0.68±0.33	
	2.5-5	0.22±0.06	ns	
	5-10	0.10±0.04	0.62±0.31	
Site #6	0-2.5	0.22±0.07	0.58±0.38	[illegible] 0.72±0.33
	2.5-5	0.15±0.07	0.57±0.32	
	5-10	ns	ns	

---

a. The error values for all radionuclides are two-sigma propagated counting errors for a single sample.

b. ns = not significant; the net sample count is less than the two-sigma propagated counting error.

APPENDIX TABLE [illegible]

Some Radionuclides in Soil Collected on [illegible] Island, [illegible] Atoll, September 1978

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[a]		
		^{137}Cs	[illegible]	Other
Site #1	0-2.5	1.2 ±0.15	ns[b]	$^{239+240}$Pu 0.0[illegible] ± [illegible] ^{90}Sr 0.[illegible] ± [illegible]
	2.5-5	0.70±0.1[illegible]	ns	
	5-10	0.53±0.11	0.62±0.33	
	10-15	0.25±0.08	ns	
	15-25	0.[illegible]0±0.06	ns	
	25-5[illegible]	[illegible]	ns	
Site #2	0-2.5	0.9[illegible]±0.13	0.64±0.36	
	2.5-5	0.41±0.08	ns	
	5-10	0.21±0.07	ns	
Site #3	0-2.5	1.[illegible] ±0.[illegible]3	ns	[illegible]U 3.8 ± 1.5 [illegible] 0.27 ± 0.12
	2.5-5	0.27±0.11	ns	
	5-10	0.36±0.08	ns	$^{239+240}$Pu 0.055 ± 0.0[illegible]
Site #4	0-2.5	0.8[illegible]±0.1[illegible]	ns	^{90}Sr 0.41 ± 0.1[illegible]
	2.5-5	1.0 ±0.12	ns	
	5-10	1.2 ±0.13	0.58±0.[illegible]4	

---

a. The error values for all radionuclides are two sigma, propagated, counting errors for a single sample.

b. ns = not significant; the net sample count is less than the two-sigma, propagated counting error.

APPENDIX TABLE 8

Predominant Radionuclides in Plants Collected
on Utirik Atoll in September 1976

Island	Sample Type		⁹⁰Sr	¹³⁷Cs	⁶⁰Co	²³⁹,²⁴⁰Pu
			Radionuclide Concentration in pCi/g, dry^a			
[illegible]	Coconut	Leaves	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	ns
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	ns	ns	[illegible]	[illegible]
[illegible]	Pandanus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Breadfruit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

---

a. The error [illegible] propagated counting errors for a single sample.

b. ns = not significant; the net sample count is less than the [illegible] propagated counting error. na = not analyzed.

APPENDIX TABLE C

Some Radionuclides in Soil Collected on [illegible] Island,[a]
[illegible] Atoll, September 1976

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[a] ^{60}Co	^{137}Cs	^{241}Am	Other
Site #1	0-2.5	0.16±0.08	3.6 ±0.26	0.26±0.12	
"	2.5-5	ns[b]	0.80±0.10	0.21±0.15	
"	5-10	0.09±0.06	0.32±0.[illegible]	ns	
Site #2	0-2.5	0.12±0.06	[illegible] ±0.26	0.64±0.14	^{239,240}Pu [illegible] ^{90}Sr [illegible]
"	2.5-5	ns	0.25±0.07	ns	
"	5-10	ns	0.16±0.03	ns	
Site #3	0-2.5	0.10±0.05	3.0 ±0.1[illegible]	0.47±0.14	
"	2.5-5	ns	0.83±0.10	ns	
"	5-10	ns	0.47±0.0[illegible]	ns	
Site #4	0-2.5	0.10±0.05	[illegible] ±0.30	0.18±0.13	^{90}Sr [illegible]
"	2.5-5	0.17±0.10	1.9 ±0.17	0.25±0.19	
"	5-10	ns	0.47±0.10	ns	
Village	0-2.5	ns	[illegible] ±0.11	ns	^{90}Sr [illegible] ^{239,240}Pu [illegible]

---

a. The error values for all radionuclides are two-sigma, propagated, counting error [illegible]

b. ns = not significant; the net sample count is less than the two-sigma, propagated, counting error.

APPENDIX TABLE 10

Some Radionuclides in Soil Collected at Utirik Atoll
September 1976

Island	Collection Location	Soil Depth (cm)	^{137}Cs	[illegible]	^{241}Am	[illegible]
[illegible]	Center of Isle	Litter	0.97±0.19	1.5±0.4	ns[b]	
"	"	0-2.5	2.3±0.22	ns	0.27±0.11	[illegible] 3-0.16 [illegible] 9-0.16
"	"	2.5-5	3.3±0.29	ns	0.40±0.19	
"	"	5-10	1.3±0.12	0.67±0.24	0.17±0.07	
"	"	10-15	0.82±0.07	ns	ns	
"	"	15-25	ns	ns	ns	
"	"	25-35	ns	ns	ns	
"	"	35-50	ns	ns	ns	
Aon	Site #1	0-2.5	3.2±0.21	ns	ns	[illegible]
"	"	2.5-5	1.6±0.16	ns	0.15±0.09	
"	"	5-10	0.19±0.07	0.99±0.27	ns	
"	"	10-15	0.38±0.06	ns	ns	
"	Site #2	0-2.5	1.4±0.15	ns	0.38±0.20	[illegible]
"	"	2.5-5	0.36±0.09	ns	0.21±0.19	
"	"	5-10	0.35±0.08	0.92±0.30	ns	
"	"	10-15	0.18±0.07	ns	ns	
"	"	15-25	0.07±0.04	0.74±0.30	ns	
"	Site #3	0-2.5	1.6±0.17	ns	0.97±0.19	
"	"	2.5-5	0.52±0.15	1.3±0.28	ns	
"	"	5-10	ns	ns	ns	

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a. The error values for all radionuclides are two-sigma, propagated, counting error [illegible] sample.

b. ns = not significant; the net sample count is less than the two-sigma, propagated counting error.

APPENDIX TABLE II

Predominant Radionuclides in Tridacna Clams from
[illegible] Island, Rongelap Atoll, September 1976

Island	Number of Clams	Tissue	Radionuclide Concentration in pCi/g, dry[a] ^{40}K	^{60}Co
[illegible]	[illegible]	Muscle	[illegible]	[illegible]
		Mantle	[illegible]	[illegible]
[illegible]	[illegible]	Kidney	[illegible]	[illegible]
[illegible]		Remainder	[illegible]	[illegible]
[illegible]	[illegible]	Muscle	[illegible]	[illegible]
		Mantle	[illegible]	[illegible]
[illegible]		Kidney	[illegible]	[illegible]
[illegible]		Remainder	[illegible]	[illegible]
[illegible]	[illegible]	Muscle	[illegible]	[illegible]
[illegible]		Mantle	[illegible]	[illegible]
[illegible]		Kidney	[illegible]	[illegible]
[illegible]	[illegible]	Remainder	[illegible]	[illegible]

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[a] [illegible] ^{40}K and ^{60}Co [illegible]

[illegible]

APPENDIX TABLE 12

Predominant Radionuclides in Plants Collected at Rongelap Atoll in September 1976

Island	Site	Sample Type		Radionuclide Concentration in pCi/g, dry[a]			
				^{60}Co	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Rongelap	[illegible]	Coconut	meat	[illegible]	[illegible]	[illegible]	[illegible]
			milk	na[b]	[illegible]	[illegible]	na[b]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	na	na
	[illegible]			[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]		meat	[illegible]	[illegible]	[illegible]	[illegible]
			milk	[illegible]	[illegible]	na	na
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		meat	[illegible]	[illegible]	[illegible]	[illegible]
			milk		[illegible]	[illegible]	[illegible]
	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]				[illegible]	[illegible]	[illegible]
Rongelap	[illegible]	Pandanus	fruit	[illegible]	[illegible]	[illegible]	na
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

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a. [illegible]

b. [illegible]

APPENDIX TABLE 13

Predominant Radionuclides in Coconut Crabs Collected at Rongelap Atoll in September 1976

Island	Tissue	^{54}Mn	^{60}Co	^{137}Cs	^{90}Sr	^{239,240}Pu
		Radionuclide Concentration in pCi/g, [illegible]^{a}				
[illegible]	Muscle	[illegible]	0.66±0.06	130±0.6	[illegible]	0.013±0.002
"	Hepatopancreas	[illegible]	[illegible]	[illegible]	[illegible]	0.058±0.0[illegible]
"	Exoskeleton	[illegible]	ns^{b}	[illegible]	[illegible]	[illegible]
Naen	Muscle	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	Hepatopancreas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	Exoskeleton	ns	[illegible]	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
	[illegible]	ns	ns	[illegible]	[illegible]	ns
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns
"	[illegible]	[illegible]	ns	[illegible]	ns	ns
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	ns	ns	[illegible]	[illegible]	[illegible]

a. [illegible]

b. ns = [illegible]

A P P E N D I X   T A B L E   14

Some Radionuclides in Soil Collected on Rongelap Island, Rongelap Atoll, in September 1976

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry^a			
		[illegible]	[illegible]	[illegible]	[illegible]
1. Sample sites along trail from church to ocean					
Site #1 "Coconut ridge"	0-2.5	0.30±0.07	37 ±0.4	0.56±0.17	1.4±0.10
Site #2	0-2.5	0.35±0.07	73 ±0.4	1.6±0.24	3.8±0.34
Site #3	0-2.5	[illegible]	73 ±0.5	1.7±0.27	1.7±0.21
Site #4 "Center of village"	0-2.5	0.34±0.07	71 ±0.4	1.1±0.2	1.8±0.20
Site #5	0-2.5	0.48±0.08	50 ±0.3	2.1±0.37	1.7±0.31
Site #6	0-2.5	ns^b	75 ±0.4	1.57±0.20	1.5±0.20
"	2.5-5	0.14±0.07	71 ±0.4	0.57±0.19	1.19±0.15
"	5-10	ns	2.6±0.2	0.20±0.07	0.20±0.09
Site #7 Edge of village	0-2.5	0.23±0.07	27 ±0.4	1.1 ±0.31	2.2±0.27
Site #8 "Ocean beach"	0-2.5	ns	1.7±0.2	ns	ns
[illegible]	[illegible]	ns	27 ±0.7	ns	ns
"	0-2.5	0.2±0.07	38 ±0.2	0.7±0.19	0.8±0.21
	2.5-5	0.27±0.09	6 ±0.5	0.22±0.18	1.08±0.1
	5-10	ns	0.7±0.1	ns	ns
	10-15	0.11±0.08	12 ±0.5	ns	ns
"	15-20	ns	1.7 ±0.1	ns	ns
"	20-35	ns	0.70±0.1	ns	ns
"	35-50	ns	0.16±0.1	ns	ns

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a. The error values are two sigma propagated counting errors for a single sample.

b. ns: not significant, the net sample count is less than the two sigma counting error.

A P P E N D I X T A B L E 15

Predominant Radionuclides in Soil Collected on Eniaetok Island,
Rongelap Atoll, September 1976

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[a]					
		[illegible]	[illegible]Cs	[illegible]Eu	[illegible]	[illegible] Pu	[illegible]
Site #1	0-2.5	1.65±0.12	23±0.7	[illegible]	[illegible]	nd[b]	[illegible]
	2.5-5	[illegible]	[illegible]	[illegible]	[illegible]	nd	nd
	5-20.5	nd[b]	[illegible]	nd	[illegible]	nd	nd
Site #2	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	nd
	2.5-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5-10	nd	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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a. [illegible]

b. nd = not significantly [illegible]
analysis.

A P P E N D I X T A B L E 16

Predominant Radionuclides in Soil Collected on
Kabelle Island, Rongelap Atoll, in September 1976

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[a]					
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	^{90}Sr
Site #1 [illegible]	0-2.5	[illegible]	34 ±[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	2.5-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	5-10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	ns[b]	[illegible]	ns	[illegible]	ns[b]	ns
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
"	[illegible]	ns	[illegible]	ns	ns	ns	ns
Site #2 [illegible]	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	ns	[illegible]
"	2.5-5	[illegible]	[illegible]	ns	[illegible]	ns	ns
"	5-10	[illegible]	[illegible]	ns	ns	ns	ns
Site #3 [illegible]	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	2.5-5	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
"	5-10	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
Site #4							
"	0-2.5	1.8 ±0.[illegible]	22 ±[illegible]	6.[illegible] ±0.36	[illegible]	[illegible]	[illegible]
"	2.5-5	[illegible] ±0.14	2[illegible] ±0.9	3.5 ±0.37	6.6 ±0.4	ns	ns
"	5-10	[illegible]	[illegible]	0.75±0.20	[illegible] ±0.23	ns	ns
Site #5	0-2.5	0.47±0.09	52 ±0.7	1.6 ±0.26	3.3 ±0.37	4.[illegible]	23 ±3.5
"	[illegible]	[illegible]±0.07	6.2±0.3	ns	0.15±0.11	na	na
"	5-10	ns	3.7±0.2	ns	ns	na	na

a. The error values for all radionuclides are two-sigma, propagated, counting errors for a single sample.

b. ns = not significant; the net sample count is less than the two-sigma, propagated counting error. na = not analyzed.

APPENDIX TABLE 17

Predominant Radionuclides in Soil Collected on Naen Island, Rongelap Atoll, in September 1976

Collection Location	Soil Depth (cm)	^{60}Co	^{125}Sb	^{137}Cs	^{155}Eu	^{207}Bi	$^{239+240}Pu$	^{90}Sr
		Radionuclide Concentration in pCi/g, dry[a]						
Site #1	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	26 [illegible]	[illegible]	[illegible]
"	2.5-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	5-10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	10-15	[illegible]	[illegible]	[illegible]	ns	ns	[illegible]	[illegible]
"	15-20	ns	ns	[illegible]	ns	ns	ns	ns
"	20-25	ns	ns	[illegible]	ns	[illegible]	ns	ns
"	25-30	ns	ns	[illegible]	ns	ns	ns	[illegible]
Site #2	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	2.5-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
"	5-10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns
"	10-15	[illegible]	[illegible]	[illegible]	ns	[illegible]	ns	ns
"	15-20	[illegible]	ns	[illegible]	[illegible]	[illegible]	ns	ns
"	20-25	[illegible]	ns	[illegible]	ns	ns	ns	ns
"	[illegible]	ns	ns	[illegible]	ns	ns	ns	ns
"	50-75	ns	ns	[illegible]	ns	ns	ns	na
Site #3	0-2.5	1.2 ±0.12	[illegible]	196 ±1	5.9 ±0.34	11 ±0.14	[illegible] ±2.9	62 ± [illegible]
"	2.5-5	3.1 ±0.21	1.3 ±[illegible]	[illegible]	6.9 ±[illegible]	14 ±[illegible]	na	na
"	5-10	2.1 ±0.16	1.2 ±0.49	155 ±1.1	[illegible] ±0.45	5.4 ±[illegible]	na	na
"	10-15	0.77±0.11	0.91±0.29	44 ±0.7	0.78±0.24	2.0 ±0.31	na	na
"	15-20	[illegible] ±0.08	[illegible]	[illegible]	[illegible] ±0.11	[illegible]	na	na
"	[illegible]	[illegible]	[illegible]	[illegible]	ns	ns	na	na
"	[illegible]	[illegible] ±0.04	ns	0.6 ±0.1	ns	ns	na	na
"	[illegible]	ns	ns	ns	ns	ns	na	na

Table 17 (Cont.)

Collection Location	Soil Depth (cm)	Radionuclide Concentration in pCi/g, dry[a] ^{60}Co	^{125}Sb	^{137}Cs	^{154}Eu	^{241}Am	^{239,240}Pu	^{90}Sr
[illegible]	0-2.5	5.5 ±0.10	[illegible]	202 ±[illegible]	27 ±[illegible]	22 ±[illegible]	57 ±3.[illegible]	236 ±36
"	2.5-5	1.4 ±0.11	ns	56 ±[illegible]	1.4 ±0.13	3.3 ±0.27	na	54 ±4.[illegible]
"	5-10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na	[illegible]
"	10-15	ns	ns	[illegible]	ns	ns	na	na
"	15-20	ns	ns	[illegible]	ns	[illegible]	na	na
"	20-25	[illegible]	ns	[illegible]	ns	ns	na	na
"	25-30	ns	[illegible]	[illegible]	ns	[illegible]	na	na
[illegible]	0-2.5	5.4 ±0.[illegible]	ns	[illegible]	[illegible]	27 ±[illegible]	[illegible] ±3.3	[illegible]
"	2.5-5	[illegible]	[illegible]	23 ±[illegible]	[illegible]	[illegible]	na	na
"	5-10	[illegible]	ns	[illegible]	ns	[illegible]	na	na
"	10-15	ns	[illegible]	[illegible]	ns	ns	na	na
"	15-20	ns	ns	[illegible]	ns	ns	na	na
[illegible]	0-2.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	na	[illegible]
"	2.5-5	[illegible]	ns	15 ±[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	5-10	[illegible]	[illegible]	22 ±[illegible]	ns	[illegible]	[illegible]	[illegible]
"	10-15	[illegible]	ns	[illegible]	[illegible]	[illegible]	na	na
"	15-25	[illegible]	[illegible]	[illegible]	ns	[illegible]	na	na

a. [illegible] error values for all radionuclides are two-sigma, propagated, counting errors for a single sample.

b. [illegible] not significant; [illegible] net sample count [illegible] less than the two-sigma, propagated counting error. na = not analyzed.

APPENDIX TABLE 18

Predominant Radionuclides in Plants Collected on Bikini Island in September and October 1976

Sample Type	Collection Site	Radionuclide Concentration in pCi/g, dry[a] ^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Coconut, [illegible]	1st BLS, row 35,6	ns[b]	[illegible]	na[b]	na
"	[illegible]	ns	[illegible]	na	na
"	Pit #5	ns	[illegible]	na	na
"	[illegible]	[illegible]	[illegible]	na	na
"	[illegible]	ns	[illegible]	na	na
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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[a] The error values for all radionuclides are two sigma, [illegible] counting errors for a single sample.

[b] ns = not significant, the net sample count is less than the two sigma, propagated counting error. na = not analyzed.

APPENDIX 5

GAMMA EMITTING RADIONUCLIDES IN
PLANTS AND SOIL SAMPLES COLLECTED
AT BIKINI ISLAND IN OCTOBER 1977 AND APRIL 1976

APPENDIX 5

Gamma Emitting Radionuclides in Plant and Soil Samples

Collected at Bikini Island in October 1977 and 1974-76

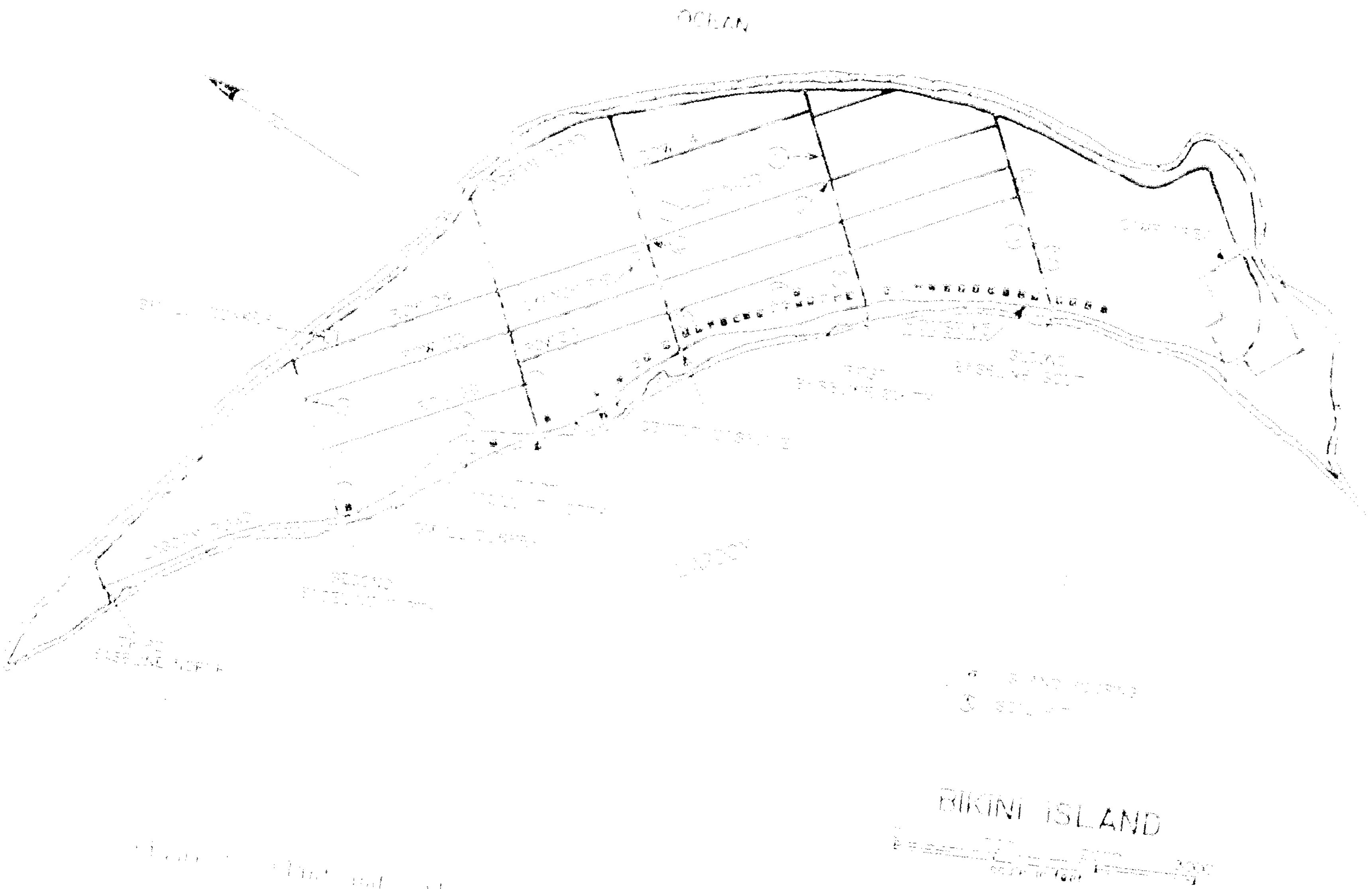
A field trip to Bikini Island in the spring of 1977 was cancelled because of the unavailability of the support ship [illegible]. However, a collection of samples was made in October 1977 as part of another program, the Laboratory's "Biogeochemistry of Transuranic Nuclides" project funded by the Division of Biomedical and Environmental Research. This collection was made on a time available basis and therefore was not as extensive as planned for the original field trip but some of the samples were collected at sites where samples had been collected in 1974, 1975 or 1976. Following is the first report of the gamma emitting radionuclides in the October 1977 Bikini Island samples and also, for the purpose of comparison, the results of analysis of similar samples collected in previous years.

The locations of the sites at Bikini Island where samples were collected in October 1977 are shown in Figure 1. The dominant gamma emitting radionuclide is ^{137}Cs and the results of analysis for this radionuclide in 33 samples from edible plants (coconuts, pandanus, breadfruit, [illegible]) are presented in Table 1 and in Figure 2. The values range from 3×10^{1} to 4.2×10^{4} pCi per gram of dry sample. Also in this table and figure are the results of analysis for ^{137}Cs in samples collected from the same collection sites in either 1974, 1975 or 1976. A perusal of the data in Table 1 and Figure 2 indicates no strong decreasing trend for ^{137}Cs in these samples for the 1974-1977 period. In fact, many of the 1977 values are greater than those for earlier years. However, the differences between years for the Cs values probably are not statistically significant because the values in Table 1 are single sample counts and the sample may not have been collected in all cases from the same plant as were samples in other years.

Soil profile samples were collected at two sites, Pit 29 and Pit [illegible], in October 1977 and the results of analysis of these samples for ^{137}Cs, ^{241}Am, ^{60}Co, and ^{155}Eu are given in Table 2. The dominant radionuclide was ^{137}Cs and the radionuclide of second greatest abundance was ^{241}Am. Also presented in Table 2 are the results of analysis of soil profile samples collected at Pit 29 in 1974. The 1977 values appear to be greater than the 1974 values for samples that are not [illegible] but the difference may not be statistically significant.

The data for ^{137}Cs in soil profile samples from Pit 29 for 1977 and 1974 are shown graphically in Figure 3. For samples above 30 cm, the 1977 values are slightly greater than the 1974 values which suggests little or no downward movement of ^{137}Cs during this period. The rate of decrease of ^{137}Cs with soil depth appears to be approximately exponential with the values of the surface and at [illegible] cm being 10^{2} and $2 \times 10^{[illegible]}$ pCi per gram of dry sample, respectively. Also in Figure 3 are ^{137}Cs values for pandanus and breadfruit samples collected at the same site (Pit 29), as the soil profile samples. The maximum value was 4.2×10^{4} pCi of ^{137}Cs per gram of dry sample for the edible portion of pandanus fruit collected in October 1977.

The 1977 radionuclide values appeared to be significantly greater at Pits 9, K and C and at house 37 and [illegible] than those found in recent years. For this reason, the persons collecting the samples were asked about the opportunities to collect samples in 1977 that duplicated the samples collected in recent years. Pit 9 was positively identified but the face of the pit from which samples had been collected earlier could not be identified because of sloughing. Pit K was dug in a depression in the ground but there was no positive identification that this was the former site of Pit K. Pit C [illegible] a filled trench that could not be located. As a result the sandbox [illegible] that was sampled in 1975 could not be positively identified as there were several [illegible] in the area. At house 21, the trench could not be found but the [illegible] behind the house that was sampled in 1977 was probably the one sampled previously. At [illegible], row 35, the trench could not be found and the [illegible] sampled was one of three that was present. Therefore, because of the uncertainty in obtaining duplicate samples, some precision in the estimate of the differences in radionuclide values between years has been lost.



[illegible] Plant and soil sampling sites at Bikini Island, October 1977

Table 1. Cesium-137 values for plants collected on Bikini Island in Octob
1977 and for similar samples collected between 1974 and 1976.

Sample Type		Collection Site	137Cs in pCi/g of dry sample* 1977	1976	1975	1974
Coconut	Leaves	Soil Pit A	240		105	
"	"	" 2	92		181	
"	"	" 3	31	133	114	
"	"	" 5	154		318	
"	"	" [illegible]	199		159	
"	"	" 6	58		69	
"	"	" #2	70			
"	"	" 13	110	40		
"	"	" #1	144	103	59	32
"	"	[illegible] Row 3	[illegible]	39		
"	Meat	Soil Pit #2	687			
"	"	" 3	78			
"	Milk	" #2	2240			
"	"	" 3	672			
Pandanus	Edible Portion	House #5	3820			2510
"	Inedible Portion	"	4440			2610
"	Leaves	"	2710	1050		1010
"	Edible Portion	Soil Pit #1	450	398		
"	Inedible Portion	"	294	164		
"	Leaves	"	250	104		
"	Edible Portion	Soil Pit #9	2670			
"	Inedible Portion	"	2050			
"	Leaves	"	417	2150		
"	"	Soil Pit C	3050	723	337	
Breadfruit	Leaves	Soil Pit C	52	42	63	
"	"	" D	282	326	37	
"	"	" 29	62	57	95	[illegible]
"	"	Soil Pit [illegible]	72	26	29	
"	Edible Portion	"	58	64		
"	Inedible Portion	"	87	55		
Papaya	Leaves	House #24	158			
"	Edible Portion	"	192	39		
"	Inedible Portion	"	696	74		

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* Single sample values. Counting error (2 SD), 5% or less of net count.

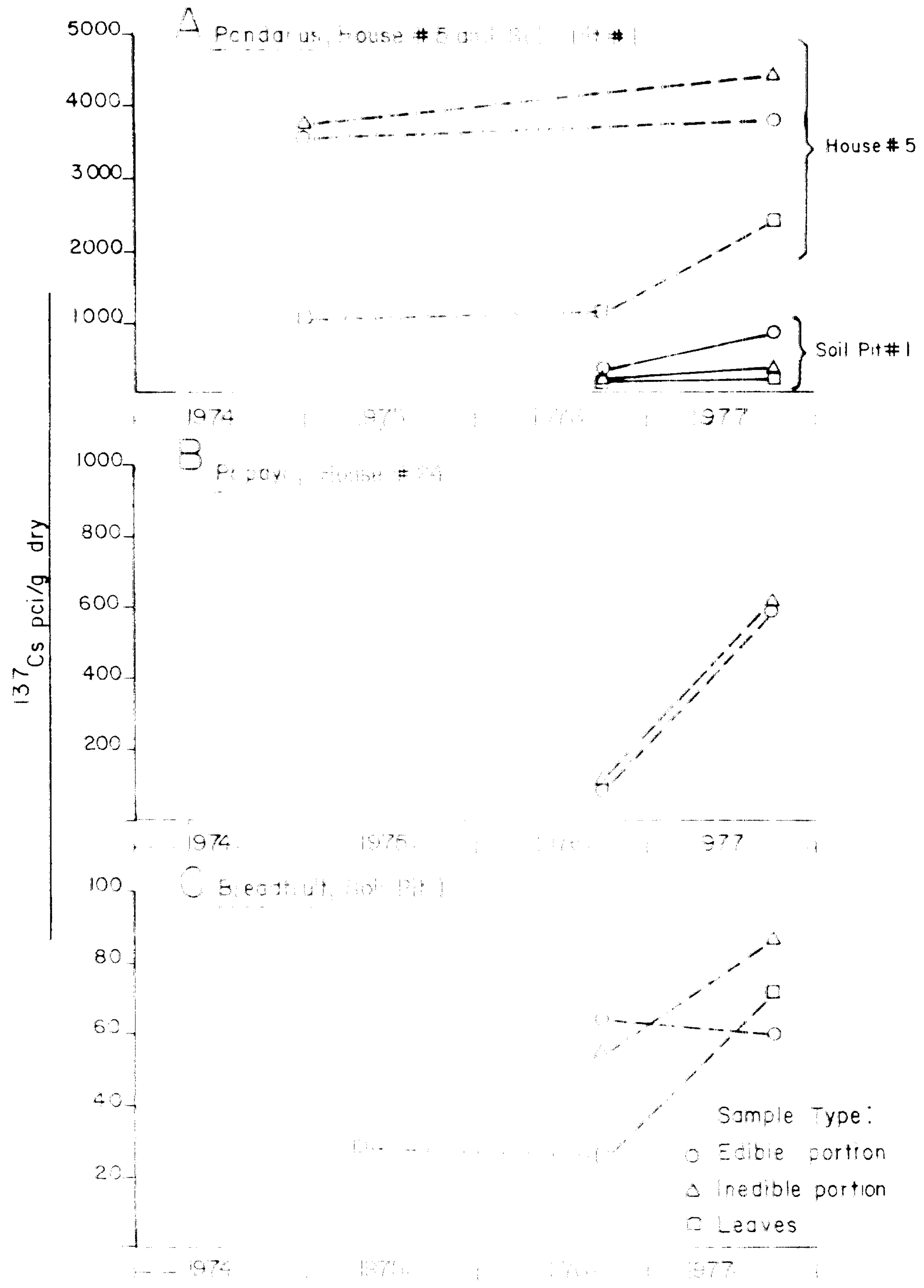

Figure 7. Cesium-137 values for food plant samples collected at various locations on Bikini Island, 1974-1977.

Table 2. Predominant gamma-emitting radionuclides in soil profile samples collected at Bikini Island in October 1977 and December 1974

Collection Site	Soil Fraction	Collection Date	Radionuclide concentration in pCi/g, dry[a] ^{241}Am	^{137}Cs	^{60}Co	Eu
Pit #9	0-2.5 cm	26 Oct. 1977	[illegible]	136 ± 1.1	1.8 ± 0.1	2.9 ± 0.3
	2.5-5	"	6.6 ± 0.5	101 ± 0.9	1.4 ± 0.1	1.9 ± 0.3
	5-10	"	1.7 ± 0.2	17 ± 0.4	0.4 ± 0.1	0.4 ± 0.1
	10-15	"	2.1 ± 0.3	13 ± 0.3	ns[b]	ns
	15-20	"	ns	3.7 ± 0.2	ns	ns
	20-25	"	ns	1.2 ± 0.1	ns	ns
	25-35	"	0.4 ± 0.2	0.4 ± 0.1	ns	ns
	35-47	"	0.7 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	ns
	47-59	"	1.7 ± 0.2	0.2 ± 0.1	ns	ns
Pit K	0-2.5 cm	30 Oct. 1977	2.6 ± 0.3	78 ± 0.5	0.6 ± 0.1	0.7 ± 0.2
	2.5-5	"	2.4 ± 0.5	72 ± 0.9	0.5 ± 0.1	0.7 ± 0.2
	5-10	"	2.6 ± 0.3	52 ± 0.7	0.5 ± 0.1	0.7 ± 0.2
	10-15	"	1.3 ± 0.3	36 ± 0.6	0.3 ± 0.1	0.4 ± 0.2
	15-25	"	1.5 ± 0.3	36 ± 0.6	0.3 ± 0.1	0.3 ± 0.2
	25-35	"	1.0 ± 0.2	15 ± 0.3	0.2 ± 0.03	0.2 ± 0.2
Pit #9	0-2.5 cm	8 Dec. 1974	3.8 ± 0.3	60 ± 0.5	1.2 ± 0.1	1.6 ± 0.1
	2.5-5	"	3.0 ± 0.2	77 ± 0.5	1.1 ± 0.1	1.7 ± 0.1
	5-10	"	1.3 ± 0.2	29 ± 0.4	0.6 ± 0.1	0.6 ± 0.1
	10-15	"	ns	2.5 ± 0.1	ns	ns
	15-25	"	ns	1.2 ± 0.1	0.01 ± 0.02	ns
	25-50	"	ns	0.4 ± 0.04	ns	ns
	50-75	"	ns	0.1 ± 0.03	ns	ns
	75-100	"	ns	0.1 ± 0.03	ns	ns

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a. Values for single samples ± counting error (2σ).

b. ns = sample count not significant.

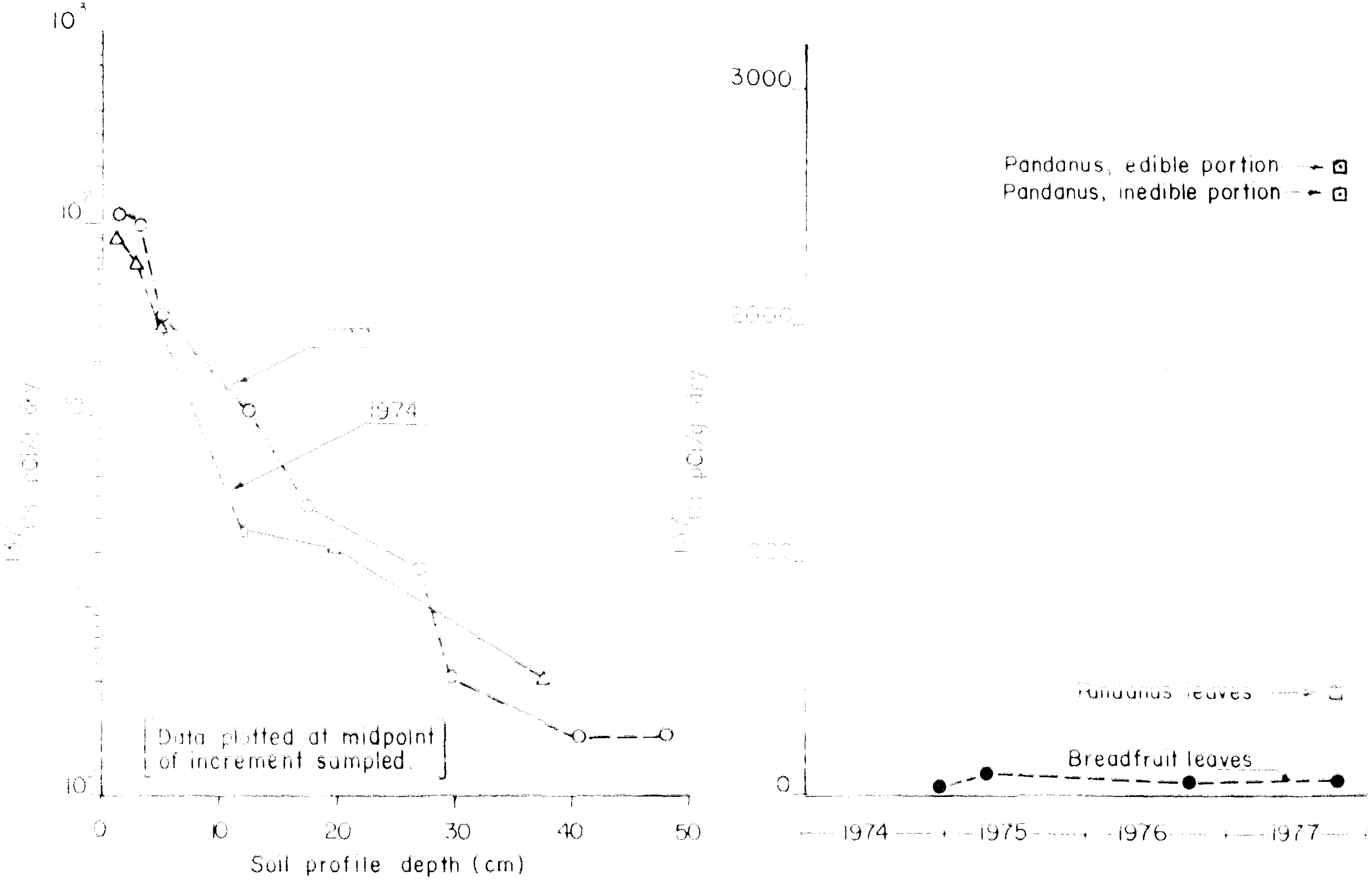

Figure 3. Cesium-137 values in soil and plant samples from Pit #9 on Bikini Island, 1974-1977.

APPENDIX 6

INTERLABORATORY COMPARISON PROGRAM AND RADIONUCLIDE DETECTION LIMITS

APPENDIX 6

Interlaboratory Comparison Program and Radionuclide Detection Limits

Since 1971, the laboratory has participated extensively in interlaboratory comparison programs to determine the kind and amount of "unknown" radionuclides in both standard and environmental samples. From these results and from the results of routine analysis of duplicate and [illegible] samples, we have corrected and improved our methods when deemed necessary [illegible]. In this way established and maintained the quality of our analytical work.

For the interlaboratory program we have analyzed about 170 samples including about 10 [illegible] species. The current programs are with the International Atomic Energy Agency (IAEA), the Environmental Protection Agency (EPA) and the Environmental Measurements Laboratory (EML) (formerly the Health and Safety Laboratory (HASL)). For IAEA, [illegible] samples are analyzed yearly; for EPA, [illegible] water and [illegible] quarterly; and for EML, samples of fresh water, sea water, [illegible], marine sediments, fish meal, vegetation meal, and soil are analyzed from time to time.

The results of our analysis and of all other laboratories participating in these programs have been tabulated and [illegible] prepared of the tabulation, "Summary of Quarterly [illegible] Results of [illegible] Analysis". The report was prepared by Dr. W. [illegible] (August 197[illegible]) and is available upon request. Generally, our results have compared favorably with the known values in the standards and with the mean values for all laboratories for the "unknown" radionuclides in the environmental samples.

The methods of analysis used for the interlaboratory program and commonly used in our laboratory for the analysis of other samples are as follows:

1. alpha emitting radionuclides — [illegible] methods for ^{210}Po, ^{238}Pu, ^{239,240}Pu and ^{241}Am; zinc sulfide scintillation phototube counting for gross alpha measurements.

2. beta emitting radionuclides — chemical separation and counting for ^{90}Sr and ^{131}I; liquid scintillation methods for [illegible] and low background, gas counting methods for gross beta measurements.

3. gamma emitting radionuclides — Ge(Li) diode or NaI(Tl) detection systems for radionuclides such as ^{54}Mn, ^{60}Co, ^{65}Zn, [illegible], [illegible], ^{207}Bi, ^{241}Am, etc.; for x-ray emitters such as [illegible], chemical separation and proportional counting.

The limits of detection for these methods are important since they govern the amount of a radionuclide that can be detected if it is present in a sample. Many factors influence the limit of detection, including the type of detector and analyzer, the presence of other radionuclides, the duration of the counting period, the size and density of the sample, and the geometry relationship of the sample and detector. Hence, the actual limits of detection can vary considerably for various radionuclides and types of samples, but can be summarized by stating that the detection limits are approximately as follows:

By gamma detection	
^{40}K	2.1 pCi/g or less
^{7}Be, ^{103}Ru, [illegible], [illegible], [illegible], [illegible]	0.41 " "
^{95}Nb, ^{95}Zr, [illegible], [illegible], [illegible], [illegible]	0.12 " "
By beta detection	
^{3}H	[illegible] pCi/liter or less
^{90}Sr	0.2 pCi/g or less
By X-ray detection	
^{55}Fe	0.02 " "
By alpha detection	
[illegible], ^{240}Pu	0.02 " "