UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

410359

JAN 26 1973

Chairman Schlesinger
Commissioner Ramey
Commissioner Larsen
Commissioner Doub
Commissioner Ray

THRU: General Manager

ENIWETOK RADIOLOGICAL SURVEY

This memorandum provides information regarding current activities on Eniwetok Atoll. These activities concern the surveys essential to the cleanup, rehabilitation, and resettlement of the atoll in connection with the announced return of Eniwetok to the Trust Territory of the Pacific Islands (TTPI).

In April 1947 the United Nations formally designated the former Japanese Pacific Mandates (Eniwetok included) as Trust Territories to be administered by the United States. Upon written notification to the U.N., Eniwetok was designated a nuclear testing site in December 1947, with the first test series there, SANDSTONE, being conducted in the spring of 1948. Prior to SANDSTONE, the Eniwetok people, about 136 in number, were moved by the United States to Ujelang Atoll where they still reside, although their number has now increased to about 432. Additional test series were conducted in the atoll during the years 1951 (GREENHOUSE), 1952 (IVY), 1954 (CASTLE), 1956 (REDWING), and 1958 (HARDTACK - PHASE I). The last of 43 tests was in July 1958. All tests have been listed publicly.

Geographic location of the atoll is shown in Figure 1. Its remoteness suggests inherent costly operations to accomplish the necessary surveys and subsequent cleanup. Figure 2 identifies the islands of the atoll and general location of the nuclear tests conducted.

On April 18, 1972, High Commissioner Johnston and Ambassador Williams jointly announced the intention of the United States to return Eniwetok Atoll to the TTPI subject to retention of some minor residual rights. Subsequently, the Department of Interior (DOI), Department of Defense (DOD), and AEC determined that a comprehensive and coordinated program to survey and clean up Eniwetok Atoll must be undertaken to make Eniwetok habitable. The program was divided into three phases: (1) Pre-cleanup Radiological and Engineering Survey, (2) Cleanup, and (3) Rehabilitation and Resettlement. As with Bikini Atoll, responsibility for cleanup and rehabilitation rests with the DOD and DOI respectively. AEC is responsible for conducting a radiological survey, assessing the results, and establishing criteria and constraints for cleanup and rehabitation, involving other agencies, as appropriate.

Organization of the Eniwetok Radiological Survey, now under way, is shown in Figure 3. The Washington Interagency Group is charged with coordination of actions to effect overall Eniwetok Atoll objectives. The Manager, Nevada Operations Office, has been directed to plan, organize, and conduct the AEC radiological field survey to develop sufficient data on the total radiological environment of Eniwetok Atoll. Technical standards and requirements for the survey and cleanup operations will be provided by responsible divisions within AEC Headquarters. Specifically:

(a) The Division of Biomedical and Environmental Research (DBER) has the responsibility for reviewing and guiding the preparation of a report on the radiological status of the atoll. This report will be prepared by the Data Evaluation Group at Lawrence Livermore Laboratory.

(b) The Division of Operational Safety (DOS) shares responsibility with DBER and the Division of Military Application (DMA) for planning the survey. DOS will provide the coordination of these plans and their extension during the survey with the Assistant General Manager for Environment and Safety (AGMES). DOS will also provide information on the survey to EPA staff at the Washington level upon request. DOS will review and evaluate all data and assessments relevant to the feasibility of various cleanup methods and methods for disposal of hazardous materials. Cleanup criteria, requirements, guidelines, and environmental and health protection standards to be employed during cleanup operations will then be developed by DOS in consultation with appropriate AEC staff sections and other agencies.

(c) The AGMEA has the overall authority and responsibility within the AEC for coordinating matters related to the rehabilitation of the Eniwetok Atoll.

The radiological survey, and the interpretive effort associated with it, is a large program superimposed on a number of technically qualified organizations. Survey activities and analytical efforts by responsible organizations are reflected in Figures 4 and 5.

As an example of the complex radiological situation which exists on Enewetok, one island, Runit, is shown in Figure 6 with a plot of gamma exposure rates on that island. Contamination from eight tests on Runit is measurable today. An early preliminary survey has confirmed the presence of a plutonium-bearing, sand layer outcropping on the ocean side of the island, and the existence of solid plutonium-bearing chunks, grains, and other particulates on the island surface and near surface. Earth and debris moving activities during and after test operations have resulted in a complex radiological situation in which adjacent areas may be quite different as to levels and vertical distribution of radioactivity in soil. Data available to date indicate that radiological contamination is less severe on other islands but is sufficient to pose a considerable problem.

At a September 7, 1972, Interagency Meeting, the following agreements with respect to funding were reached:

(a) The AEC will fund the radiological aspects of the precleanup survey, the conduct of any other radiological survey activity that might be required to understand conditions in the environment as they relate to exposures of people and developments of standards, and the conduct of periodic follow-up radiological surveys that take place after cleanup. If later field and/or laboratory work is done by the AEC in support of cleanup, AEC should be reimbursed by DOD.

(b) DOD would be responsible for funding the engineering portions of the precleanup survey and those monitoring and survey activities that are required to support cleanup operations and to insure safety of personnel involved in cleanup activities. DOD also would fund the later cleanup of both radiological and non-radiological activities. DOI would be responsible for funding rehabilitation costs once cleanup is completed.

Present best estimate of the cost of the AEC precleanup radiological survey is $1.3M. Costs of subsequent studies and radiological monitoring activities are estimated to be approximately $1M per year for FY 1974 and beyond. DOD costs for cleanup and related activities are estimated at between $20-40M and may go higher. The actual final costs are highly dependent on the amount of soil and debris needed to be removed and subsequent disposal methods employed. To date the DOD has committed approximately $500K in the precleanup engineering survey.

The initial field survey was contemplated for the period October 12-December 6, 1972. The first week of this schedule was started, but not completed, when Typhoon Olga caused a suspension of activities. Subsequently, it was necessary to revise and reschedule the survey to account for weather factors and logistic limitations. An aerial radiological and photographic survey of the atoll was accomplished November 8-25 during the period of minimal logistic support. Survey activities were resumed during the week of November 27 on a revised schedule and will now extend to mid-February 1973. The AEC radiological survey now appears to be progressing smoothly and collected samples are being returned to the CONUS for analysis. Data to date, based mainly on the results of the aerial survey, appear to be generally consistent with earlier knowledge and expectations.

(signed)
F. C. Gilbert for

Frank A. Camm
Major General, USA
Assistant General Manager
for Military Application

Enclosures:
Figures 1, 2, 3,
4, 5, and 6

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OFFICE ▶	MA:Tests	MA:PA&B	DOS	DBER	AGMMA
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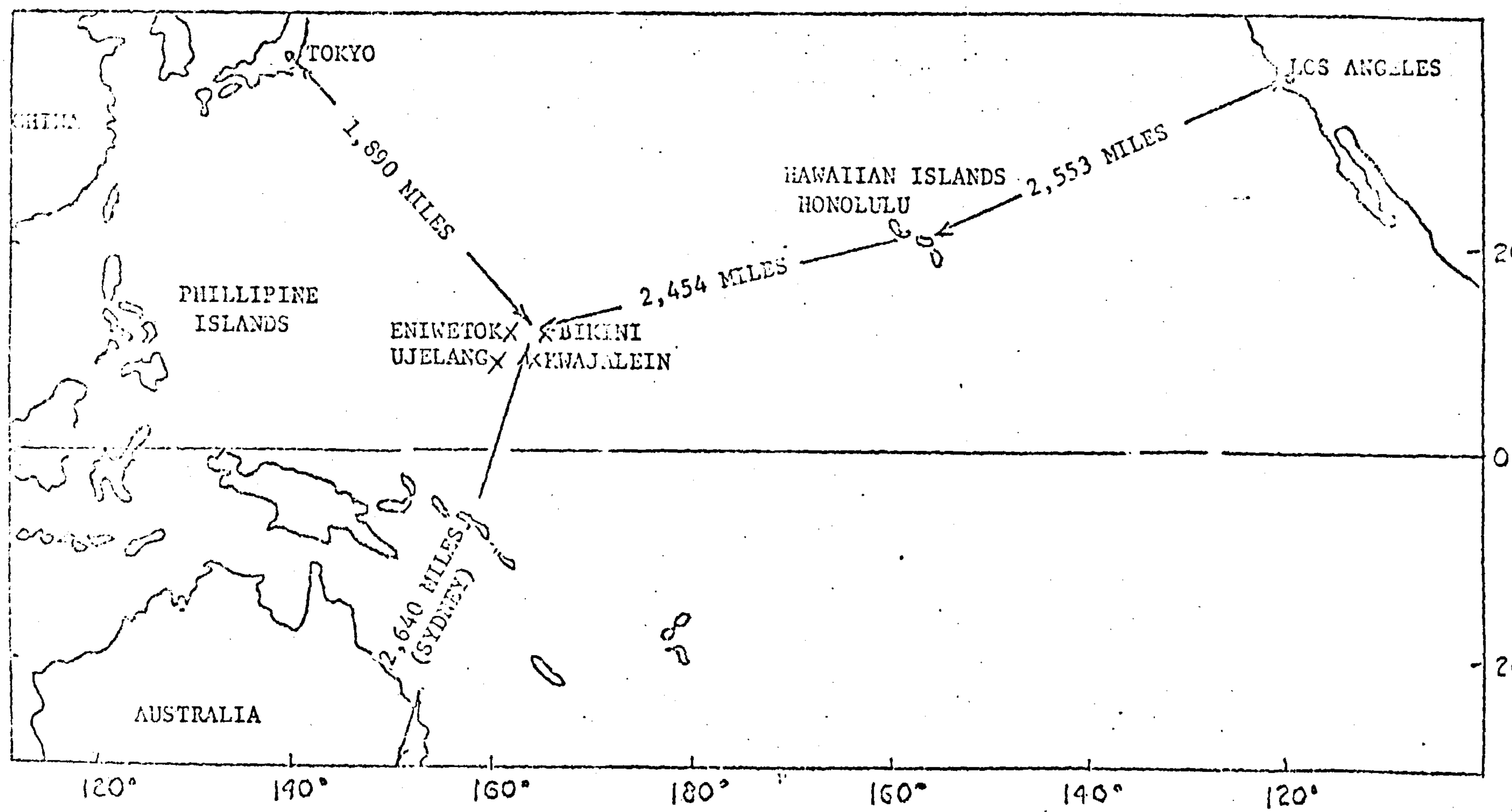
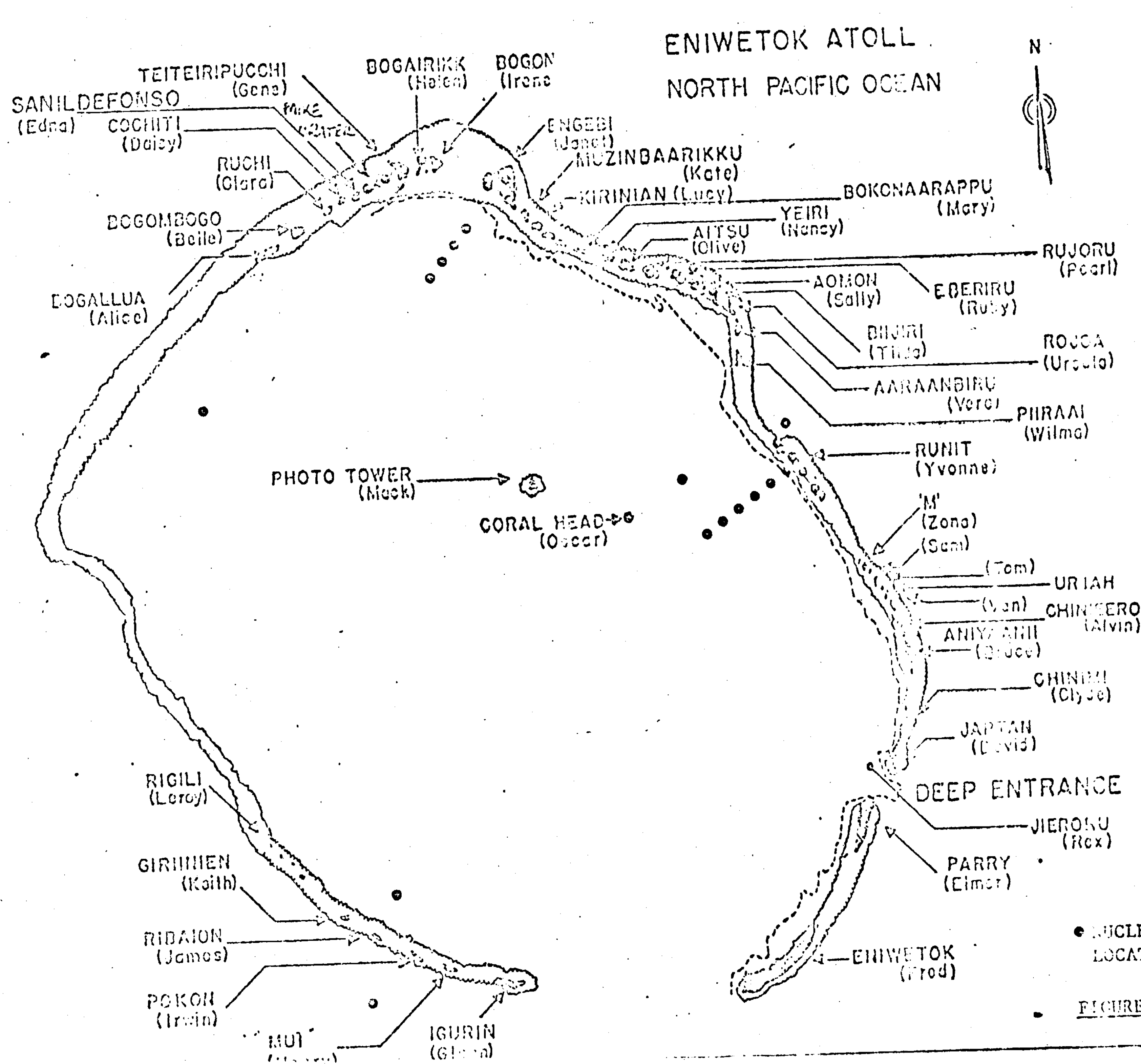

TOKYO
1,890 MILES
LOS ANGELES
2,553 MILES
HAWAIIAN ISLANDS
HONOLULU
2,454 MILES
PHILLIPINE
ISLANDS
ENIWETOK
UJELANG
BIKINI
KWAJALEIN
2,640 MILES
(SYDNEY)
AUSTRALIA
20°
0°
20°
120°
140°
160°
180°
160°
140°
120°

FIGURE 1



● NUCLEAR TEST LOCATIONS (APPRO

FIGURE 2

ORGANIZATION OF THE ENIWETOK SURVEY PROGRAM

MR. JOHN DEYOUNG ---- INTERIOR
CAPT GORDON SCHULLER- DOD (OASD/ISA)

CAPT WILLIAM W. GAY - AEC
EPA "COLLABORATION"

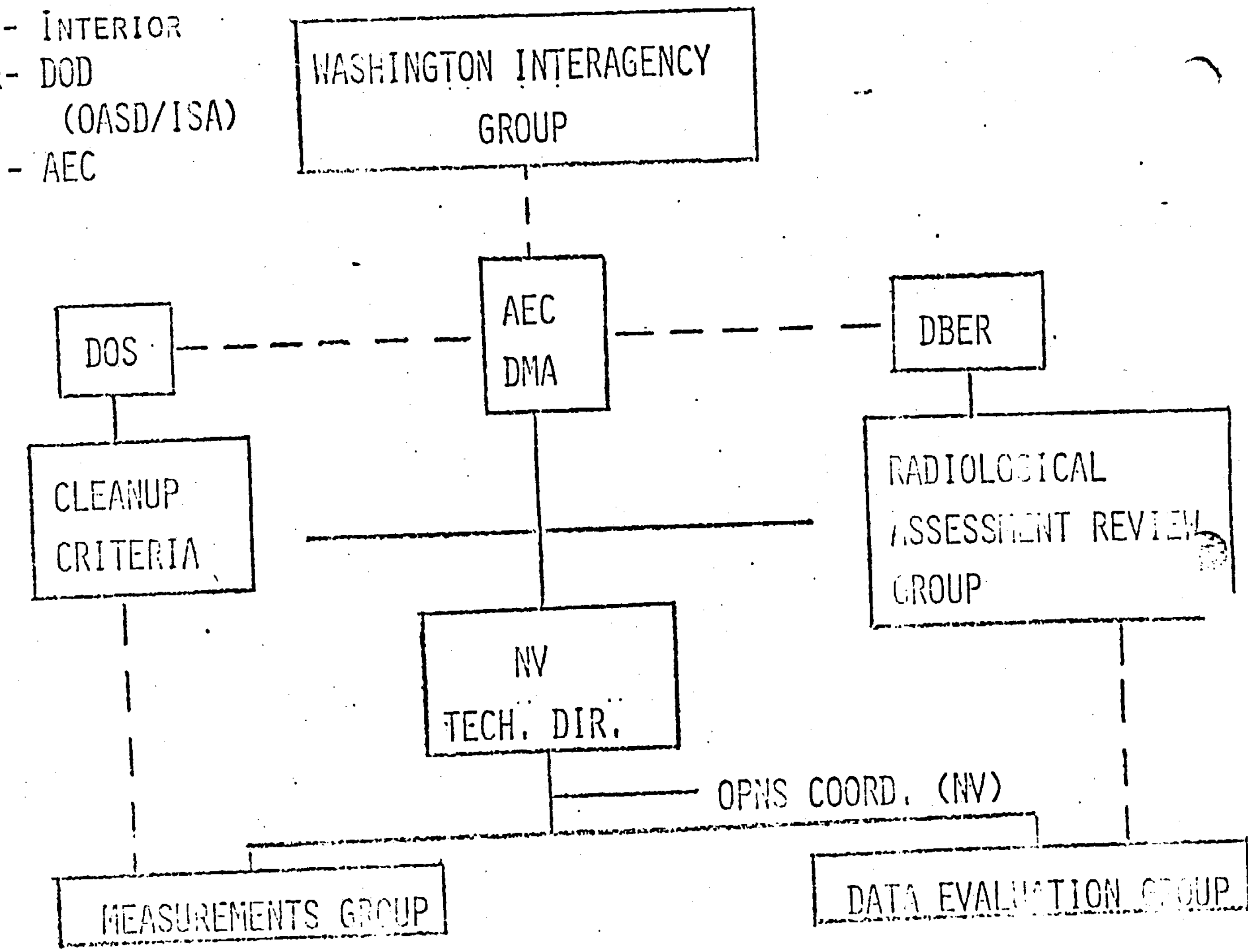


FIGURE 3

SURVEY DETAIL

EXTERNAL DOSE AND SOIL SURVEY (3000 SAMPLES)

EXTERNAL GAMMA DOSE AND DOSE RATE

SOIL SAMPLING -- CORES, SIDE WALL, AND SURFACE

AERIAL MEASUREMENTS (QUICK LOOK AND PHOTO)

AIR, BIOTA, AND POTABLE WATER SURVEY (1000)

AIR PARTICULATES

COLLECTION OF FOOD PLANTS AND ANIMALS

RAD CHEM ANALYSIS OF WATER

AQUATIC SURVEY (900 SAMPLES)

BIOCHEMICAL BEHAVIOR OF TRANSURANIUM ELEMENTS

SHALLOW WATER CORING, WATER SAMPLING, DREDGING, IN SITU DETECTION MEASUREMENTS

MARINE SAMPLING -- DEEPER REGIONS OF LAGOON

COLLECTION OF EDIBLE MARINE VERTEBRATES AND INVERTEBRATES

FIGURE 4

LABORATORY ANALYTICAL CAPABILITY

LABORATORY	KIND OF ANALYTICAL WORK
LLL	SAMPLE PREPARATION - SOIL AND BIOTA
	COMPLETE ANALYTICAL TREATMENT, SEA WATER
	GAMMA ANALYSIS, ALL TYPES OF SAMPLES, MARINE SURVEY
MCL	GAMMA ANALYSIS
	SOIL DISSOLUTION AND ANALYSIS FOR PU AND ^{90}SR
	ANALYSIS OF AIR FILTERS
UW	MARINE SURVEY
	^{55}FE ANALYSIS
	^{90}SR ANALYSIS
CONTRACT ANALYSES	GAMMA ANALYSIS
	SOIL DISSOLUTION AND ANALYSIS FOR PU AND ^{90}SR
NERC (EPA) LAS VEGAS	ANALYSIS FOR PU
LASL	PU HEALTH STUDIES

FIGURE 5

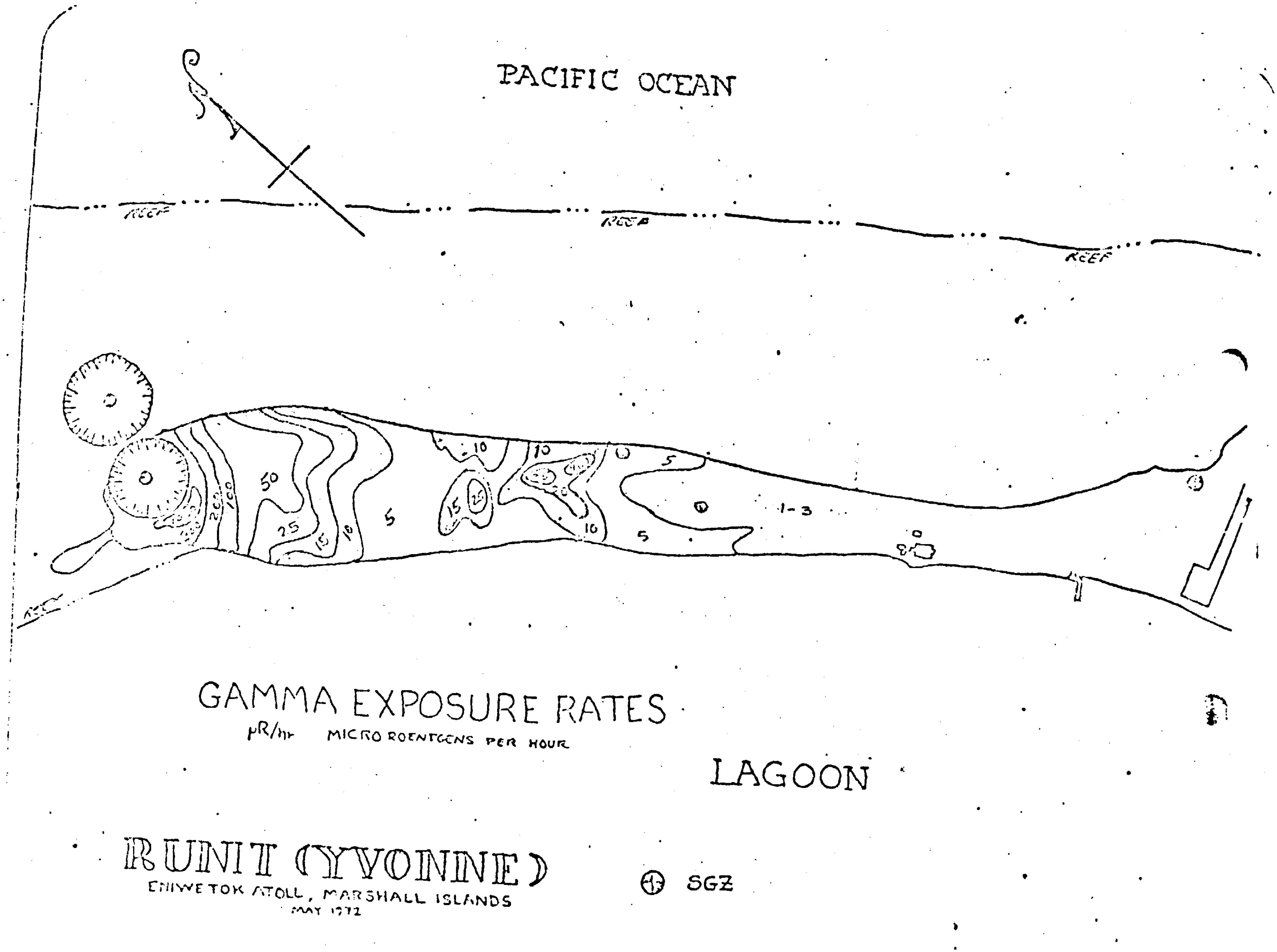

PACIFIC OCEAN
REEF
REEF
REEF
REEF
50
25
15
10
5
200
100
10
15
25
10
10
5
5
1-3
GAMMA EXPOSURE RATES
μR/hr MICRO ROENTGENS PER HOUR
LAGOON
RUNIT (YVONNE)
ENIWETOK ATOLL, MARSHALL ISLANDS
MAY 1972
SGZ

FIGURE 6

Health Physics Support

Field Monitoring (Radsafe support for field ops)

Film badging incl. processing, record keeping, etc.

Anticontamination clothing, laundry, etc.

Other personnel dosimetry, bioassay, etc.

Technical Support

Debris identification and classification.

* In situ measurement of soil.

*Soil sample collection and documentation.

*Sample preparation.

*Radiochemical analysis, both counting and wet chemistry.

Documentation of disposal of contaminated material.

*Interpretation of data for certification and documentation.

GAMMA DOSE RATES AT RONGELAP ATOLL, 1954-1963

INTRODUCTION

Rongelap Atoll, Marshall Islands, was accidentally contaminated on March 1, 1954 with radioactive fallout from a thermonuclear device detonated at Bikini Atoll some 80 miles to the west. Eighty-two natives residing on Rongelap Island were evacuated and repatriated in June 1957. The atoll, its inhabitants and its economy have been briefly characterized[1]. The decline of gamma dose rates resulting from the fallout is discussed in this report.

RESULTS

Dose rates on D + 1

Gamma dose rates at Rongelap Atoll on D + 1 (time of detonation plus one day) were estimated to be 3.5 r per hour at the inhabited islet of Rongelap in the south and 35 r per hour at uninhabited Lomuilal islet in the northern part of the atoll[2], Fig. 1. These estimates were based on extrapolations of measurements made two days after initial fallout[2]. The subsequent decline of gamma dose rates, based on survey meter readings taken three feet above the ground at Rongelap and Kabelle islets, is compared with the theoretical decay[3] in Figs. 2 and 3. The theoretical curve is based on fission products from slow neutron fission and the assumptions that there is no fractionation and that the radionuclides are distributed over an infinite plane, while at Rongelap measurable amounts of activity remained on the trees. The actual measurements fit closely to the theoretical decay curve for Rongelap islet and at least for the first four years after fallout at Kabelle islet in spite of the assumptions made in determining the theoretical curve and the variability of the field measurements. The measurements on one small islet may vary by a factor of more than three, even when the identical instrument is used by the same person.

Decline following first storm

About two weeks after initial contamination there was a storm with heavy rain, and a subsequent reduction in gamma dose rate somewhat greater than would have been expected on a theoretical basis[2,4], (Fig. 2).

Fallout in 1956 and 1958

The rises in gamma dose rates in 1956 and 1958 were due to operations Redwing and Hardtack. Even though there was a measurable amount of contamination, as was seen by the short-lived radionuclides present and by following the beta decay rates in plants collected in 1958, the total contribution was a fraction of one per cent of the fallout deposited in 1954. Therefore the Redwing and Hardtack fallout are insignificant when considering the long-range picture.

Selection of areas and reproducibility of repeated measurements

In March 1958, stakes were set out in various parts of Rongelap islet in an attempt to provide a means of repeating measurements at identical locations. Stakes proved to be unsatisfactory since they only served to attract the curious, which resulted in trampling and disturbance of the areas and in some cases removal of the stakes. A practical solution to this problem was to select general areas within which measurements were to be taken. These areas were located with relation to pathways, roads, buildings, and measured distances from landmarks. In each general area measurements were taken over different types of vegetation, soil, the pathways themselves, over litter, and under Pandanus trees and other tall plants. In August 1958, the set of measurements was repeated three times at Rongelap islet and twice at both Eniaetok and Kabelle islets. At Rongelap islet the average for each set of readings ranged from 0.046 to 0.067 mr/hr. At Eniaetok the range of the average readings was 0.073 to 0.079 mr/hr and at Kabelle islet, 0.137 to 0.178 mr/hr.

Local differences in dose rates at three feet

The highest levels measured were generally under trees, particularly under Pandanus trees where litter had accumulated. The highest levels at Rongelap islet in 1955 were measured in the remaining palm-frond huts where fallout remained trapped in the roof and the wall thatching. Readings one inch above the floor were lower than those at three feet above the ground and readings close to the walls and roof were highest of all. There were relatively high readings over some open areas where soil algae were abundant. The soil algae form a crust roughly one centimeter thick and retain most of the radionuclides from fallout.

Return to background level

The return to background level, < 0.02 mr/hr, occurred first, as would be expected, in the intertidal zone, except for a few small areas of beach rock covered with a film of algae. Levels of < 0.02 mr/hr were measured in July, 1957 in the intertidal zones at Kabelle and Rongelap islets and in the newly constructed village on Rongelap islet. Construction of the village entailed the removal of the thatched huts and bulldozing of a considerable part of the area.

Local differences in dose rates at one inch

Survey meter readings were also taken at one inch above the ground with the beta shield both open and closed. There was no apparent correlation between these readings and the gamma dose rate readings at three feet, except in a very general way, but such readings were useful in selecting areas from which to sample and indicated local distribution of the activity. For example, when measurements were made one inch over the ground with the shield open in 1959, the levels were higher after the litter was removed from the soil and there were markedly higher levels of activity over areas covered with soil algae than over bare sand. Attempts also were made with a survey meter to determine local differences in activity in trees. This was unsuccessful, since the general levels of activity masked local effects within the trees, even though laboratory analyses showed that the activity in lichens and mosses collected from the bark was several times higher than in the bare portions of the trees. The use of survey meters to determine the vertical distribution of activity in soil pits was impracticable due to the high background levels from surrounding contamination and the fact that the bulk of the radioactivity was in the surface inch or less of soil.

Film badges

In September 1959, film badges sealed against moisture were exposed at Rongelap and Kabelle islets to measure gamma doses in different areas. The badges were provided and set out by Radiation Safety personnel at the Pacific Proving Ground. The limit of detection was an accumulated dose of 10 mr. Three badges were placed at each location, one suspended by strings three feet above the ground and away from tree trunks, one three feet above the ground attached to a tree, and one on the ground. Gamma dose rates measured with a survey meter at each location indicated that the accumulated dose in 69 out of 116 film badges would be in excess of 10 mr, but less than 20 mr. The results were, however, negative for all badges. The discrepancy between the doses calculated from the survey meter measurements and those obtained with film badges may be explained by differences in sensitivity of the two methods to the gamma energies present in the field. Calibration was based on a radium standard rather than on actual fallout material. This discrepancy does not invalidate the decline curves in Figs. 2 and 3 since the theoretical curve (solid line) is based on measurements with a survey meter similar to those used for the various measurements made. However, the discrepancy does point out that while relative levels of activity can be determined accurately by any one type of measurement, absolute values depend on calibration with radioactive sources having the same range and proportion of energies as the fallout material.

DISCUSSION

Decline and fallout composition

It has turned out in practice at Rongelap Atoll that when a large number of survey meter readings are taken and these are averaged, a pattern of decline of gamma-dose rates consistent with the theoretical decay for mixed fission products emerges. This is true even though the theoretical curve is based on the decay of mixed fission products from U^{235} distributed uniformly over an infinite plane and disregards differences in both the composition and distribution of fallout radionuclides in the actual field situation. The fallout at Rongelap consisted of mixed fission products and neutron-induced radionuclides from a thermonuclear device. The induced activities contributing to the gamma activity are of shorter half life than the long-lived fission product, 30-year Cs^{137}. It therefore might have been expected that the early decline in gamma dose rates at Rongelap would have been more rapid than the theoretical decay of mixed fission products alone. As the art of producing thermonuclear devices progresses the fission yield per kiloton will decrease. There will be a higher proportion of induced radionuclides to fission products and the decline of gamma dose rates will be more rapid. Therefore, in the future, long-range predictions of residual gamma dose rates based on the Rongelap experience would be likely to yield higher values than would actually occur.

Fractionation of fallout

In addition to the differences in composition of fallout from different devices and variations in measurements there is fractionation of the radionuclides, a change in species composition with time or distance from origin. The various factors involved in fractionation are discussed in detail in the Congressional Hearings, 1959[5] and with specific reference to the March 1, 1954 explosion in "The Effects of Nuclear Weapons," 1962[4].

Redistribution of fallout

Reduction of gamma-dose rate levels due to redistribution of fallout possibly occurred during the first storm after fallout (Dunning, 1957), but thereafter redistribution had very little effect on the gamma dose rates during the first four years after fallout. The exception, of course, is the relatively rapid decline of radioactivity in the intertidal zone. Such rapid decline would also be anticipated in areas in which there is heavy erosion. An example is the man-made erosion by bulldozers in the village area at Rongelap. The reduction of gamma dose rates following the storm could have been due to the washing of fallout material from the leaves of the vegetation and perhaps also to some shielding effect by additional moisture in the soil. It was certainly not due to rapid vertical movement of material in the soil. Analysis of soil leachates and soil cores shows that vertical movement of radionuclides in atoll soils is very slow. For example, cores taken in immature soils in 1963 still contained 90 per cent of the activity in the top centimeter. However, the reduction of gamma-dose rates to approximately half the predicted levels in 1959-63 probably reflects the downward movement of the long-lived gamma-emitter Cs^{137} in the soil. Cesium-137 and Sb^{125} are very slowly leached in the atoll soils while other gamma-emitters, Ce^{144}-Pr^{144}, Eu^{155}, Zn^{65}, Co^{60}, and Mn^{54} tend to remain at the surface[1,6,7]. Although the gamma-dose rate values at Rongelap islet in 1959 63 fall on the theoretical curve, it appears that the levels due to the 1954 fallout have fallen below values predicted by the theoretical curve here also. Since the theoretical curve had reached background levels by 1959 it would be expected that the sum of gamma-dose rates due to the fallout and due to background would be approximately twice background.

CONCLUSIONS

The Rongelap experience has shown that the decline of gamma dose rates can be approximated from the decay curve for

U^{235} fission products in a local or intermediate fallout situation. As instrumentation, techniques of calibration and the predictability of the radionuclide spectrum from nuclear devices continue to improve, so will the usefulness of gamma-dose rate measurements for predicting the decline of gamma-dose rates. Practically speaking, the reliability of such measurements will depend upon the experience and judgement of the individuals making the measurements, the variety of environmental situations encountered and the time available for making such measurements. Their reliability is further substantiated by the fact that the levels of specific radionuclides in the various land organisms at different islands were roughly correlated with the gamma dose rates. Errors in predicted levels will tend to be conservative, i.e., higher than actual levels.

RECOMMENDATIONS

It would be useful in any future operations to have available known mixtures of radionuclides simulating the fallout radionuclides for a particular device, or better, a sample of the raw fallout material collected at each site to be studied. This mixture could then be used to calibrate instruments, film badges and chemical dosimeters as time went on and as the spectrum of gamma-energies changed. Comparison of the decay of gamma-dose rates from the mixture, with decline of gamma-dose rates in the field, would give a more accurate indication of the overall effect of the redistribution of radionuclides on the gamma dose rates.

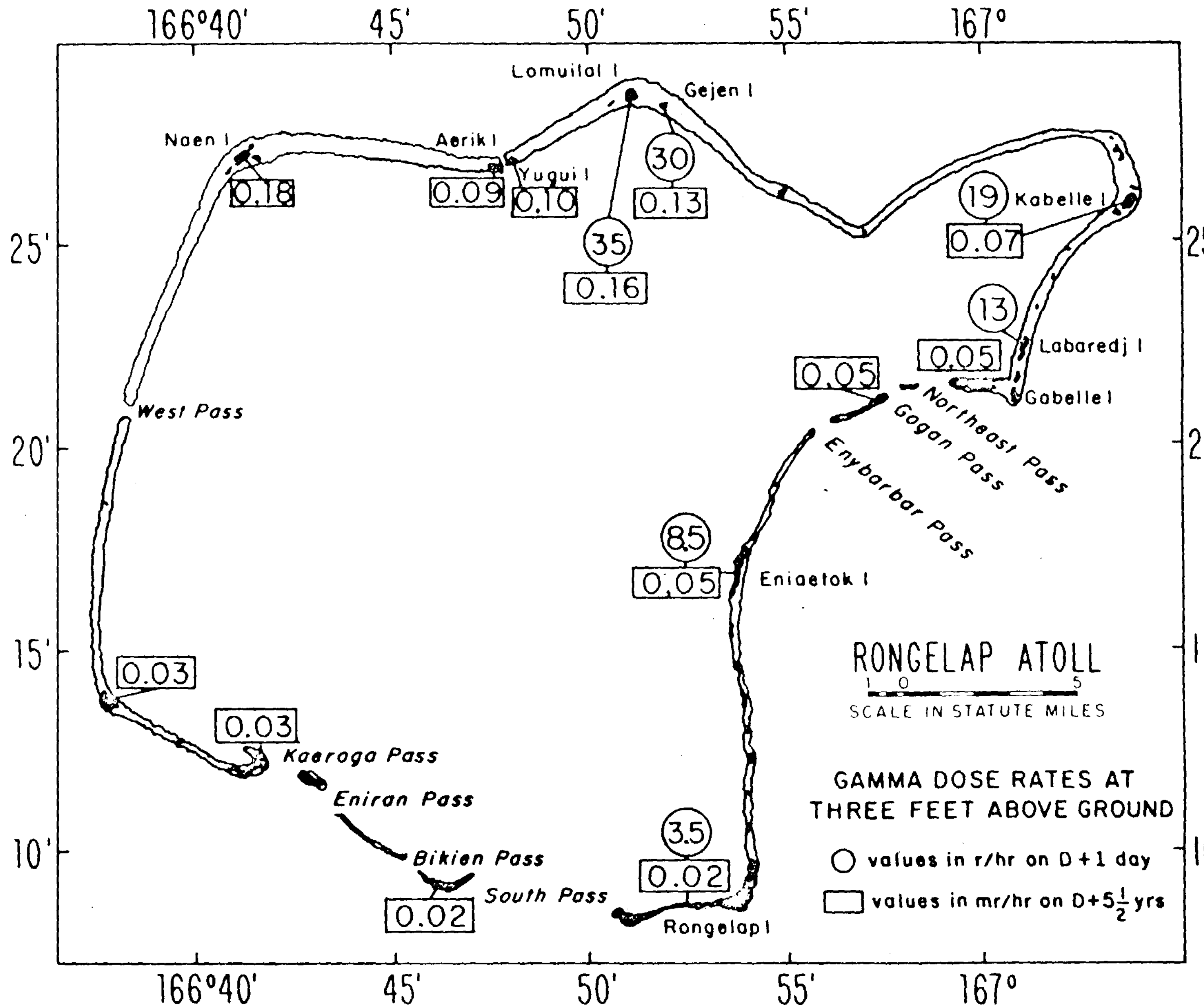


Fig. 1. Gamma Dose Rates on D + 1 Day and D + 5-1/2 Years.

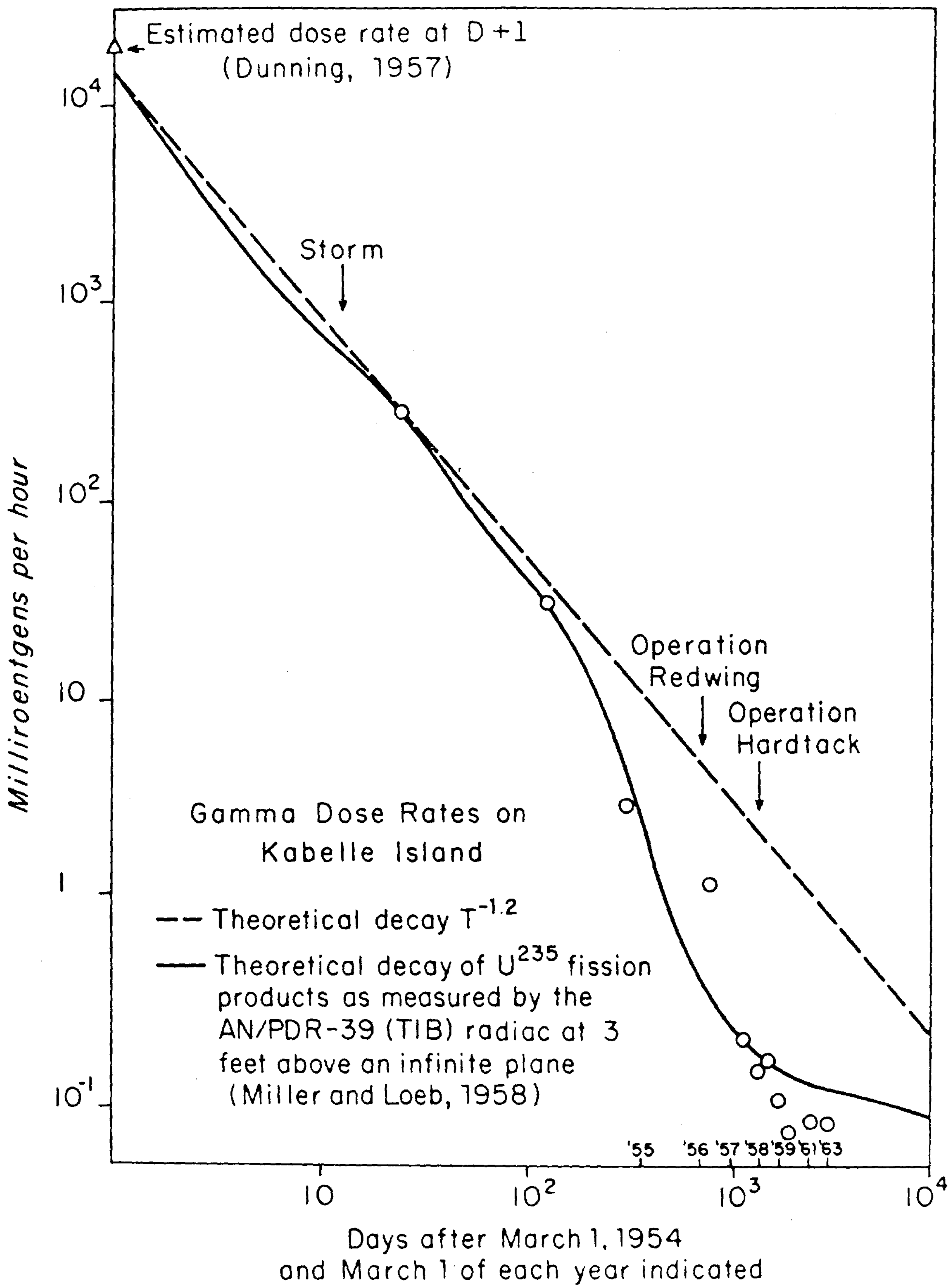


Fig. 3. Decline of Gamma Dose Rates at Kabelle Islet.

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