*DRAFT ENVIRONMENTAL IMPACT STATEMENT*

# CLEAN UP, REHABILITATION, RESETTLEMENT OF ENEWETAK ATOLL — MARSHALL ISLANDS

SEPT 1974

DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

Volume II of III

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# HOLMES & NARVER, INC.

*A Resource Sciences company*

*Advanced Technology/Engineering/Construction/Management/Maintenance & Operations*

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# DRAFT ENVIRONMENTAL IMPACT STATEMENT

# CLEAN UP, REHABILITATION, RESETTLEMENT OF ENEWETAK ATOLL — MARSHALL ISLANDS

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Volume II of III

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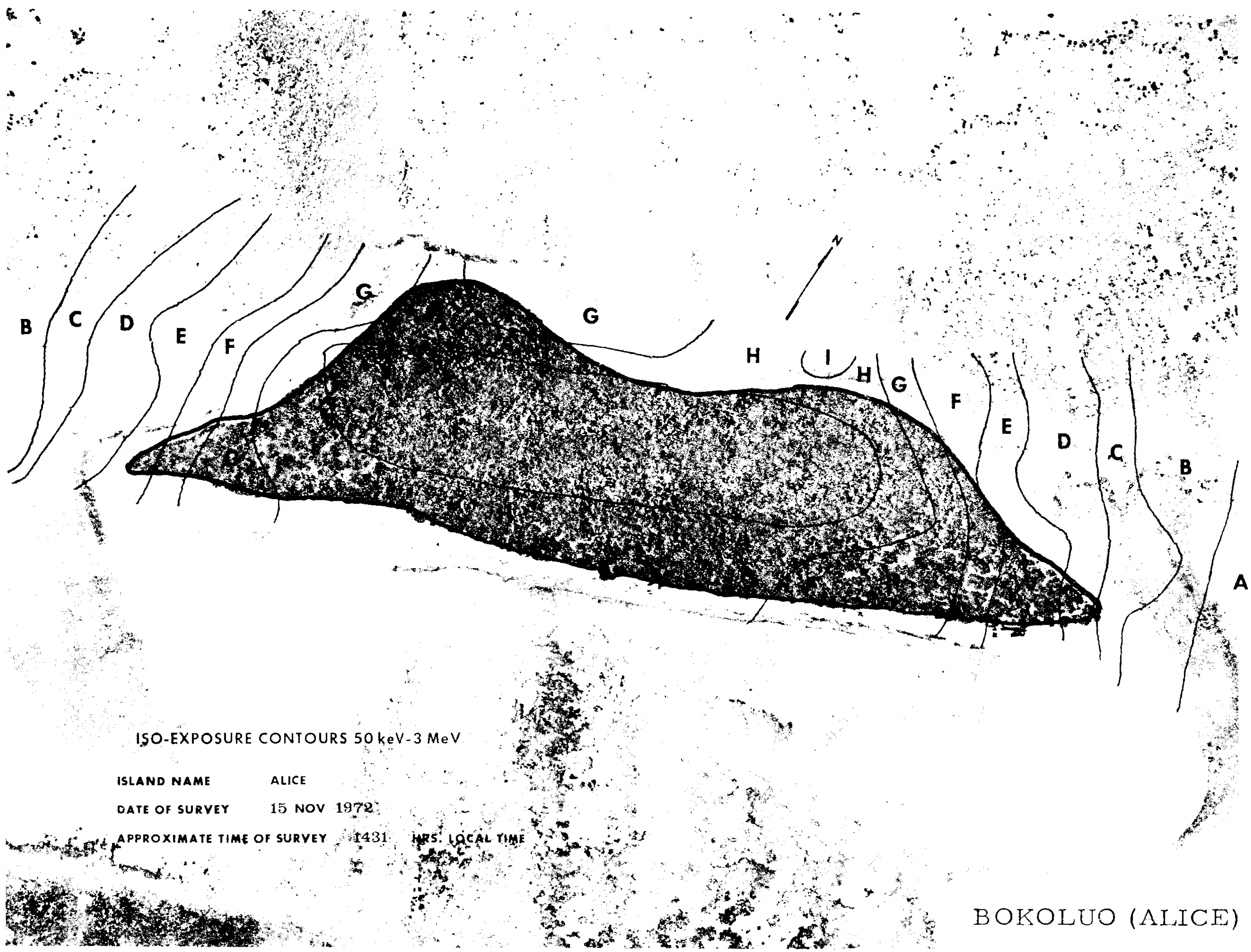
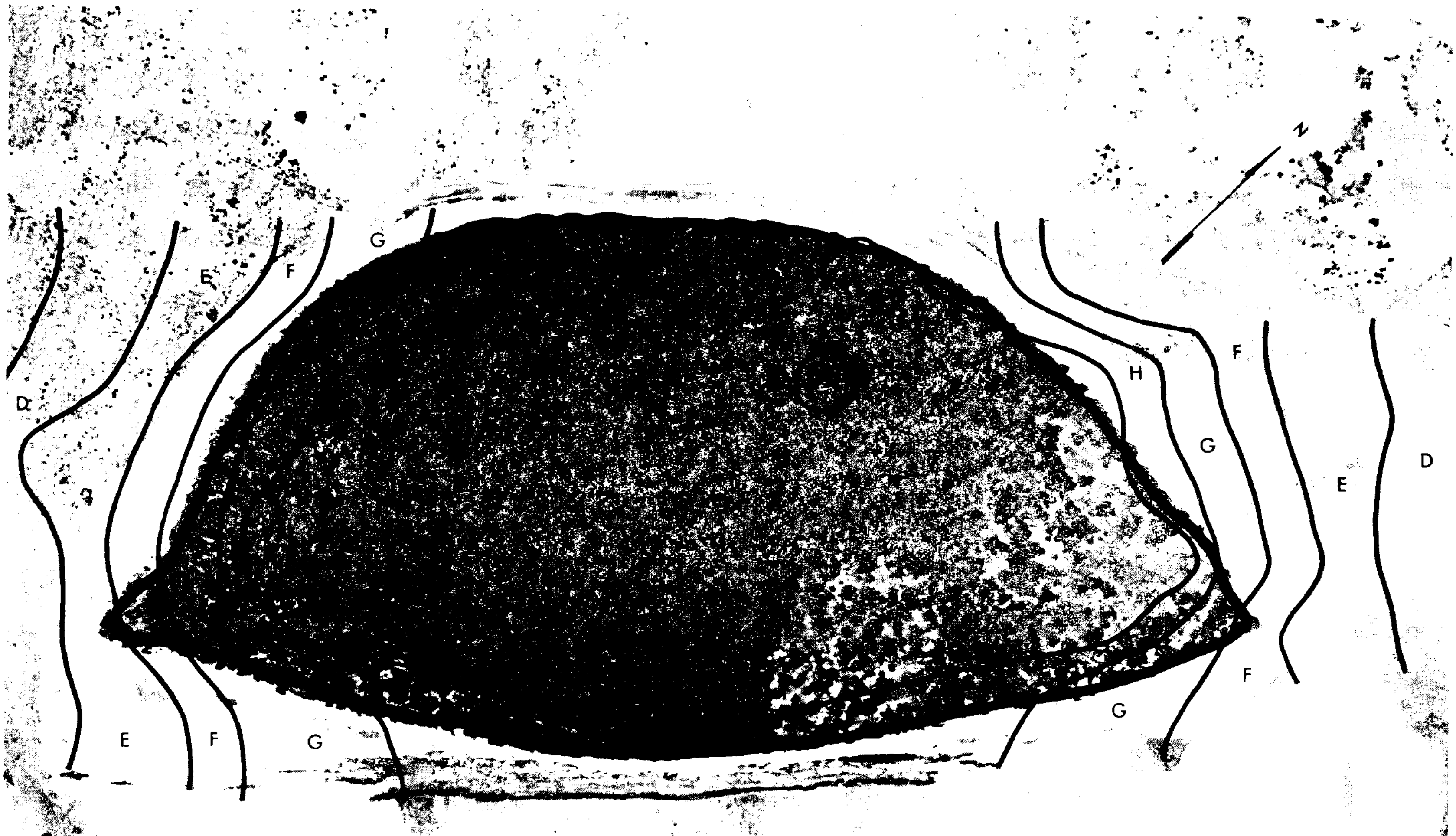
TABLE A-1

CONTOUR MAP KEY

For Use With the EG&G Aerial Radiological Survey

| Symbol | Gross Count Exposure Rate (μR/hr) ("b" Figures Series) |
|---|---|
| A | 0 to 1.0 |
| B | 1.0 to 1.5 |
| C | 1.5 to 2.0 |
| D | 2.0 to 4 |
| E | 4 to 8 |
| F | 8 to 16 |
| G | 16 to 33 |
| H | 33 to 66 |
| I | 66 to 130 |
| J | 130 to 260 |
| K | 260 to 520 |
| L | 520 to 1050 |


B
C
D
E
F
G
G
H
I
H
G
F
E
D
C
B
A
N
ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME ALICE
DATE OF SURVEY 15 NOV 1972
APPROXIMATE TIME OF SURVEY 1431 HRS. LOCAL TIME
BOKOLUO (ALICE)



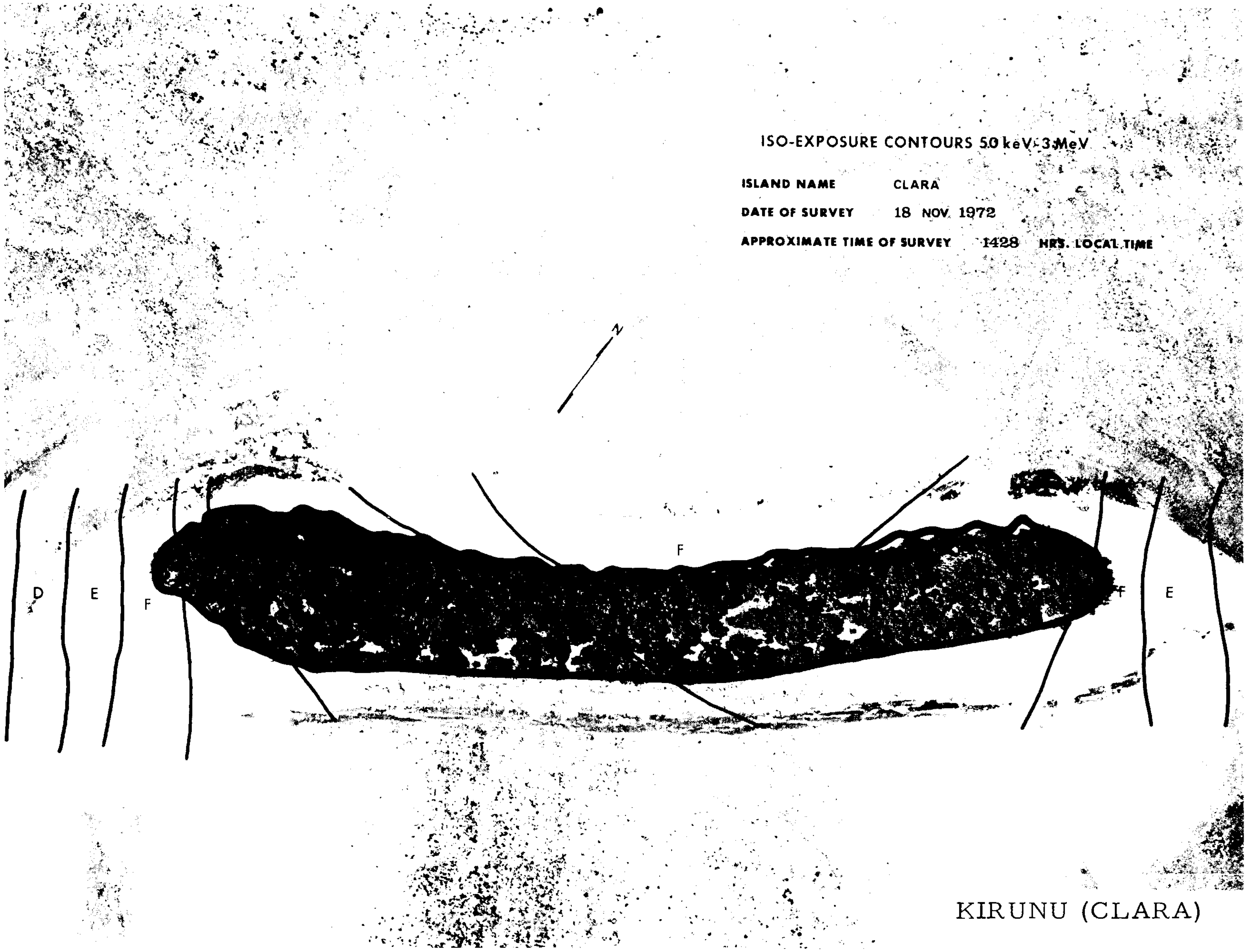

ISO-EXPOSURE CONTOURS 50 keV-3 MeV

**ISLAND NAME** BELLE

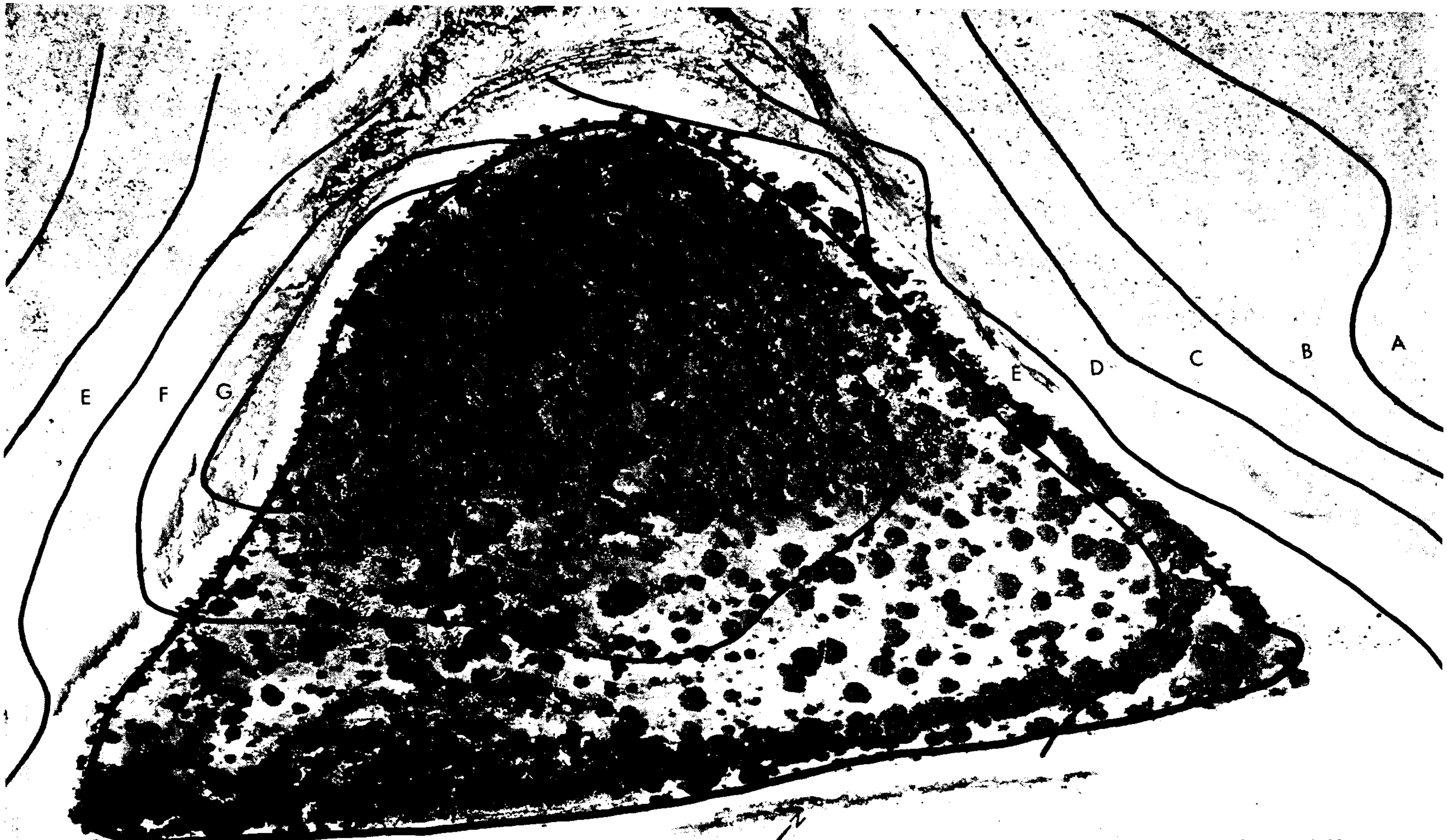
**DATE OF SURVEY** 15 NOV 1972

**APPROXIMATE TIME OF SURVEY** 1408 **HRS. LOCAL TIME**

BOKOMBAKO (BELLE)




KIRUNU (CLARA)



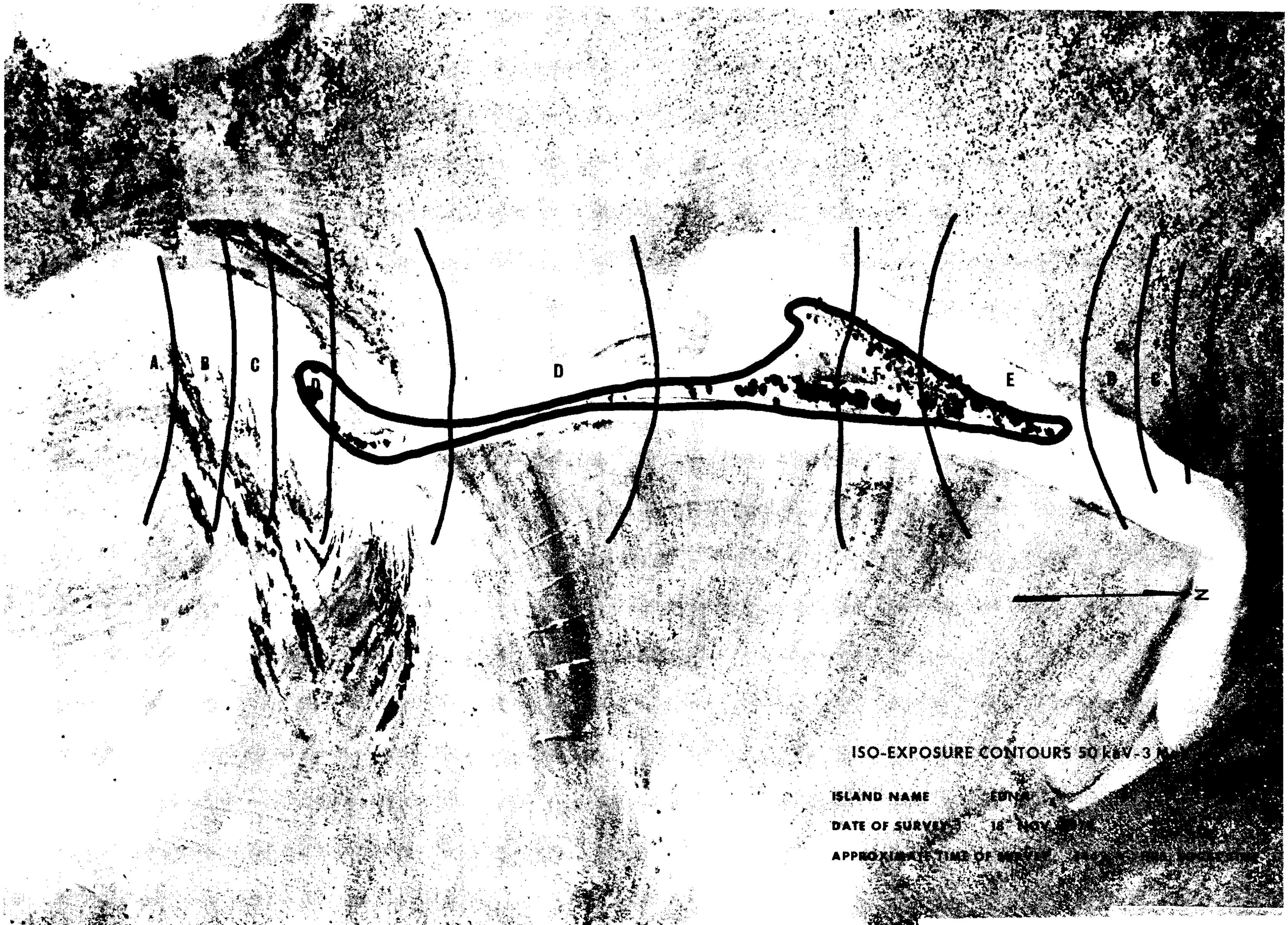

ISO-EXPOSURE CONTOURS 50 keV-3 MeV

ISLAND NAME DAISY

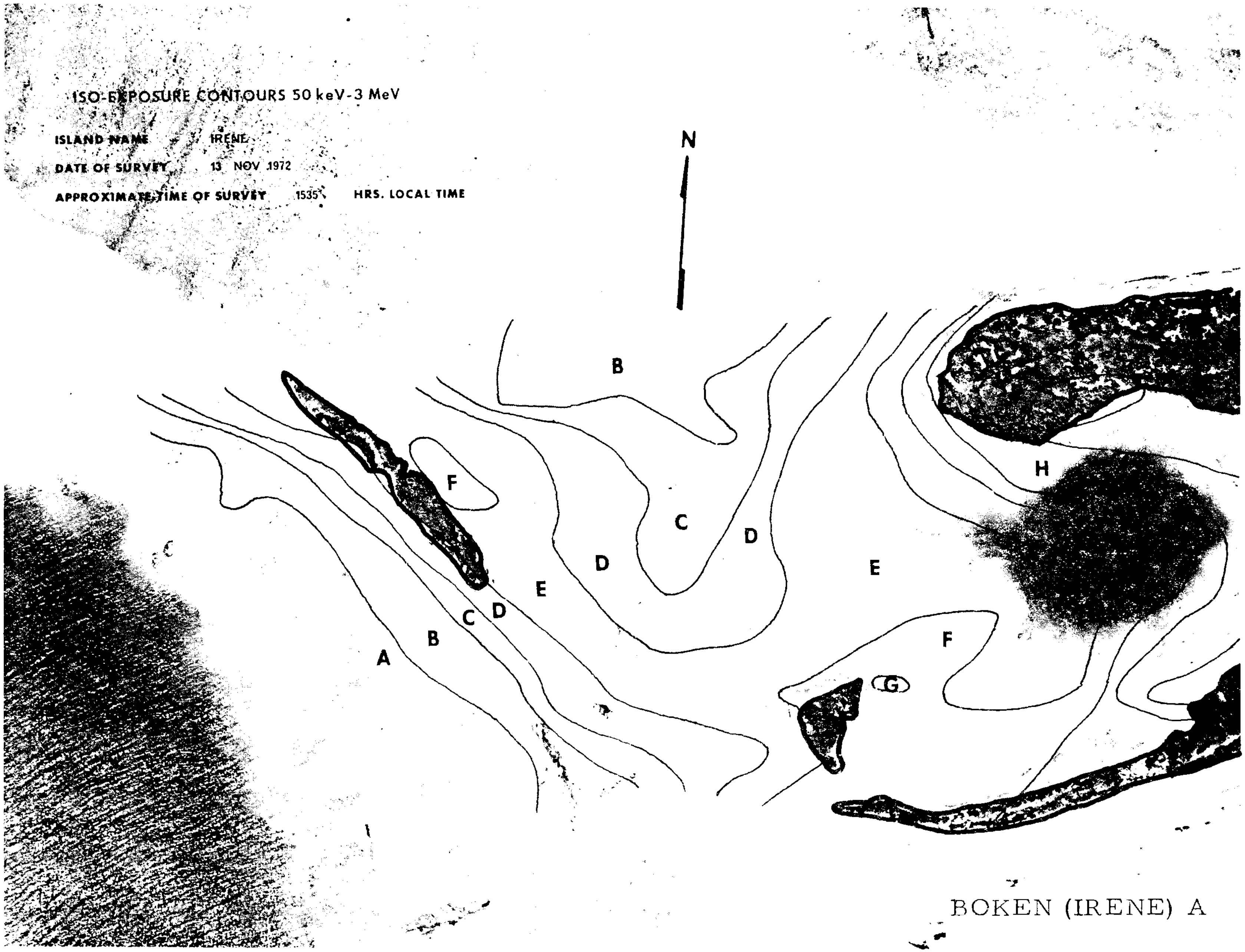
DATE OF SURVEY 18 NOV 1972

APPROXIMATE TIME OF SURVEY 1137 HRS. LOCAL TIME

LOUJ (DAISY)

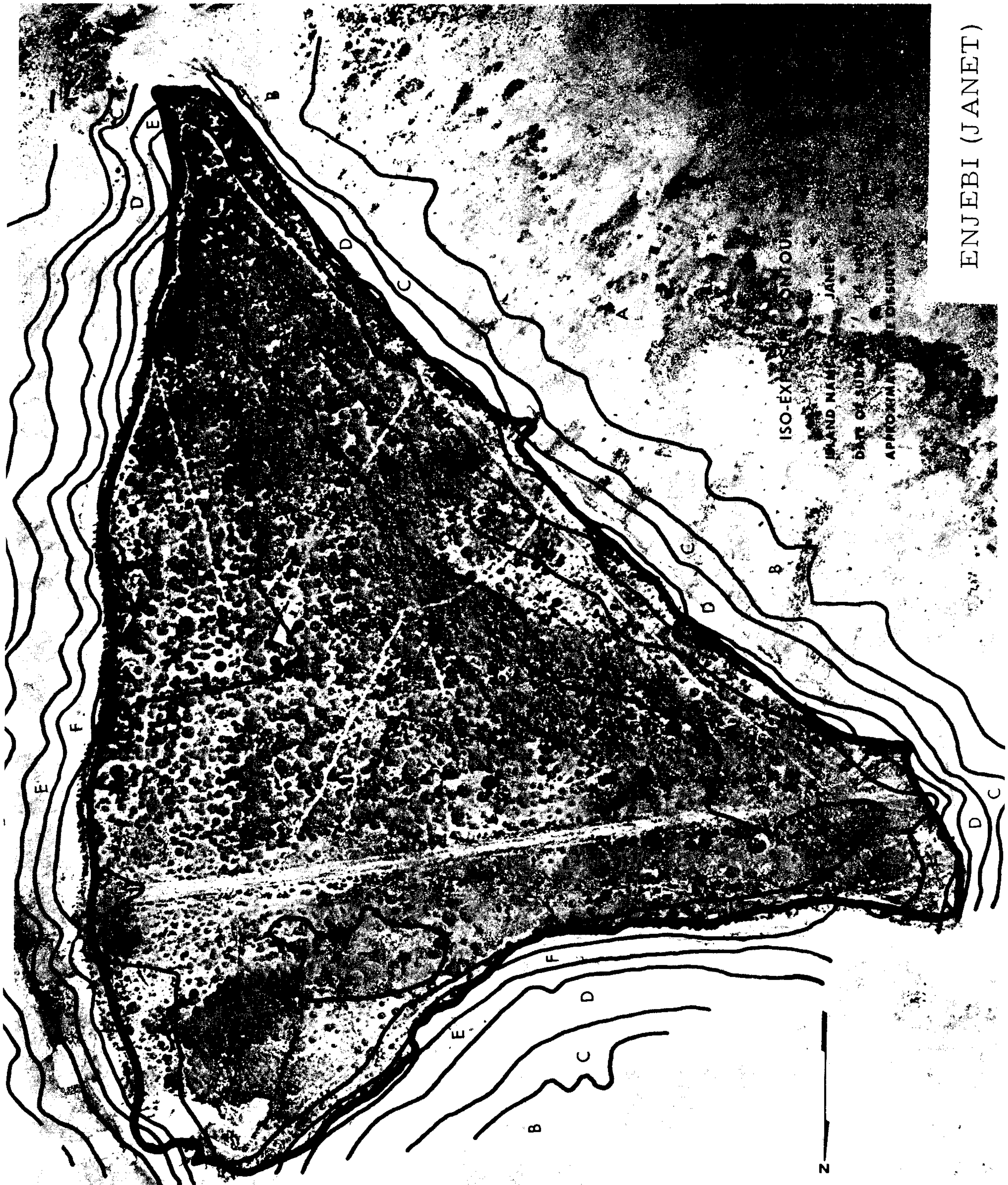



BOKINWOTME (EDNA)

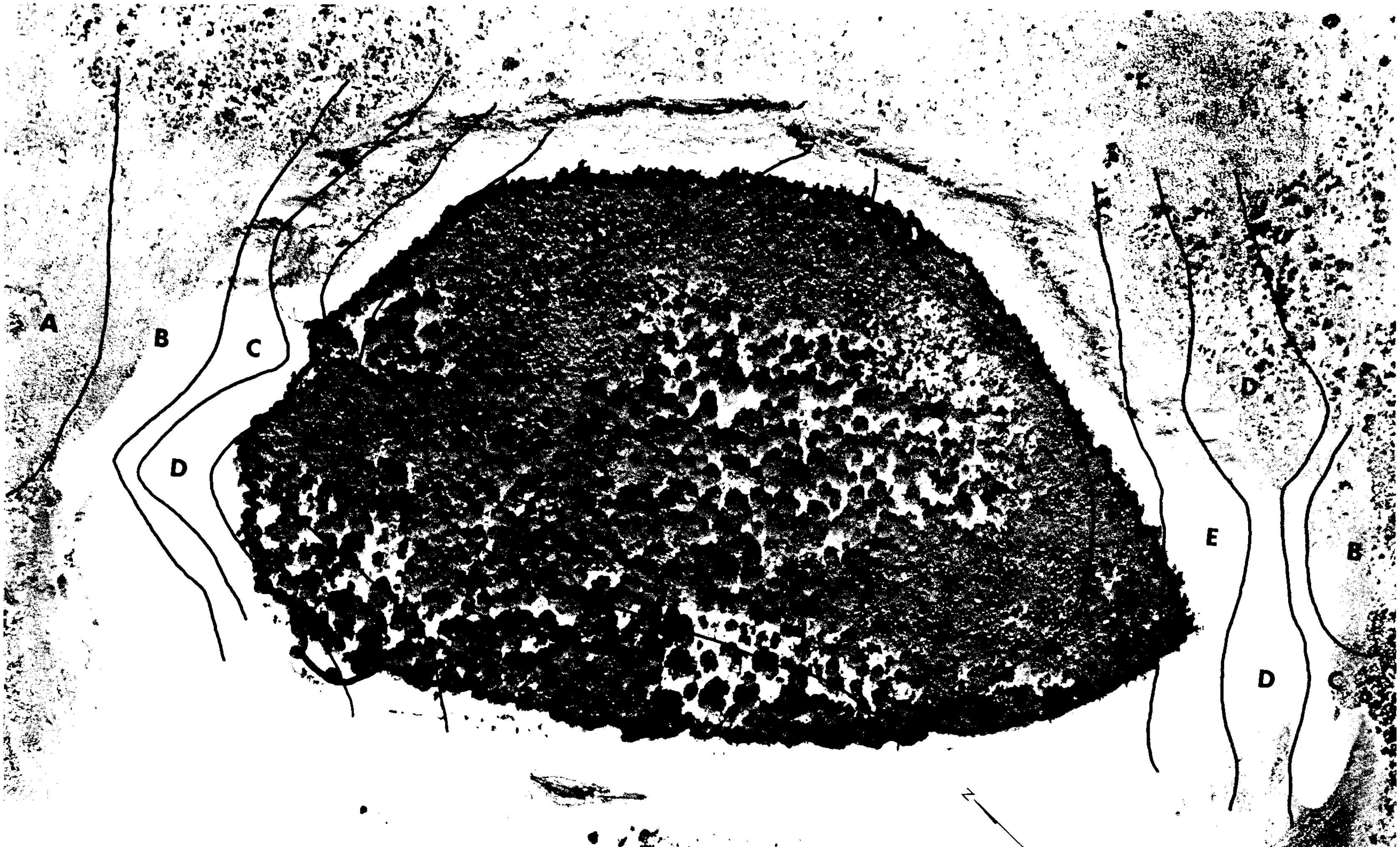



BOKEN (IRENE) A


BOKEN (IRENE) B




ENJEBI (JANET)



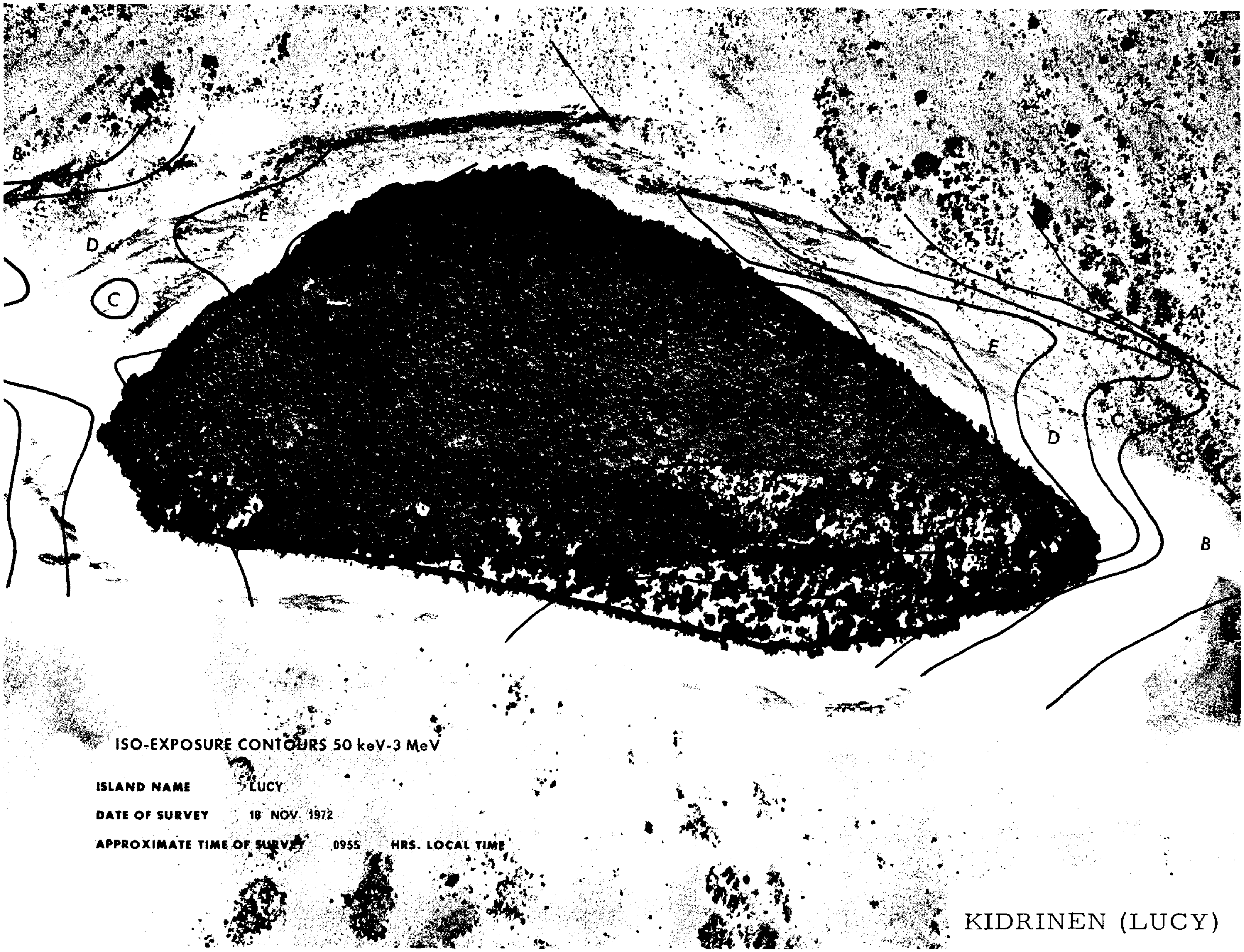

ISO-EXPOSURE CONTOURS 50 keV-3 MeV

**ISLAND NAME** KATE

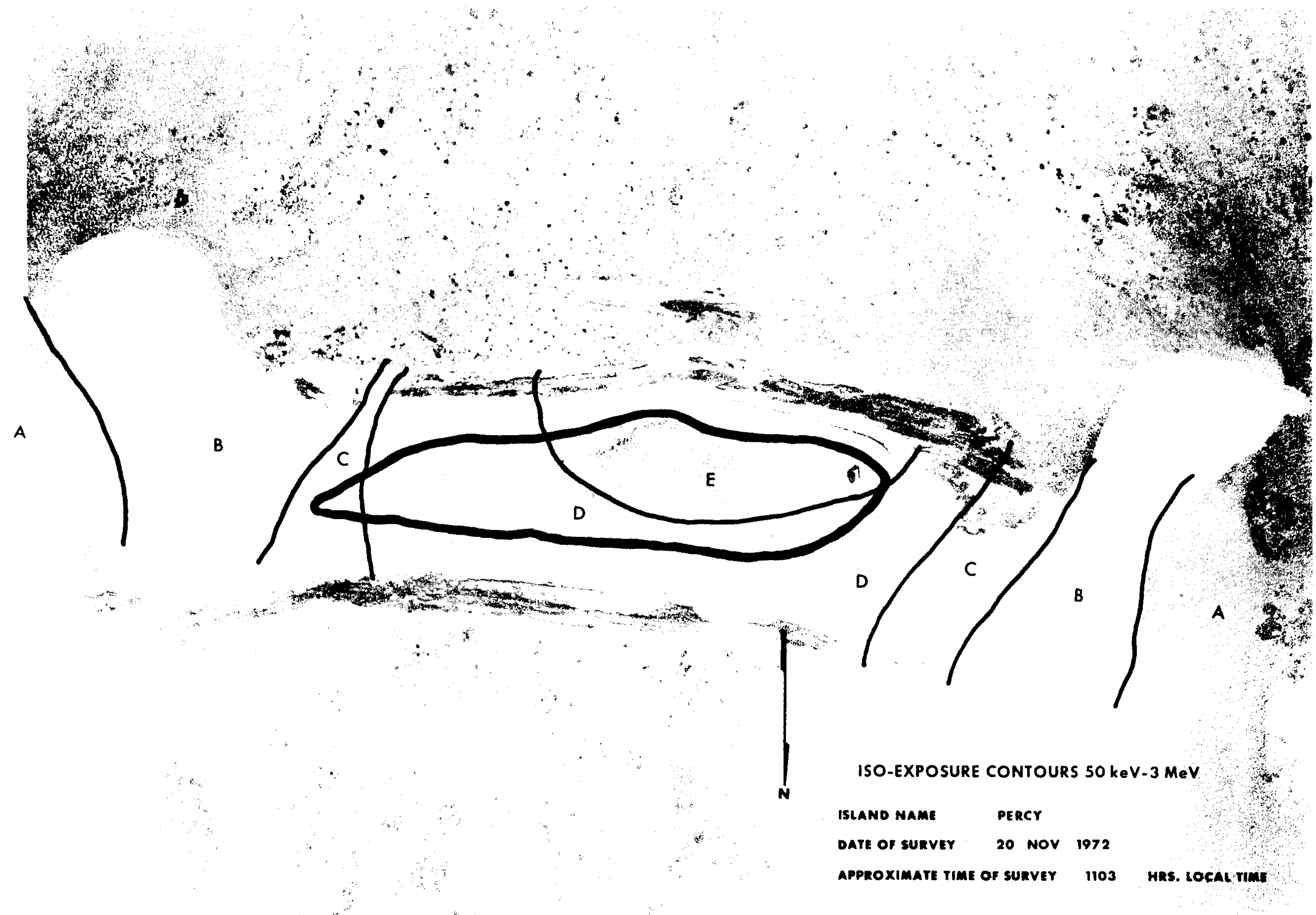
**DATE OF SURVEY** 15 NOV 1972

**APPROXIMATE TIME OF SURVEY** 1447 **HRS. LOCAL TIME**

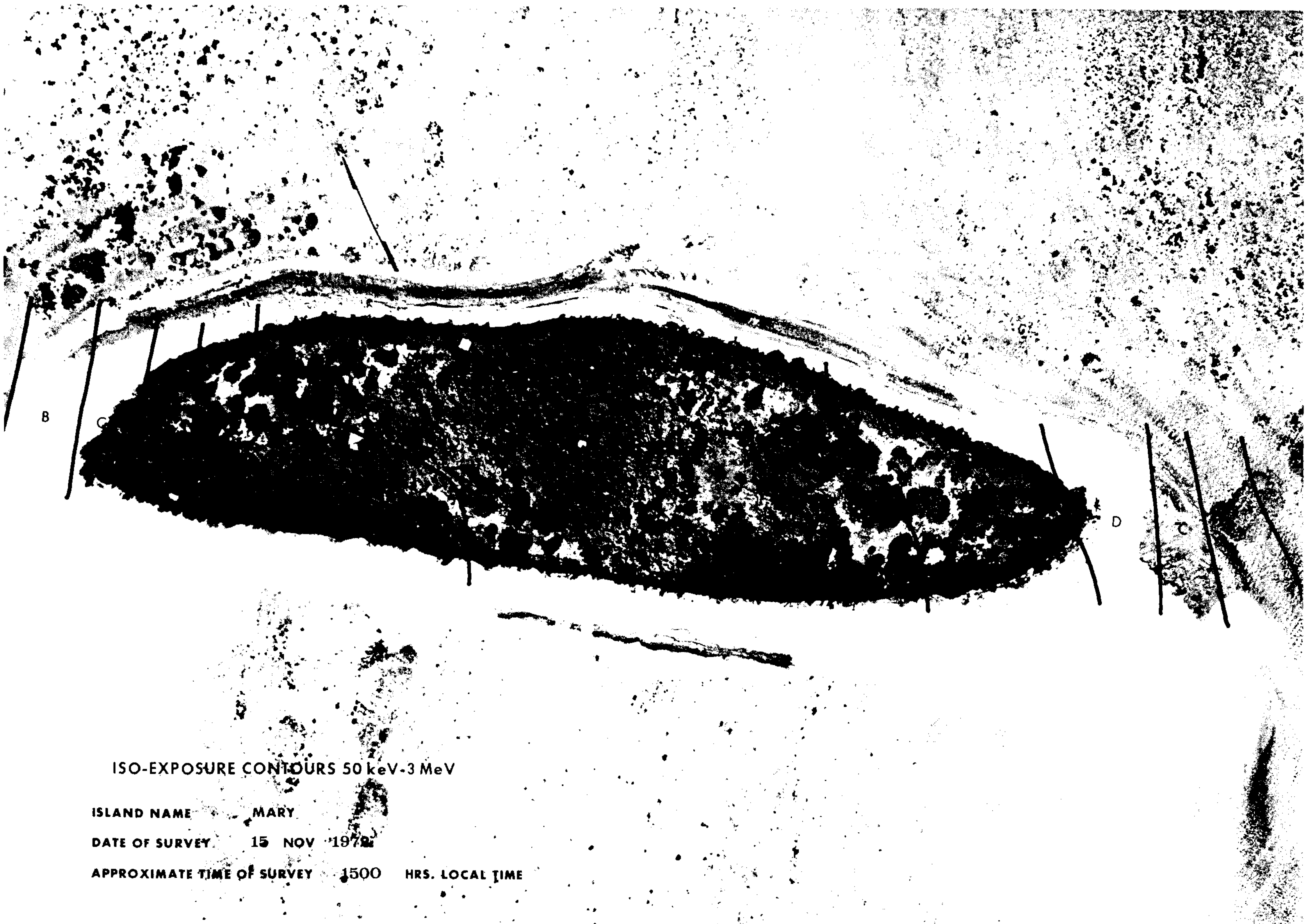
MIJIKADREK (KATE)




KIDRINEN (LUCY)



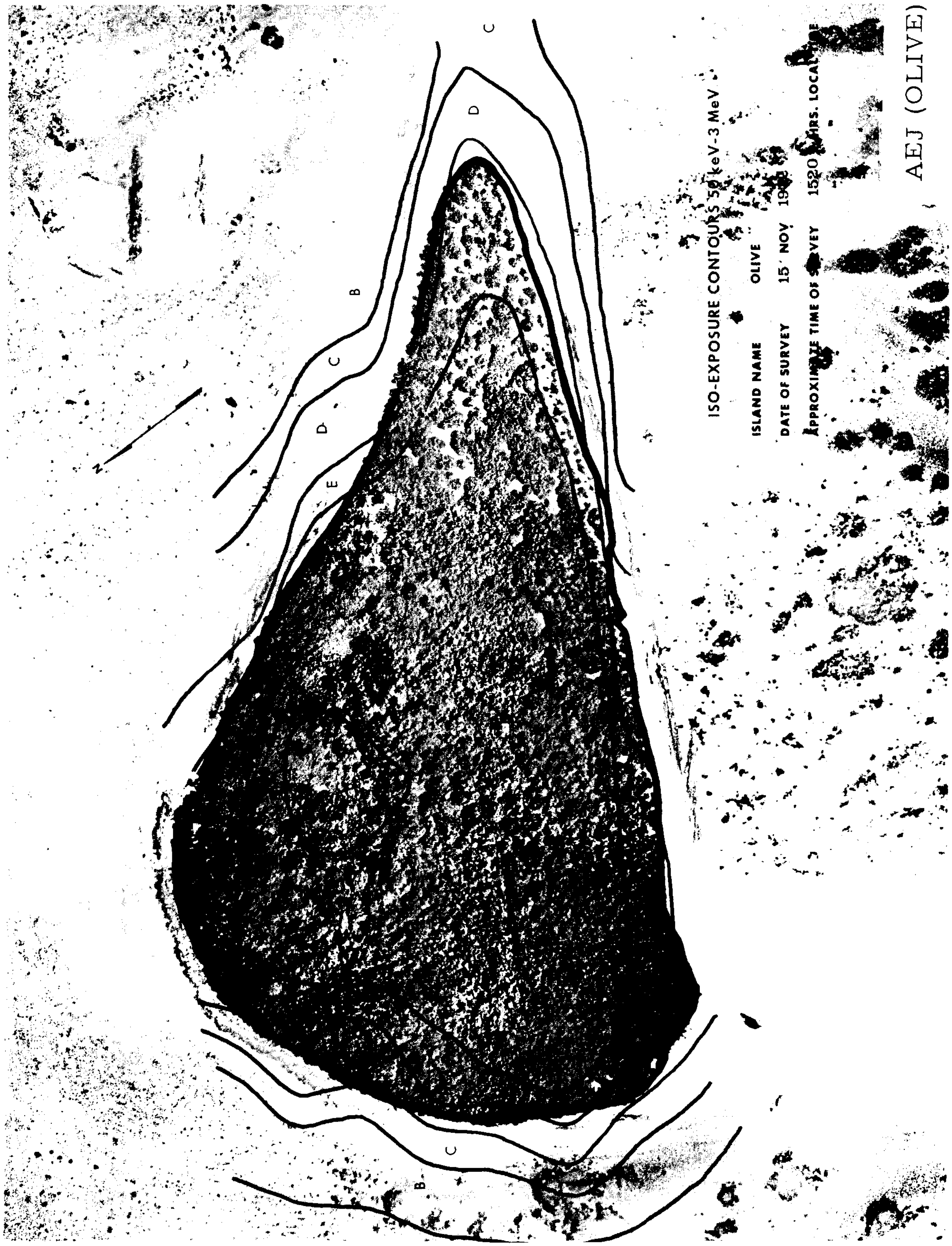

TAIWEL (PERCY)

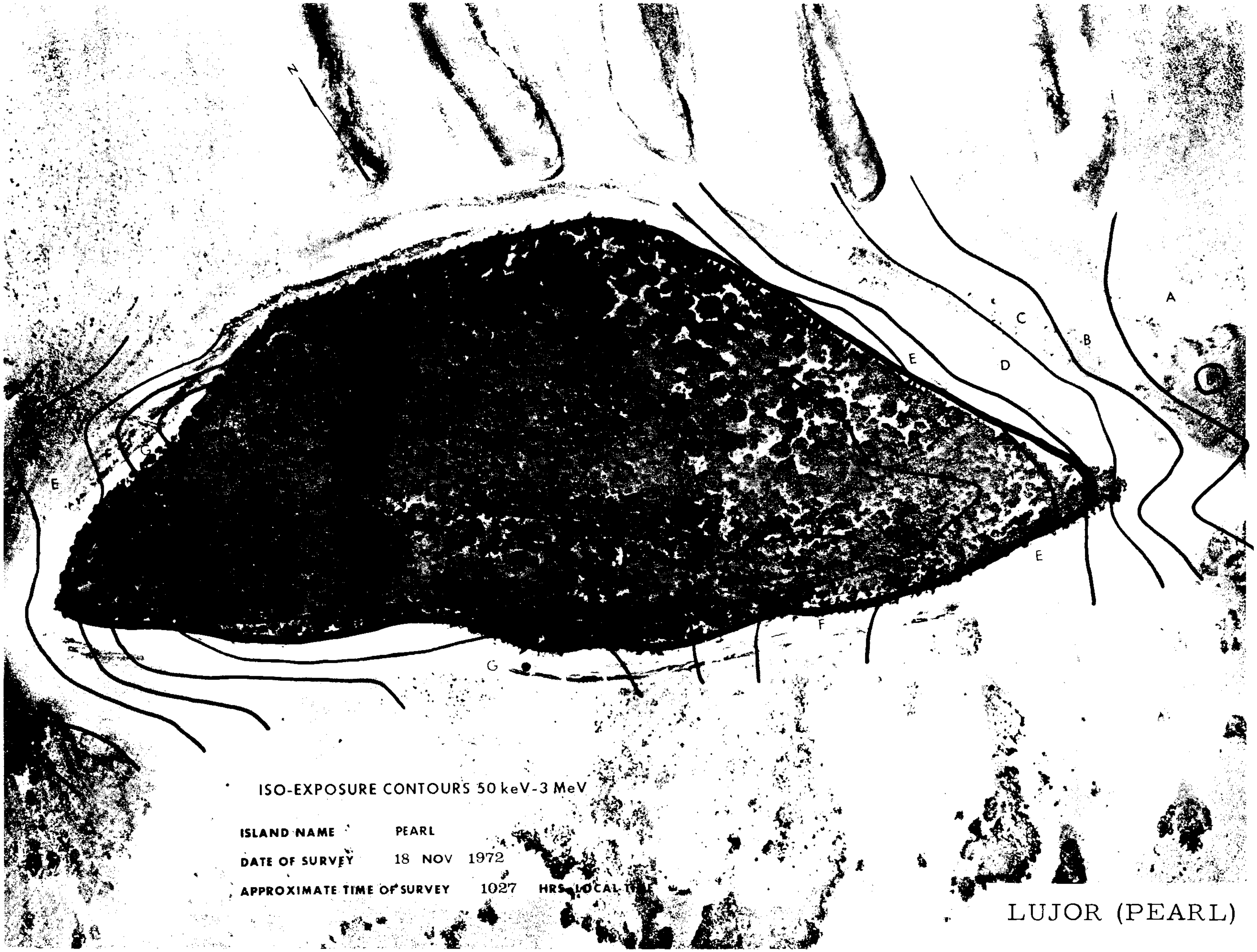


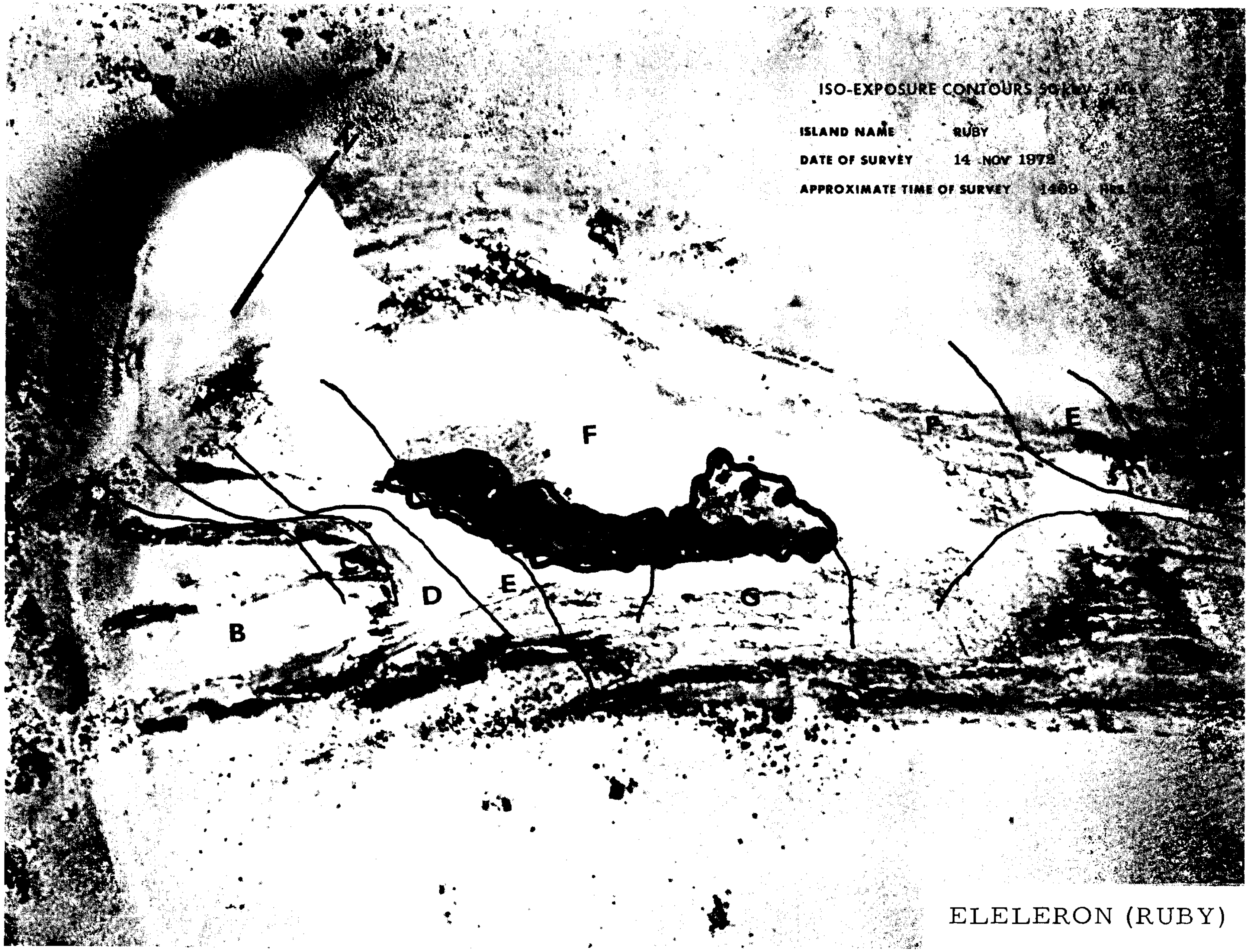

BOKENELAB (MARY)


ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME NANCY
DATE OF SURVEY 15 NOV 1972
APPROXIMATE TIME OF SURVEY 1511 HRS. LOCAL TIME
A
B
C
D
B
N

ELLE (NANCY)


ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME OLIVE
DATE OF SURVEY 15 NOV
APPROXIMATE TIME OF SURVEY 1520 HRS. LOCAL
AEJ (OLIVE)
N
B
C
D
E
C
B


N
A
B
C
D
E
F
G
ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME PEARL
DATE OF SURVEY 18 NOV 1972
APPROXIMATE TIME OF SURVEY 1027 HRS
LUJOR (PEARL)

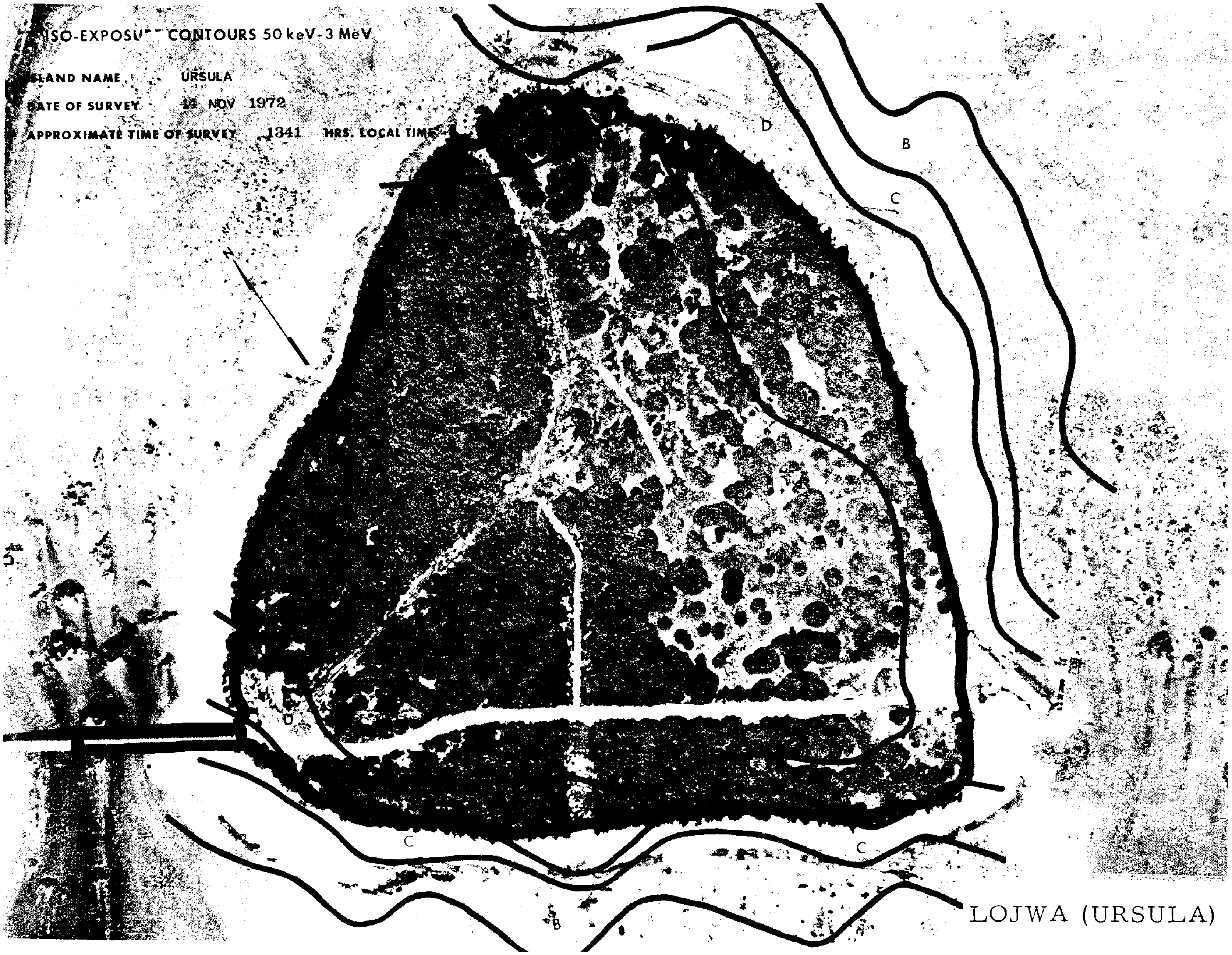



ELELERON (RUBY)

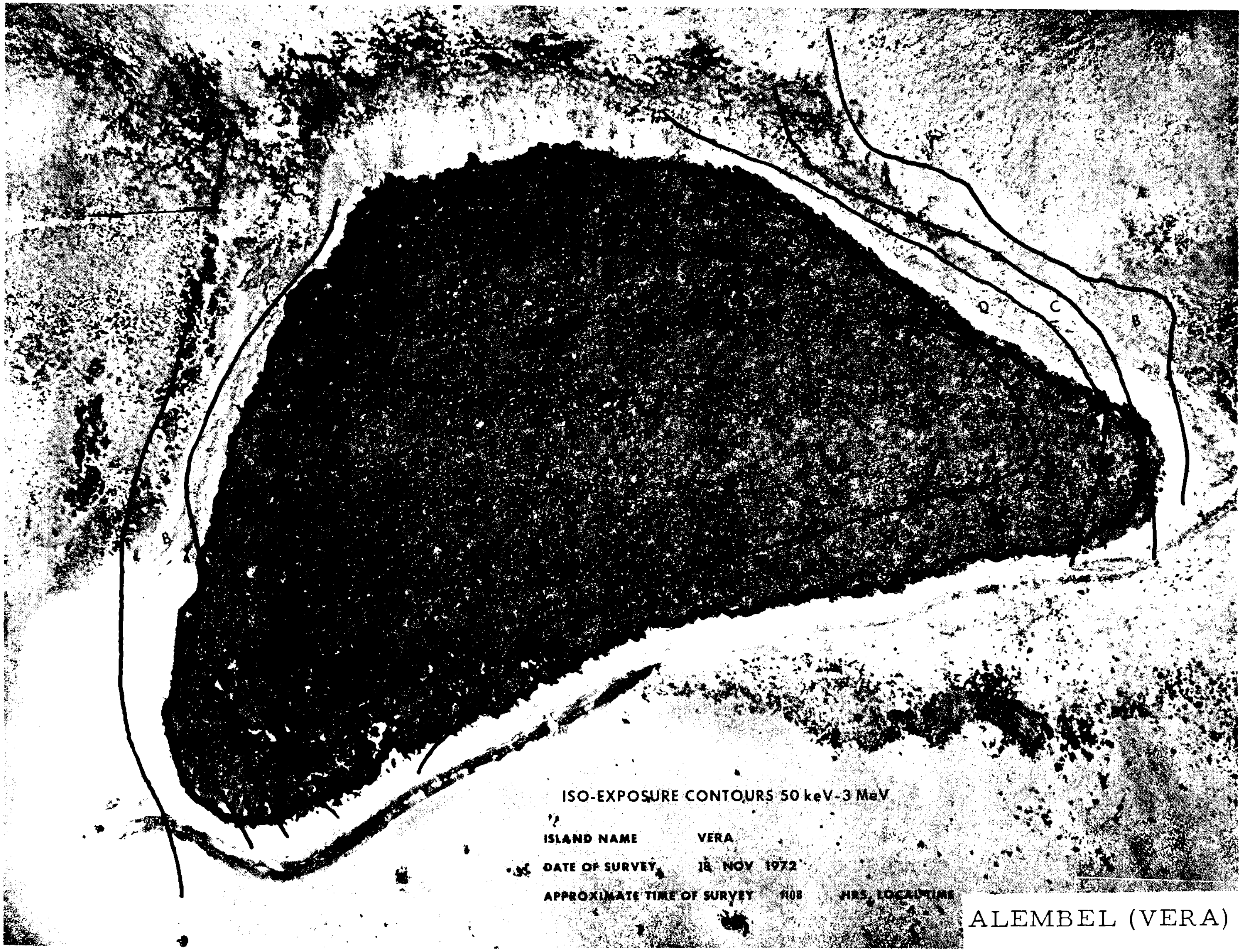
ISO... ...ONTOURS 50 keV-3 MeV
ISLAND NAME SALLY
DATE OF SURVEY 14 NOV 1972
APPROXIMATE TIME OF SURVEY : 1228 HRS. LOCAL TIME
A
B
C
D
E
F
G


AOMON (SALLY)


BIJILE (TILDA)

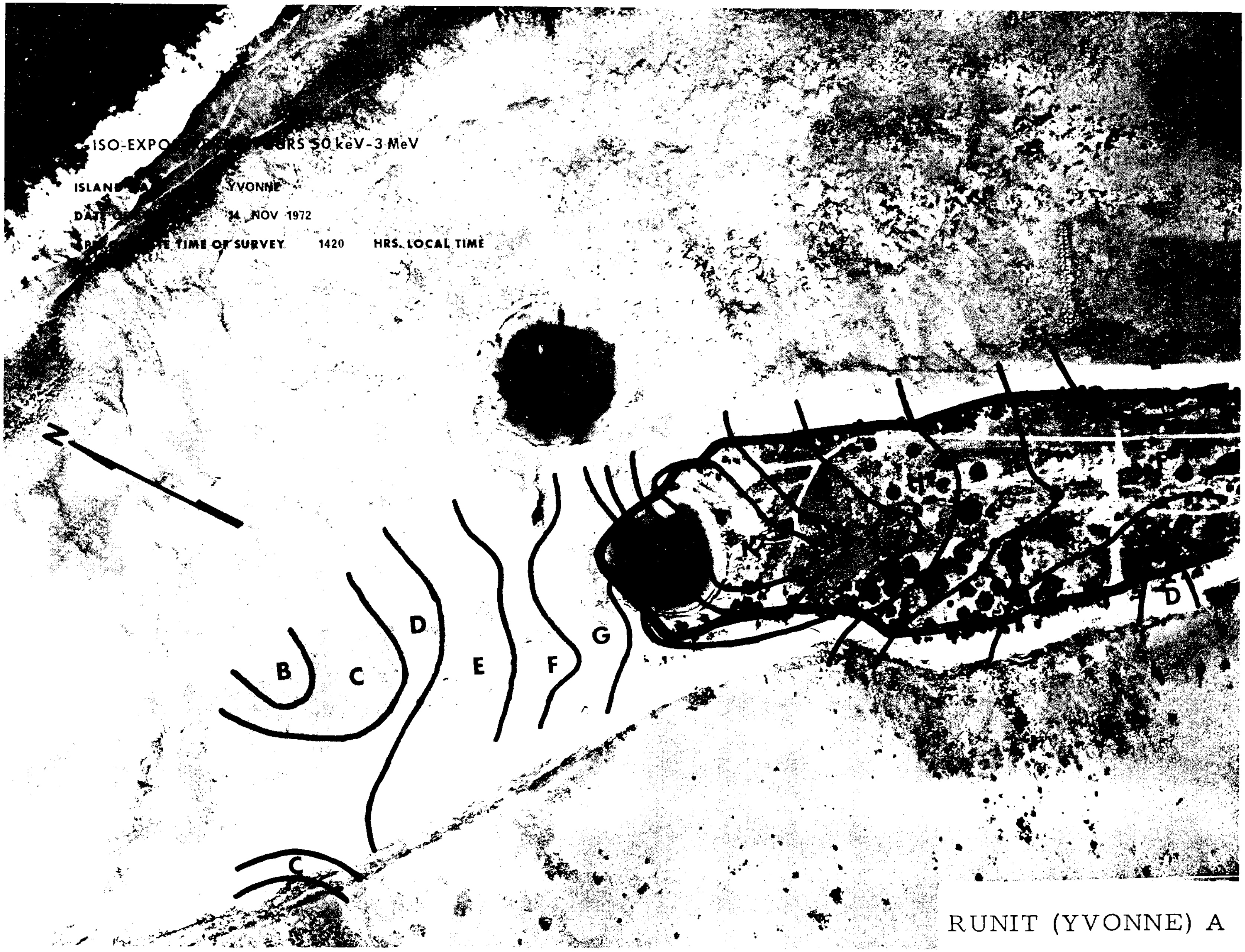



LOJWA (URSULA)

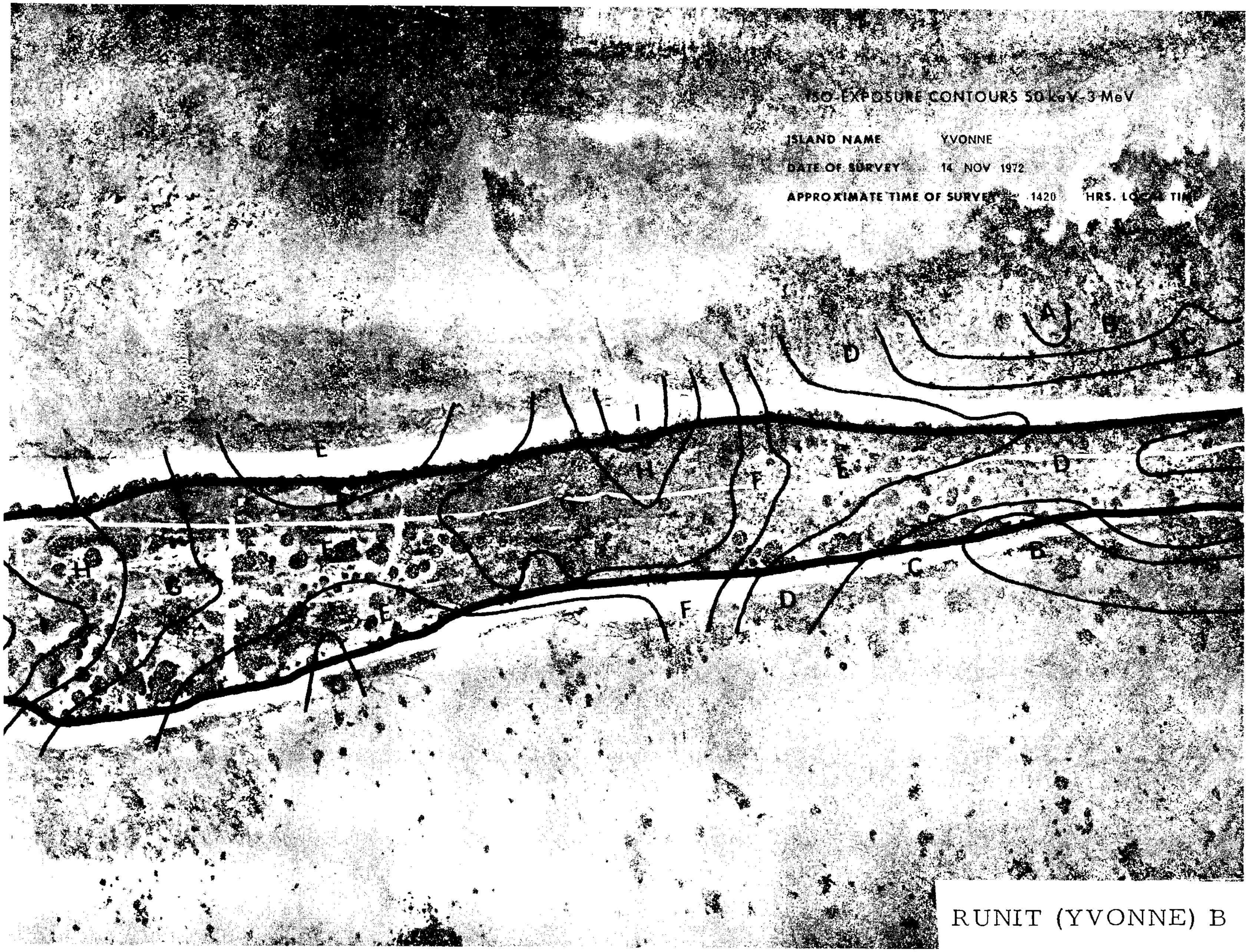



ALEMBEL (VERA)


BILLAE (WILMA)

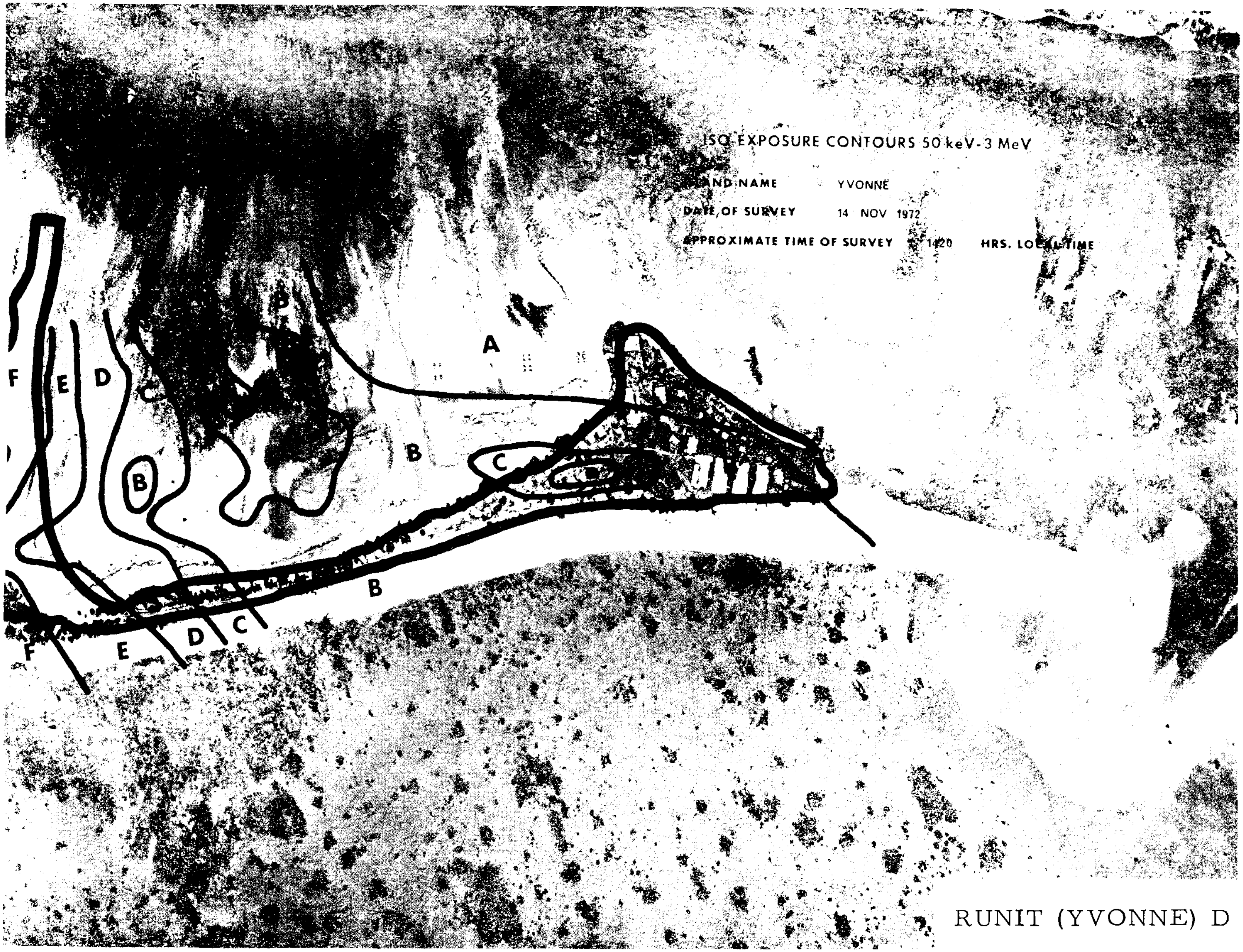



RUNIT (YVONNE) A

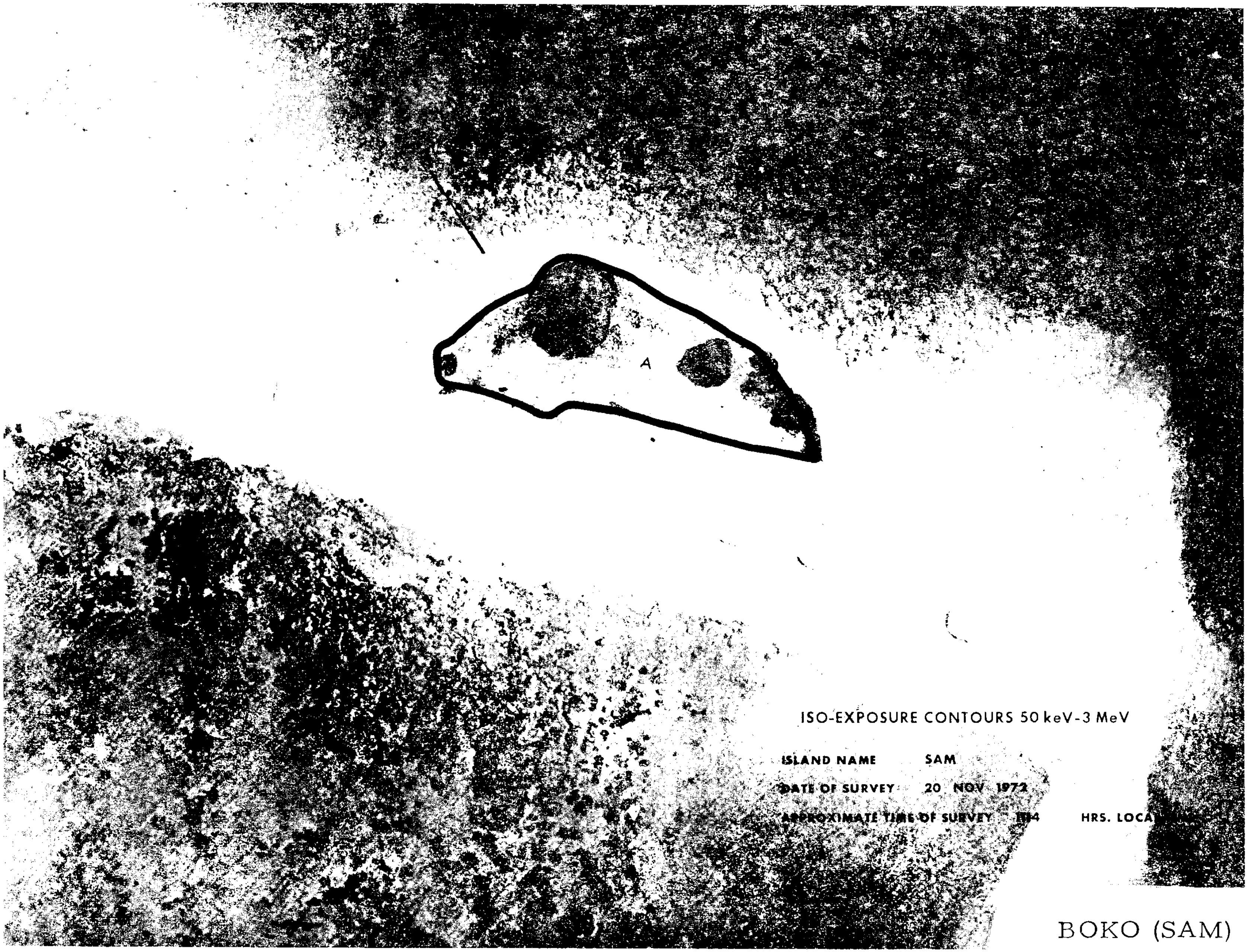



RUNIT (YVONNE) B


RUNIT (YVONNE) C




RUNIT (YVONNE) D

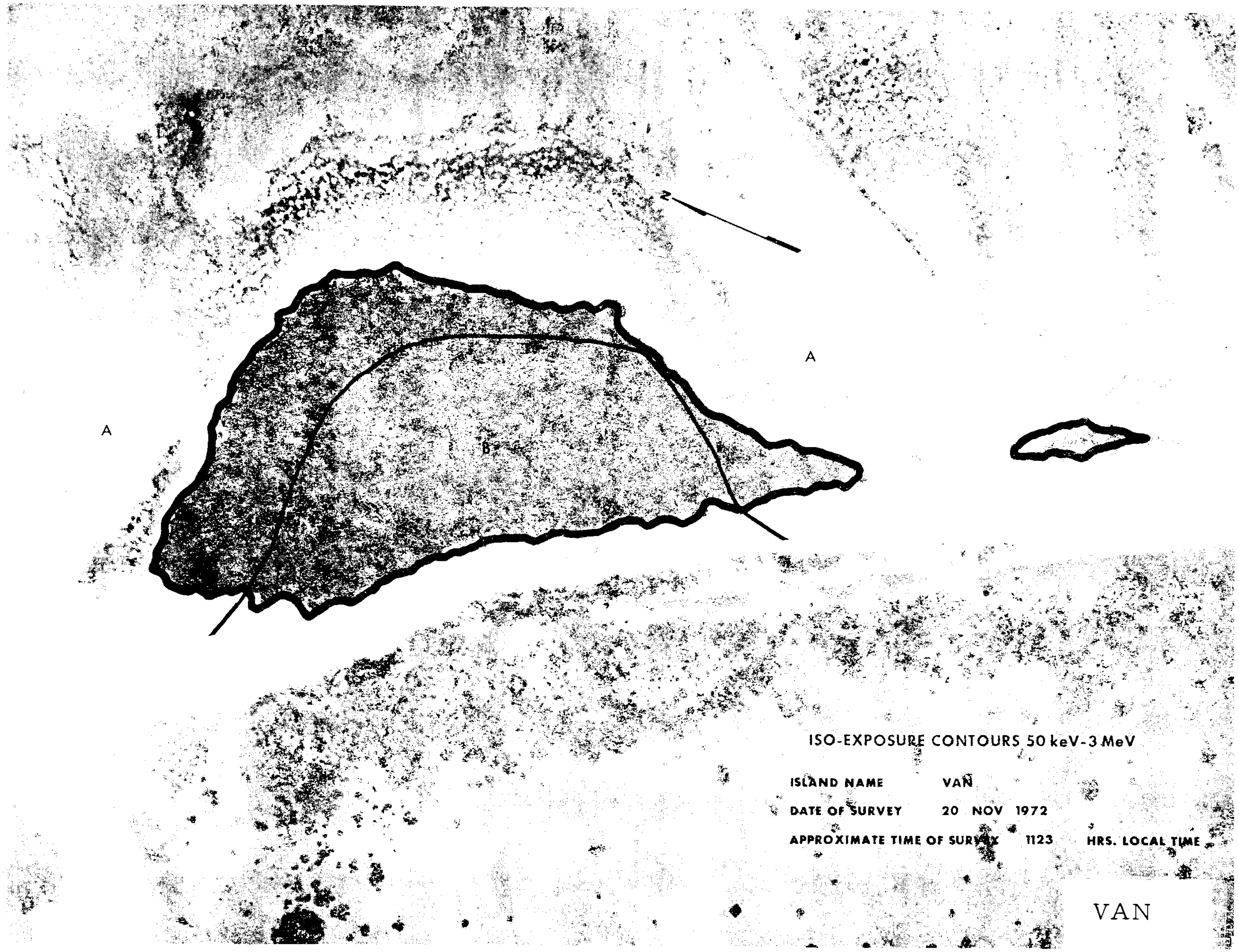

A
ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME SAM
DATE OF SURVEY 20 NOV 1972
APPROXIMATE TIME OF SURVEY
HRS. LOCA

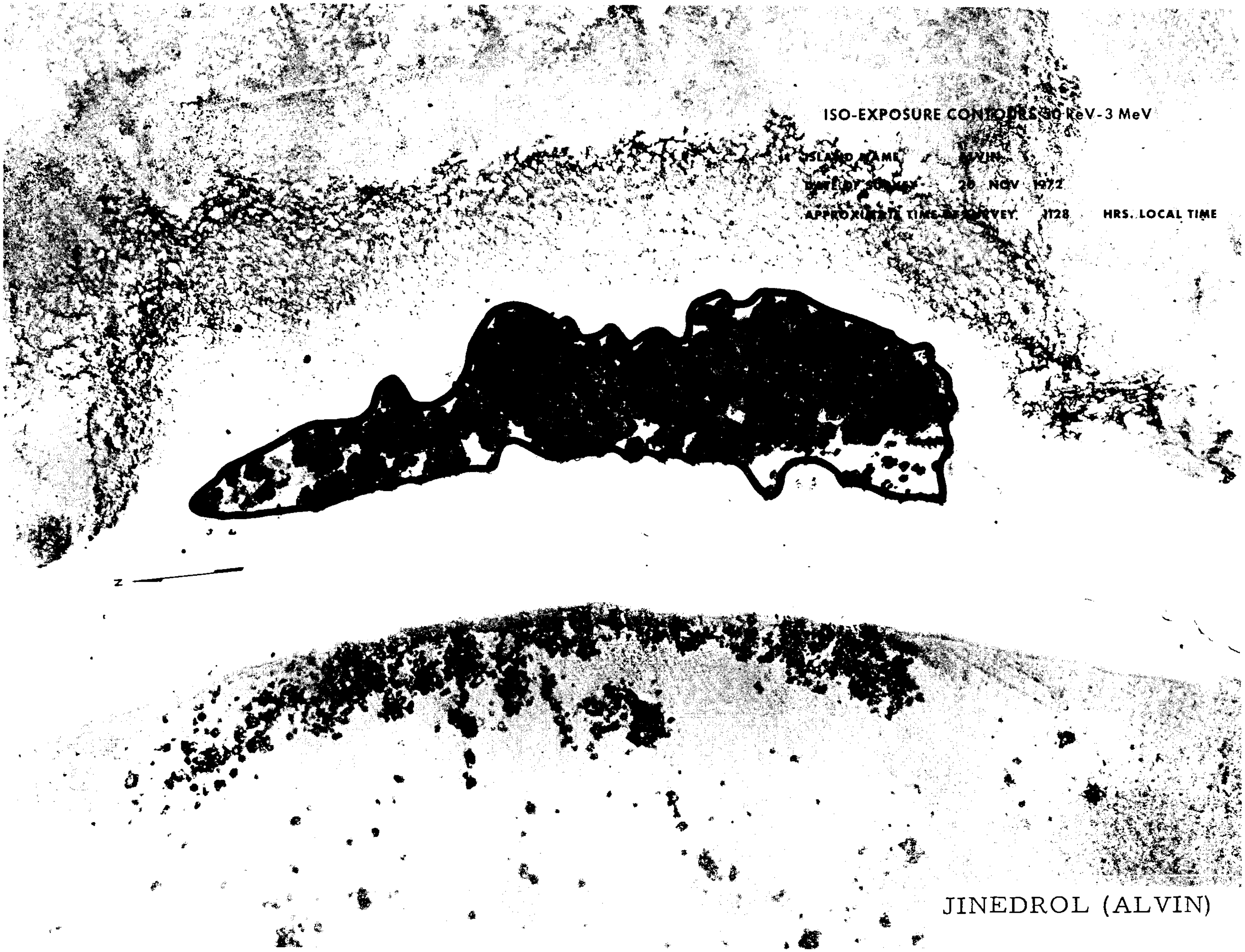
BOKO (SAM)


ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME TOM
DATE OF SURVEY 20 NOV 1972
APPROXIMATE TIME OF SURVEY 1116 HRS. LOCAL TIME
N

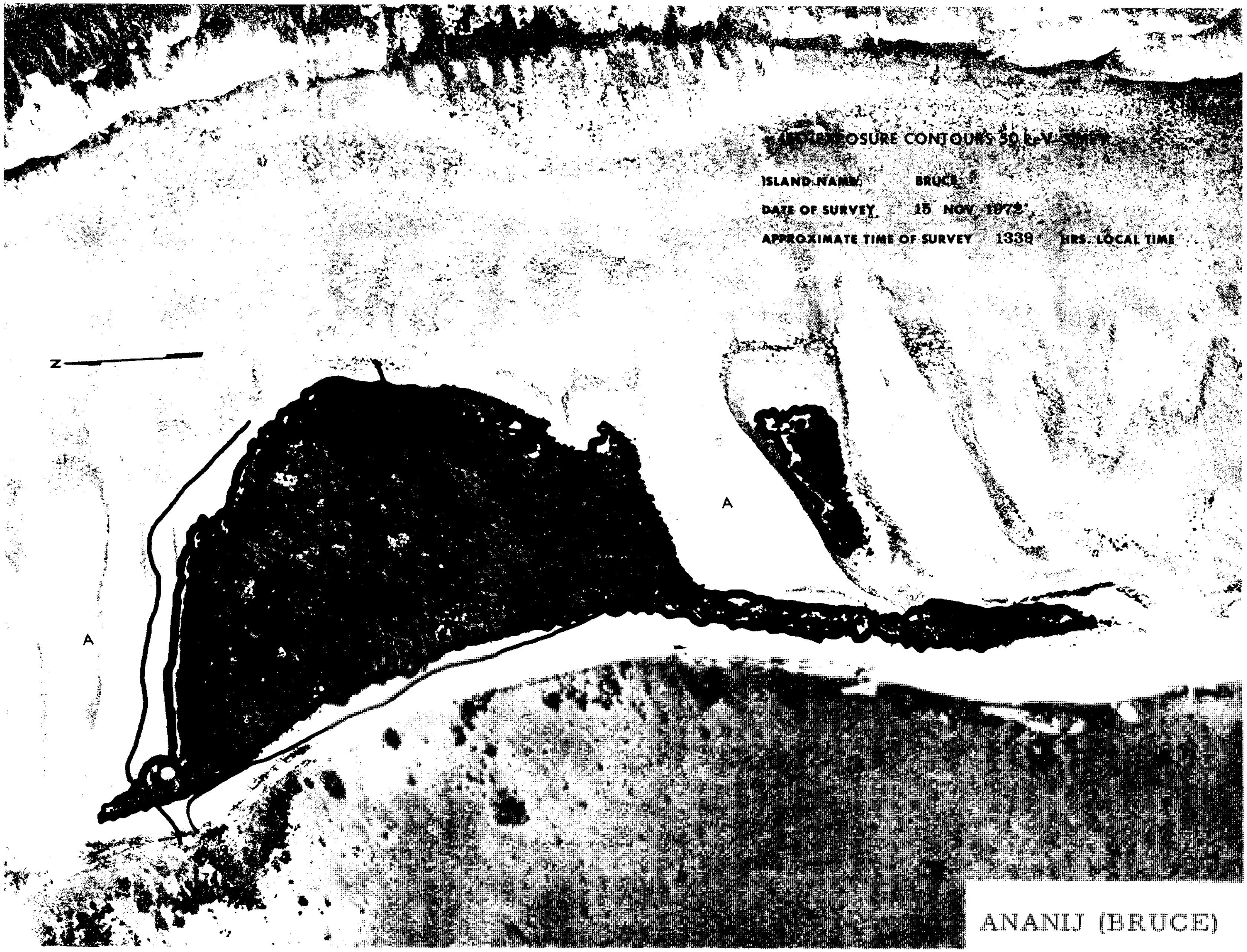
MUNJUR (TOM)

INEDRAL (URIAH)


N
A
A
B
ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME VAN
DATE OF SURVEY 20 NOV 1972
APPROXIMATE TIME OF SURVEY 1123 HRS. LOCAL TIME
VAN



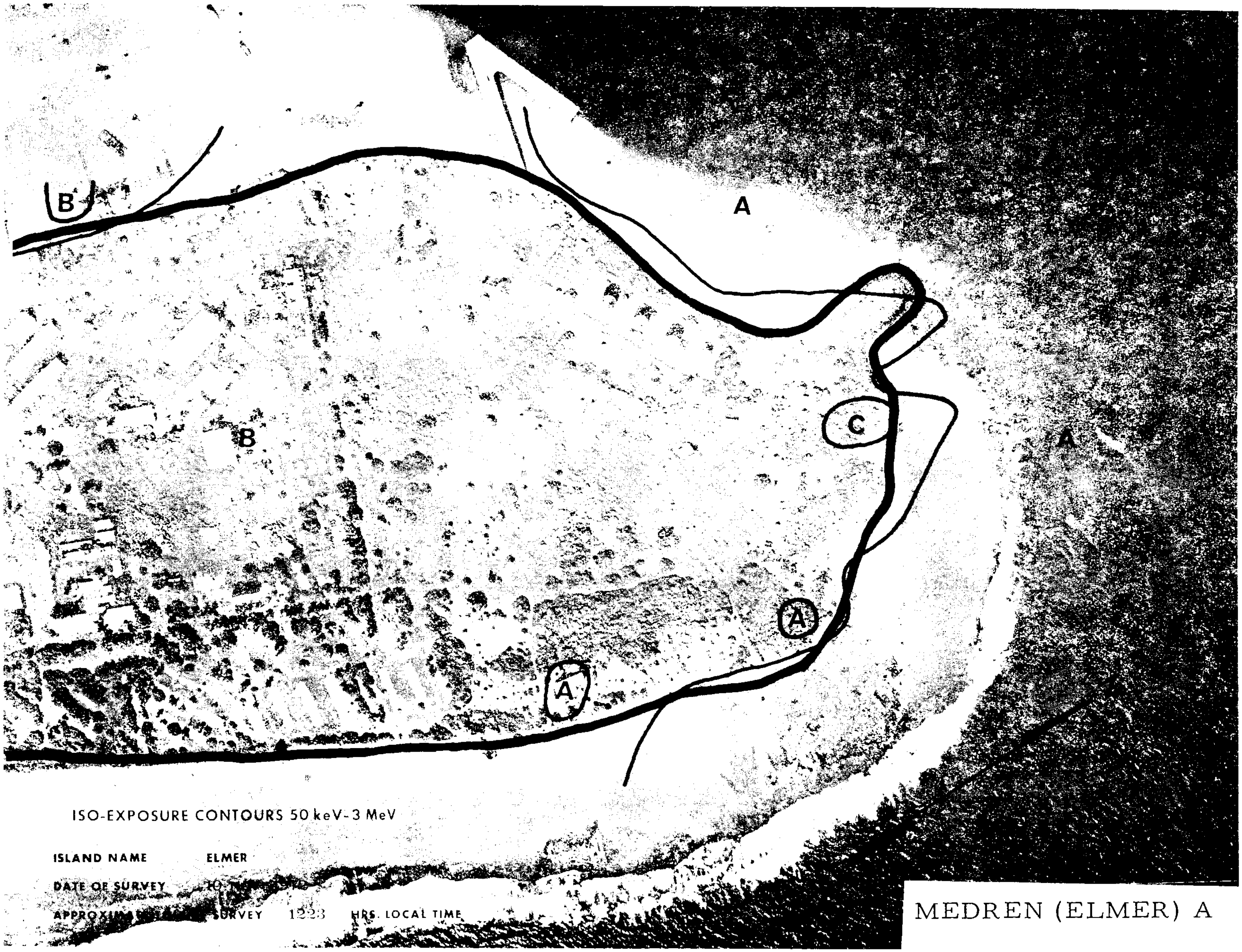

JINEDROL (ALVIN)



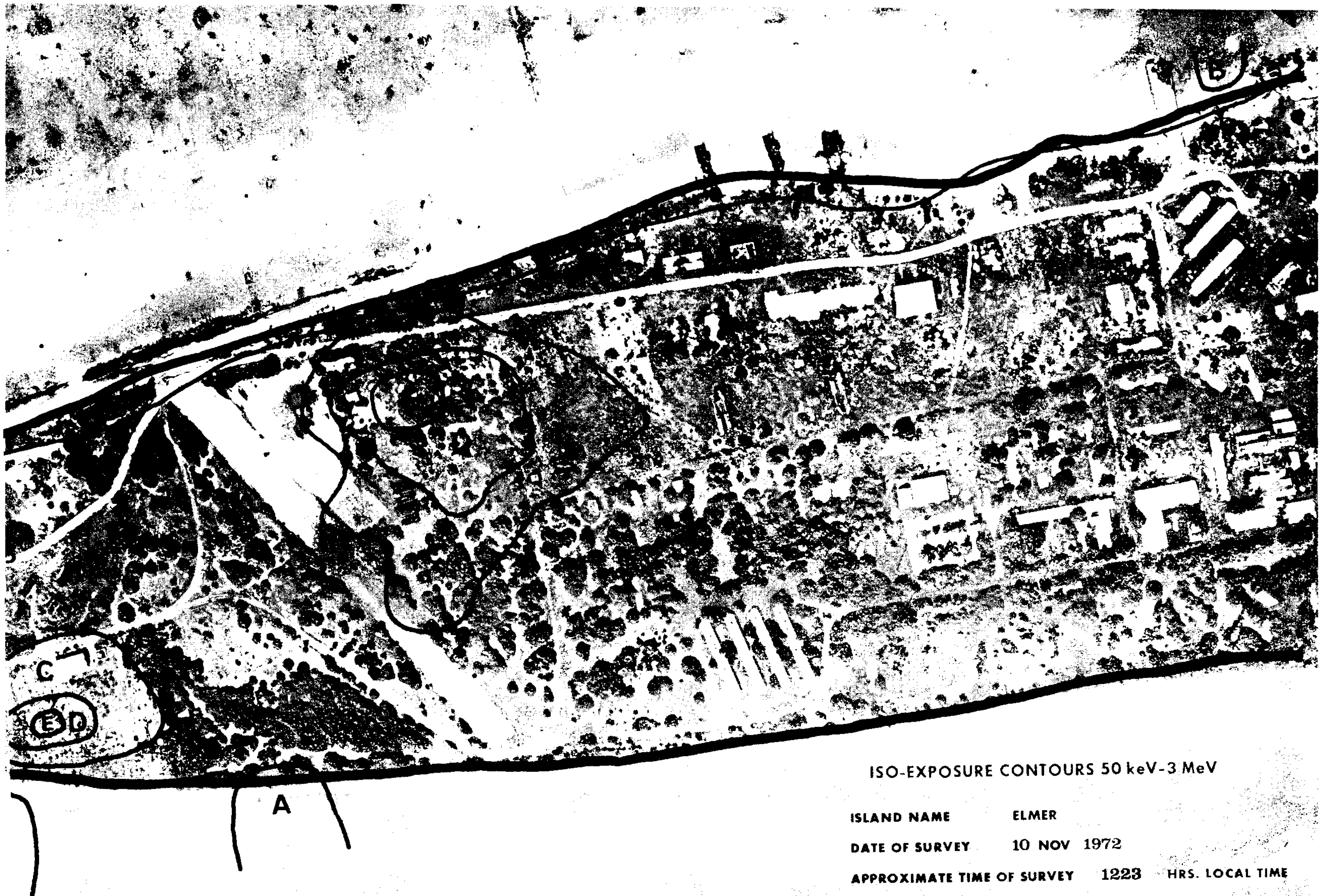

ANANIJ (BRUCE)

JINIMI (CLYDE)


JAPTAN (DAVID)




MEDREN (ELMER) A



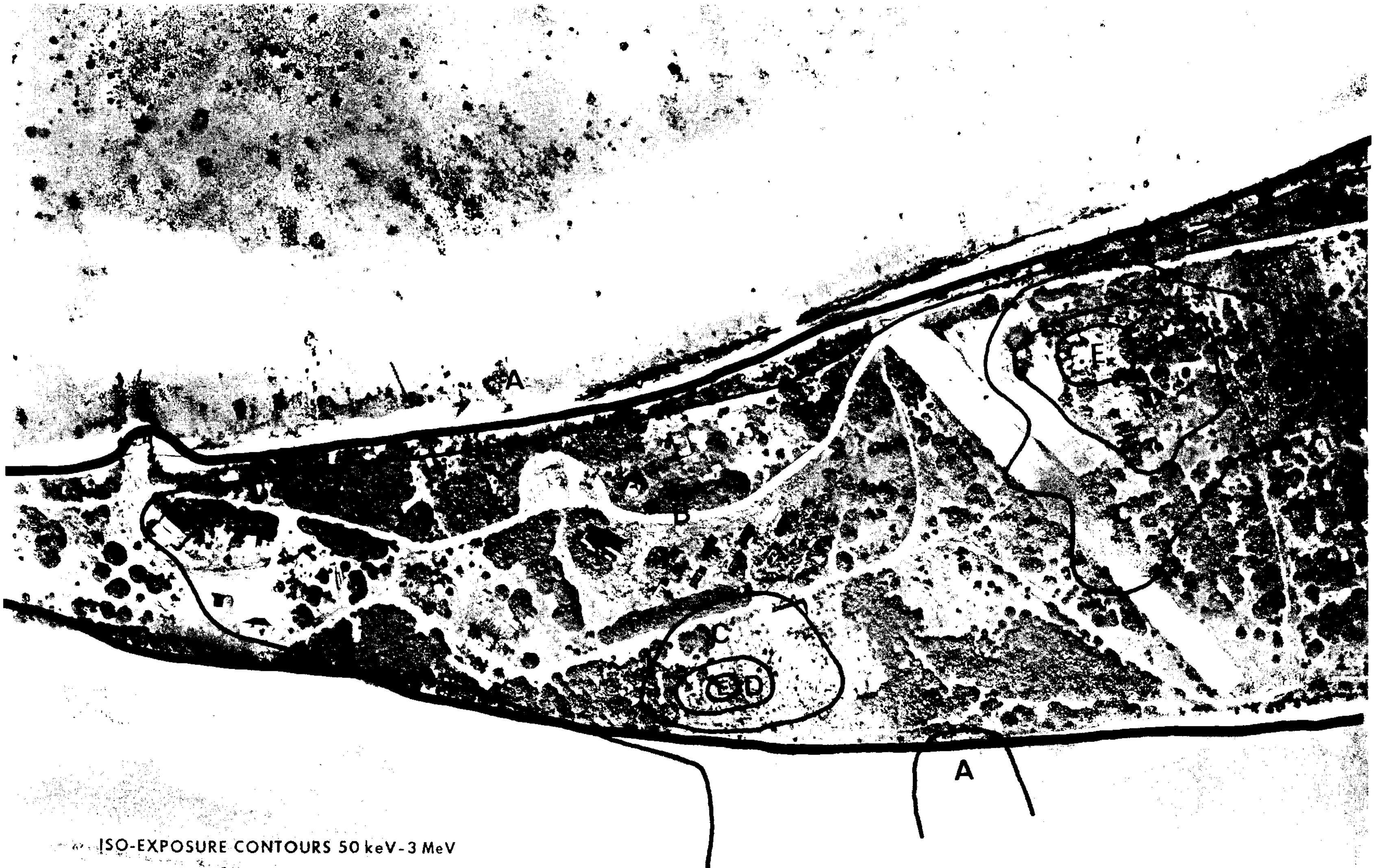

ISO-EXPOSURE CONTOURS 50 keV-3 MeV

ISLAND NAME ELMER

DATE OF SURVEY 10 NOV 1972

APPROXIMATE TIME OF SURVEY 1223 HRS. LOCAL TIME

MEDREN (ELMER) B



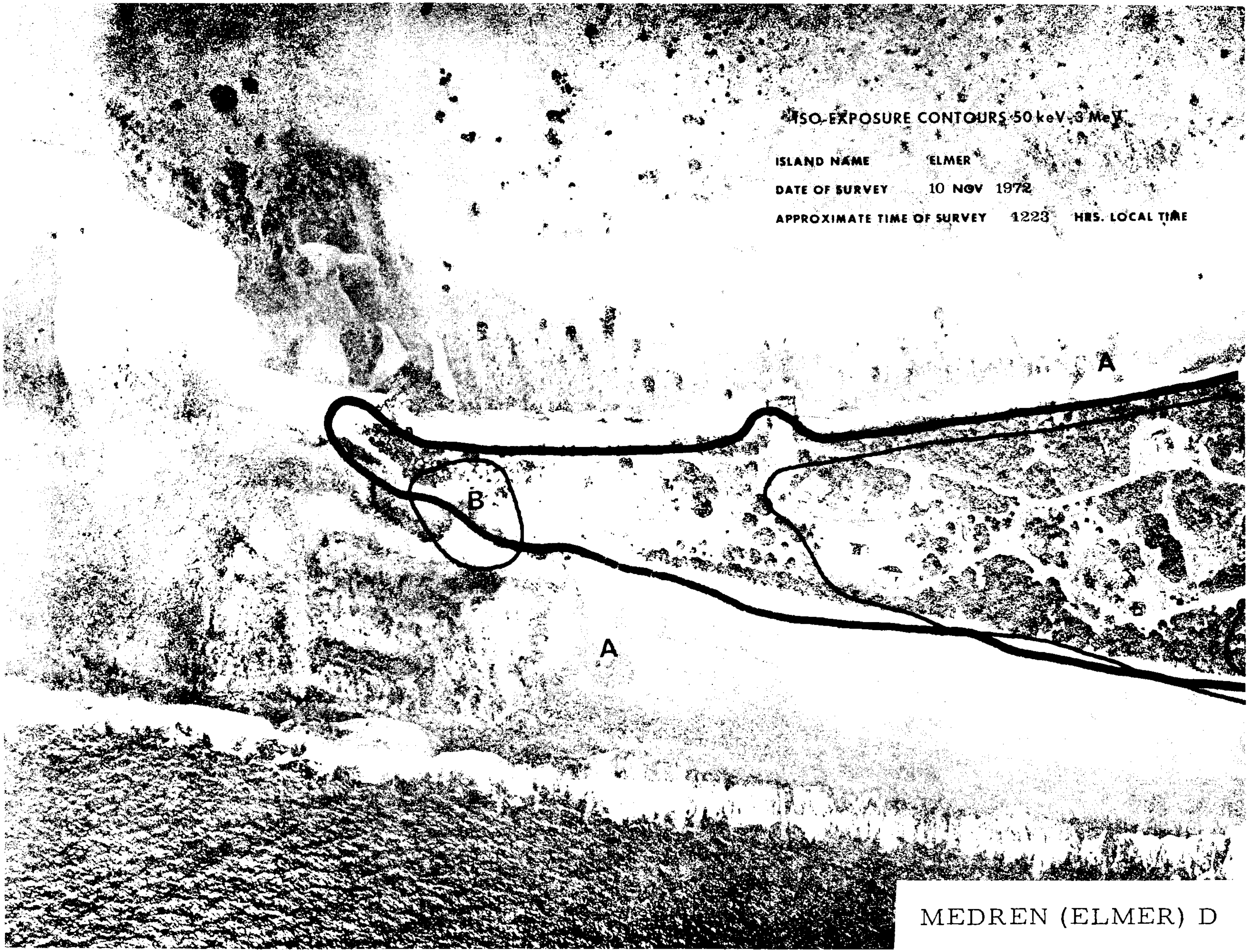

ISO-EXPOSURE CONTOURS 50 keV-3 MeV

ISLAND NAME ELMER

DATE OF SURVEY 10 NOV 1972

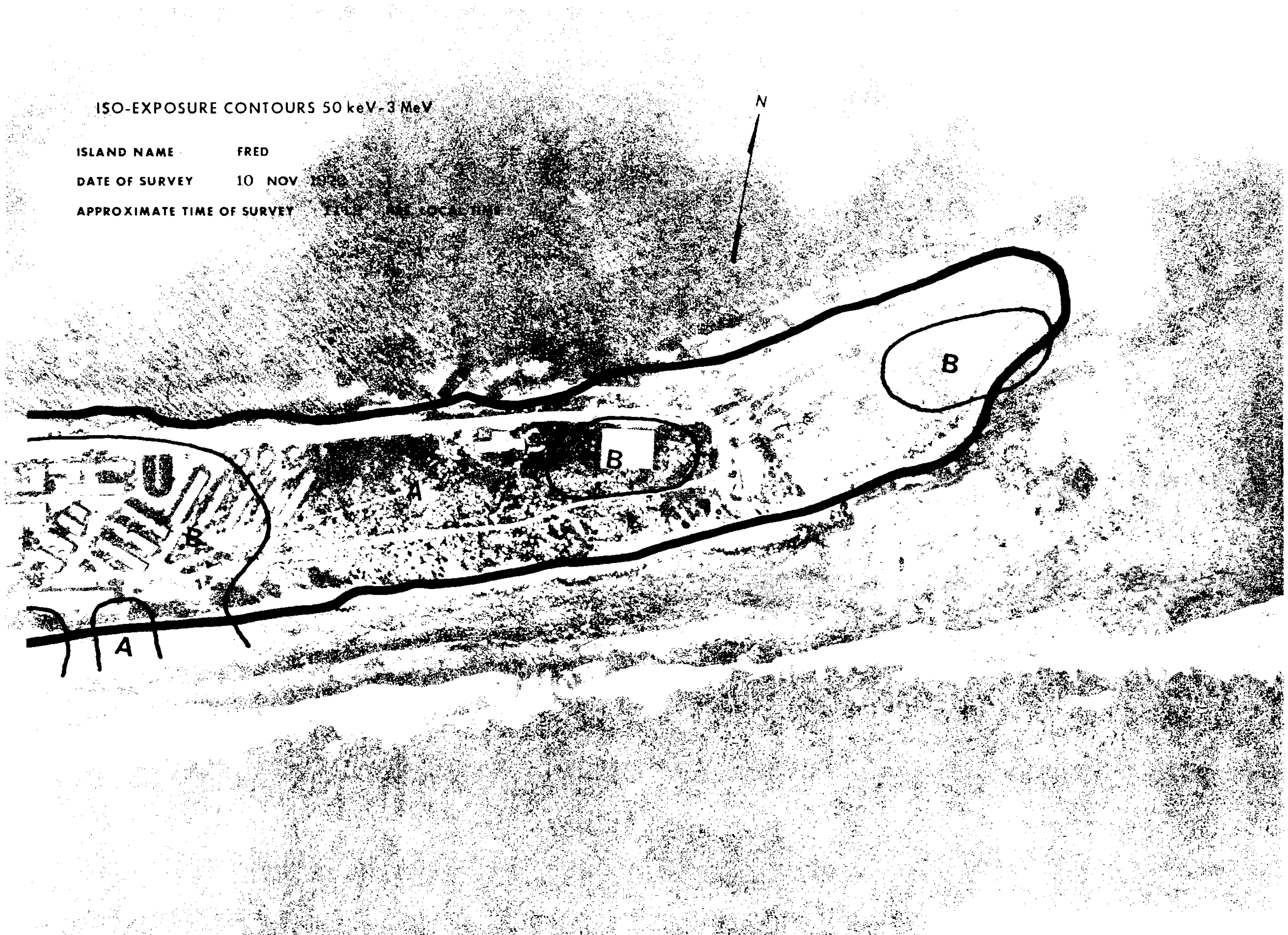
APPROXIMATE TIME OF SURVEY 1223 HRS. LOCAL TIME

MEDREN (ELMER) C

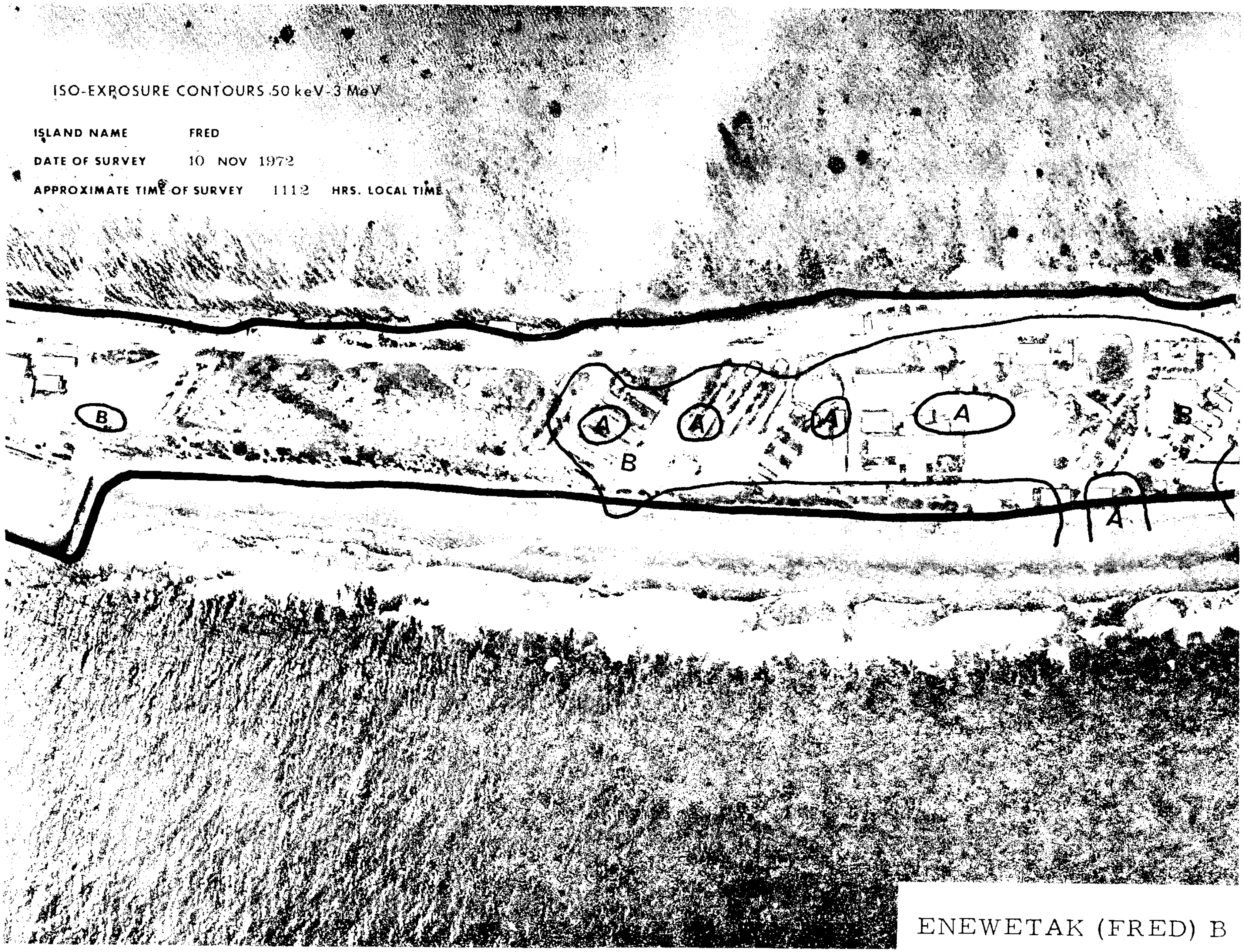



MEDREN (ELMER) D

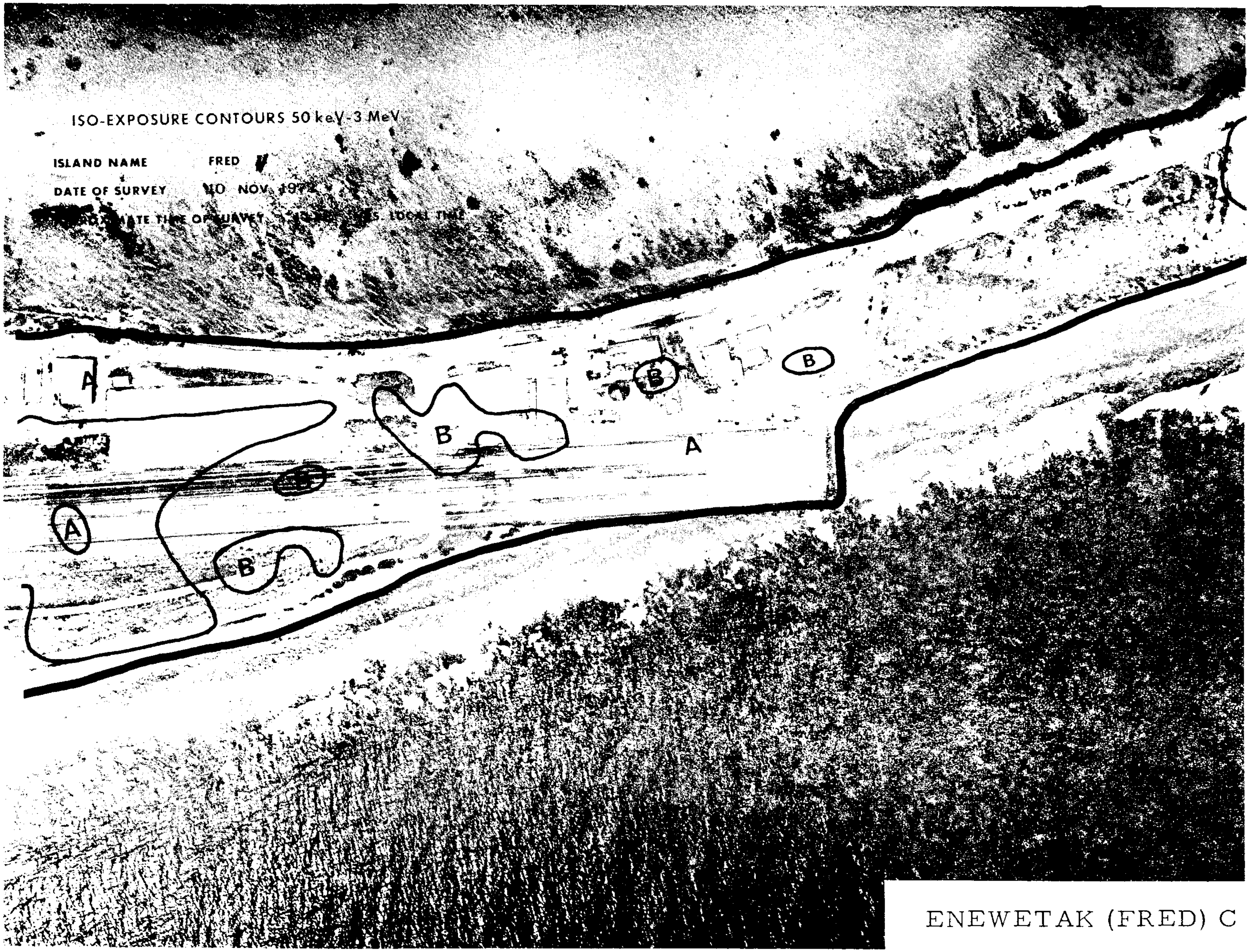
BOKANDRETOK (WALT)



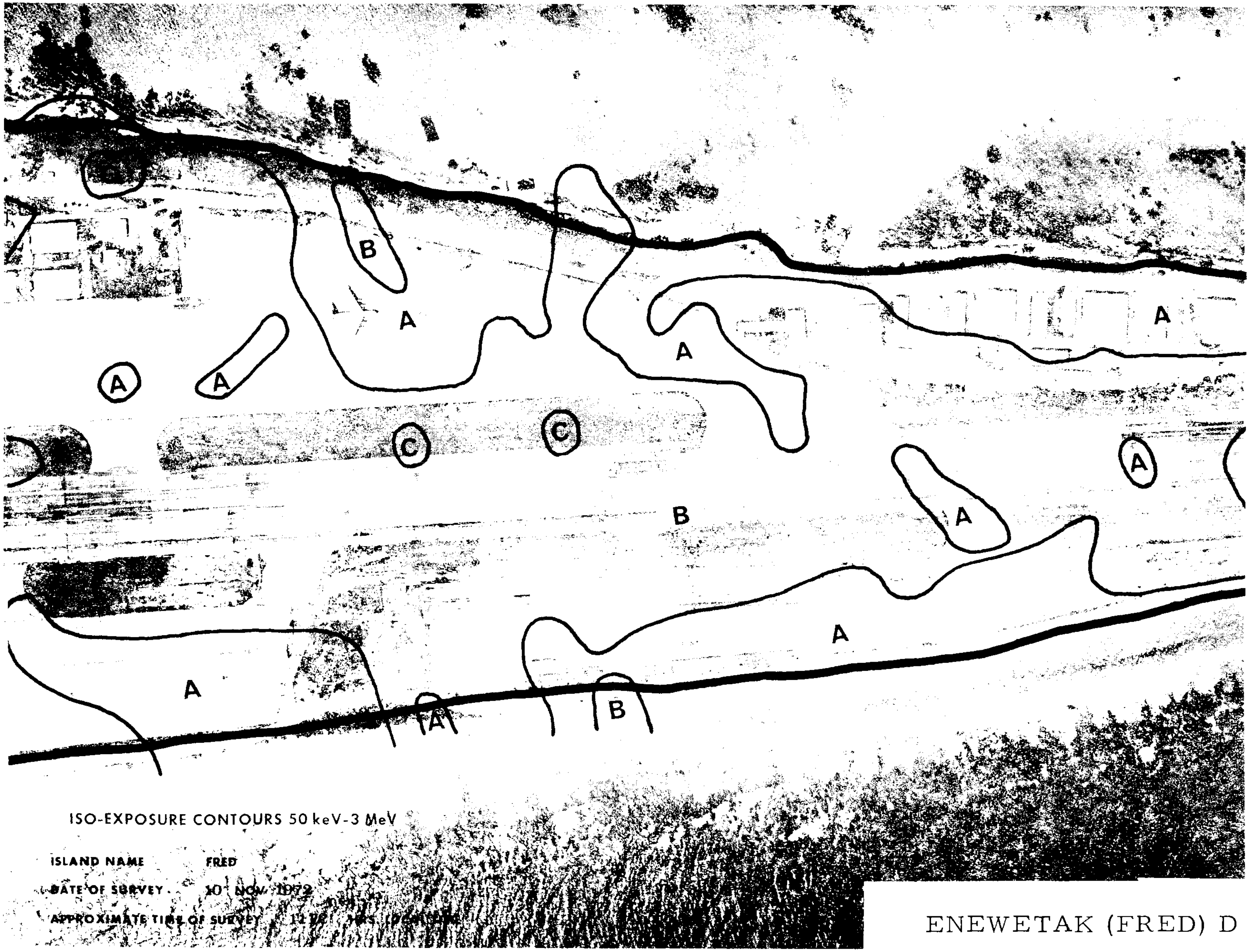

ENEWETAK (FRED) A



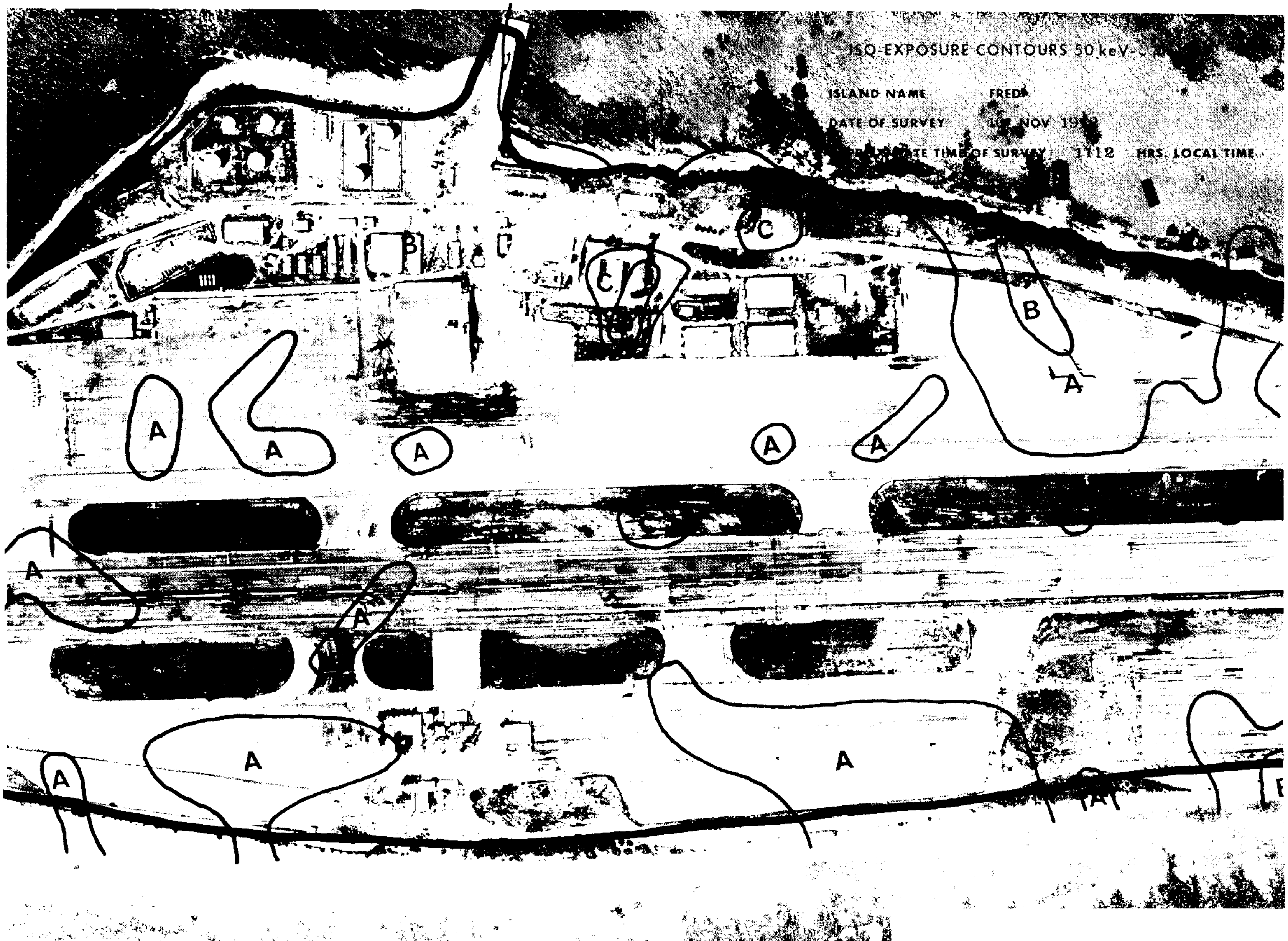

ENEWETAK (FRED) B



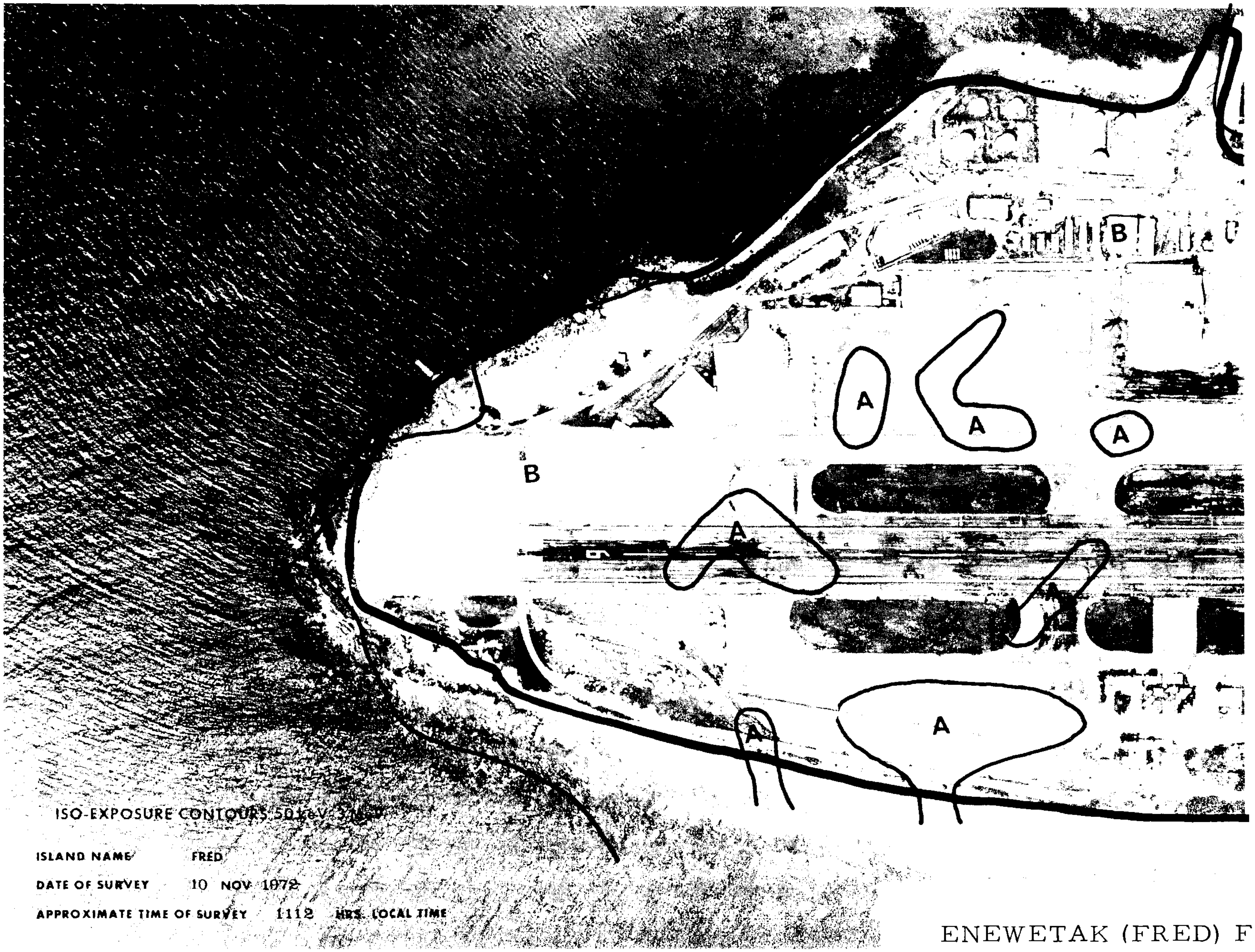
ENEWETAK (FRED) C



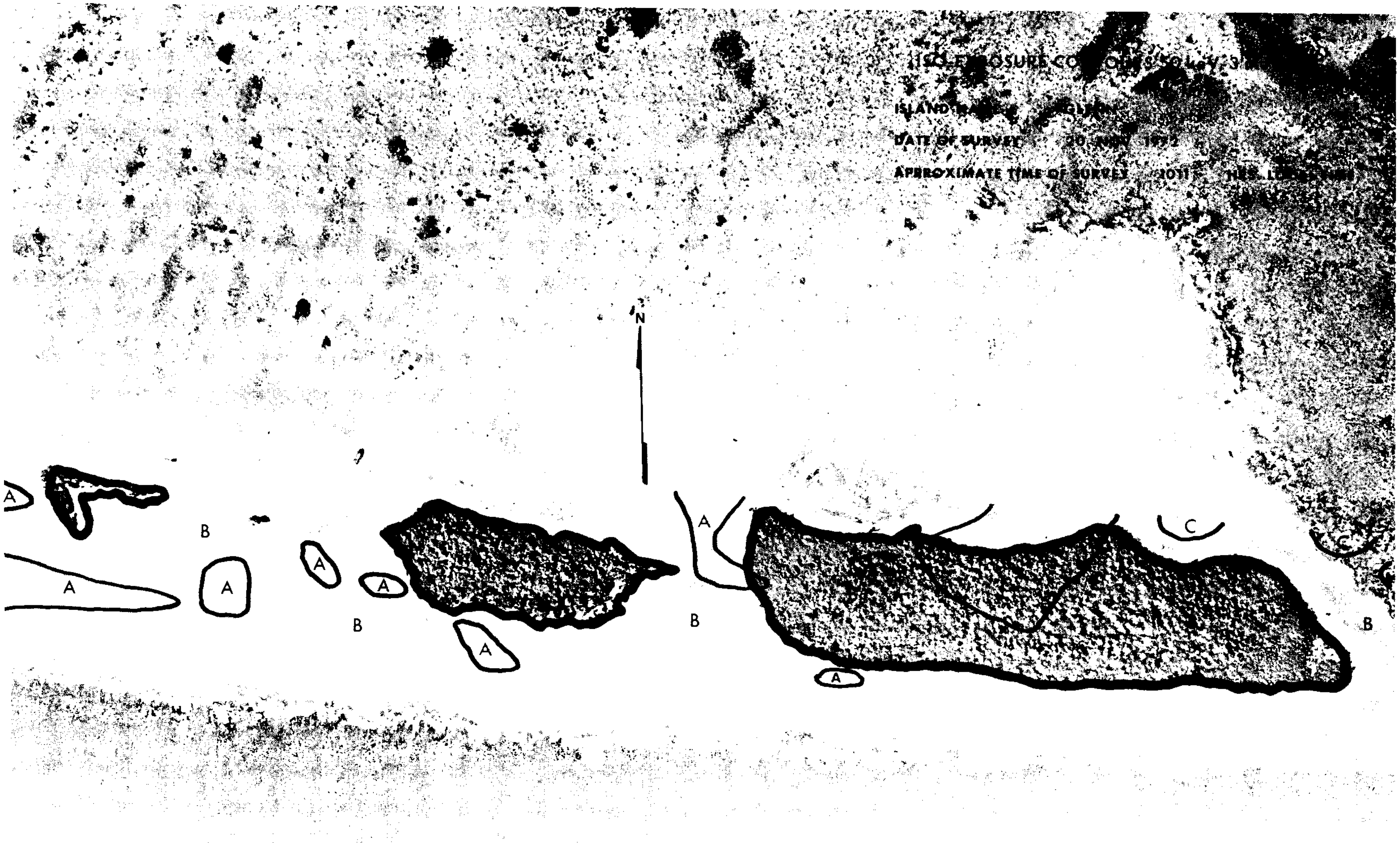

ENEWETAK (FRED) D



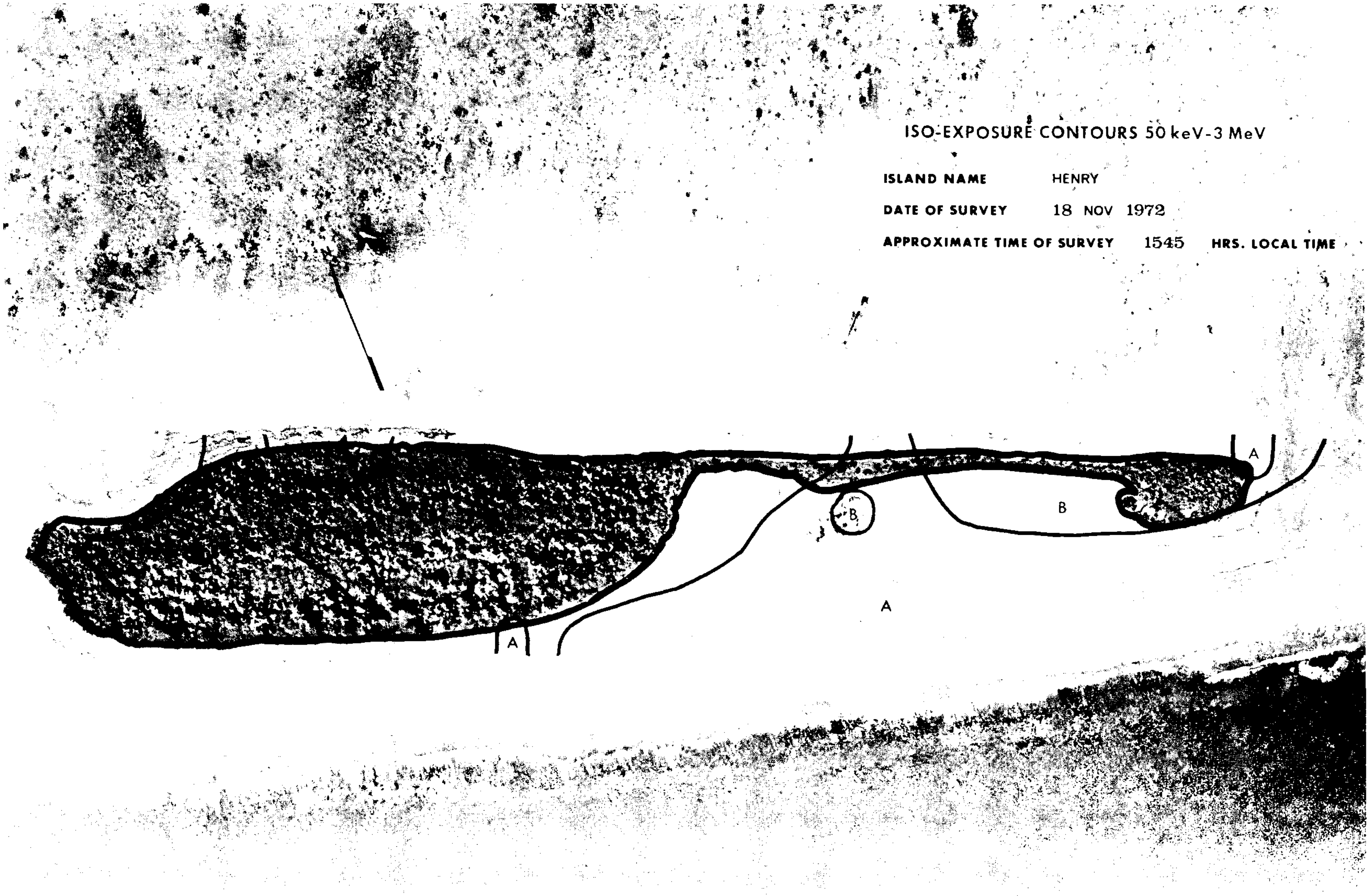

ENEWETAK (FRED) E



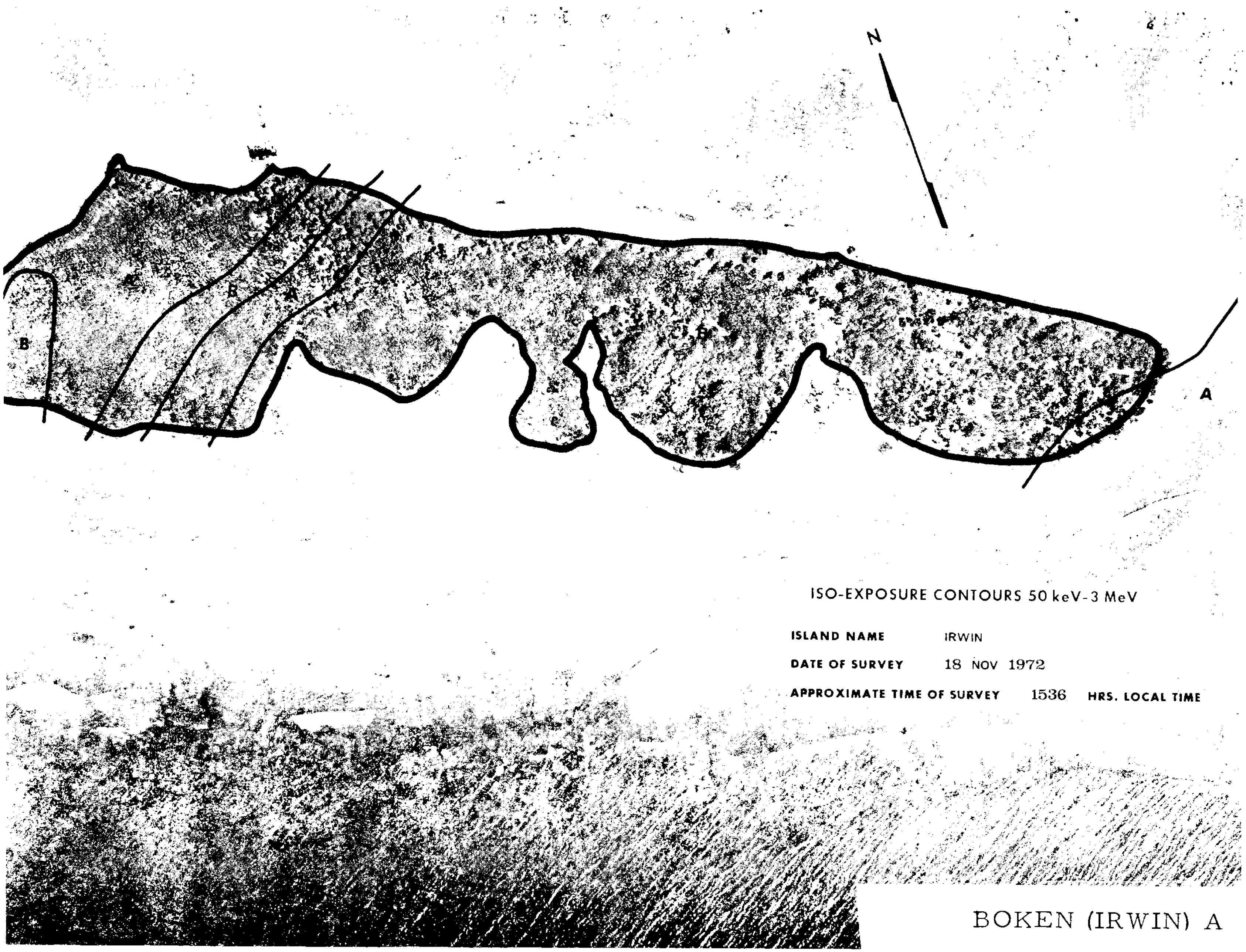

ENEWETAK (FRED) F




IKUREN (GLENN)


ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME HENRY
DATE OF SURVEY 18 NOV 1972
APPROXIMATE TIME OF SURVEY 1545 HRS. LOCAL TIME
A
B
B
A
A

MUT (HENRY)



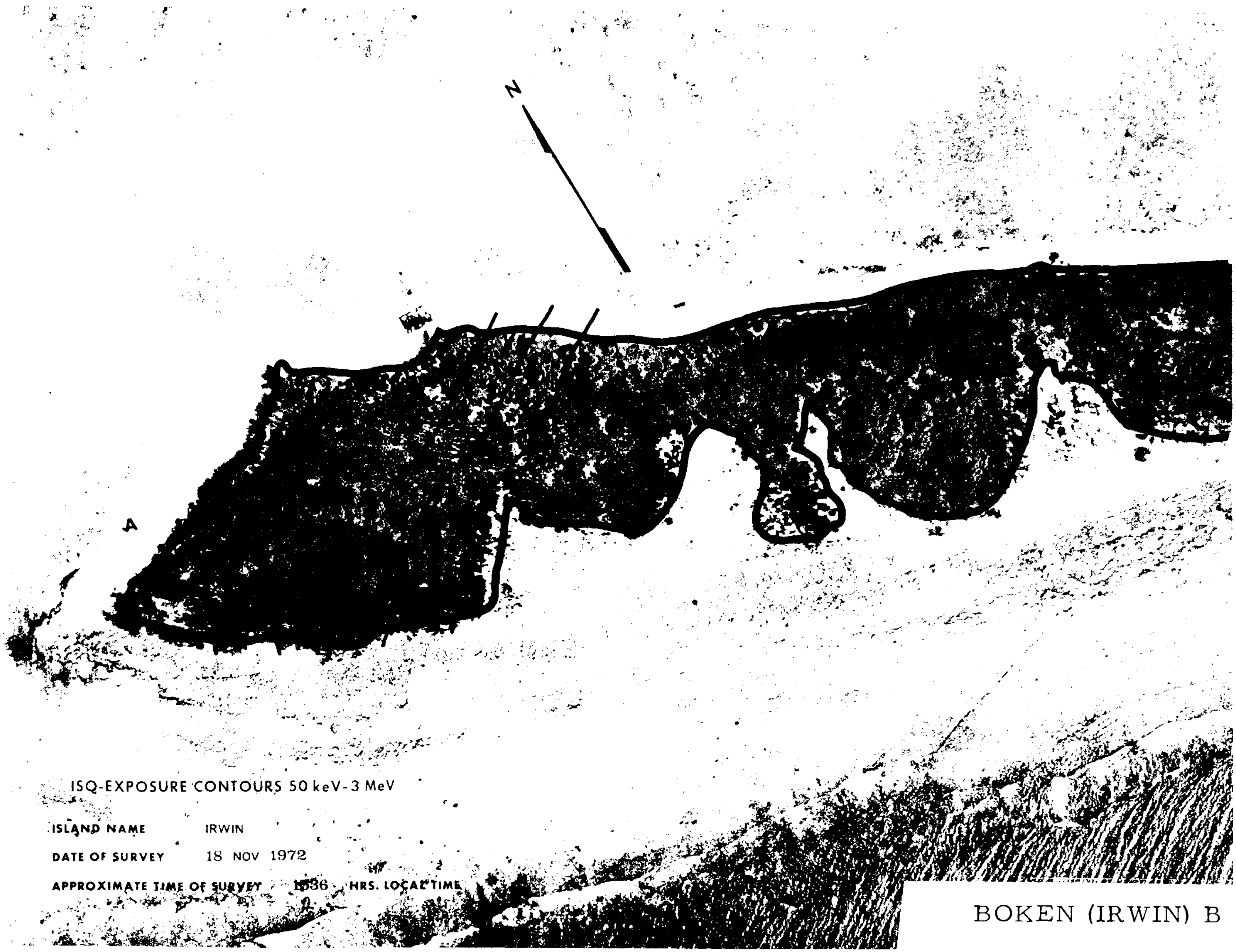

ISO-EXPOSURE CONTOURS 50 keV-3 MeV

**ISLAND NAME** IRWIN

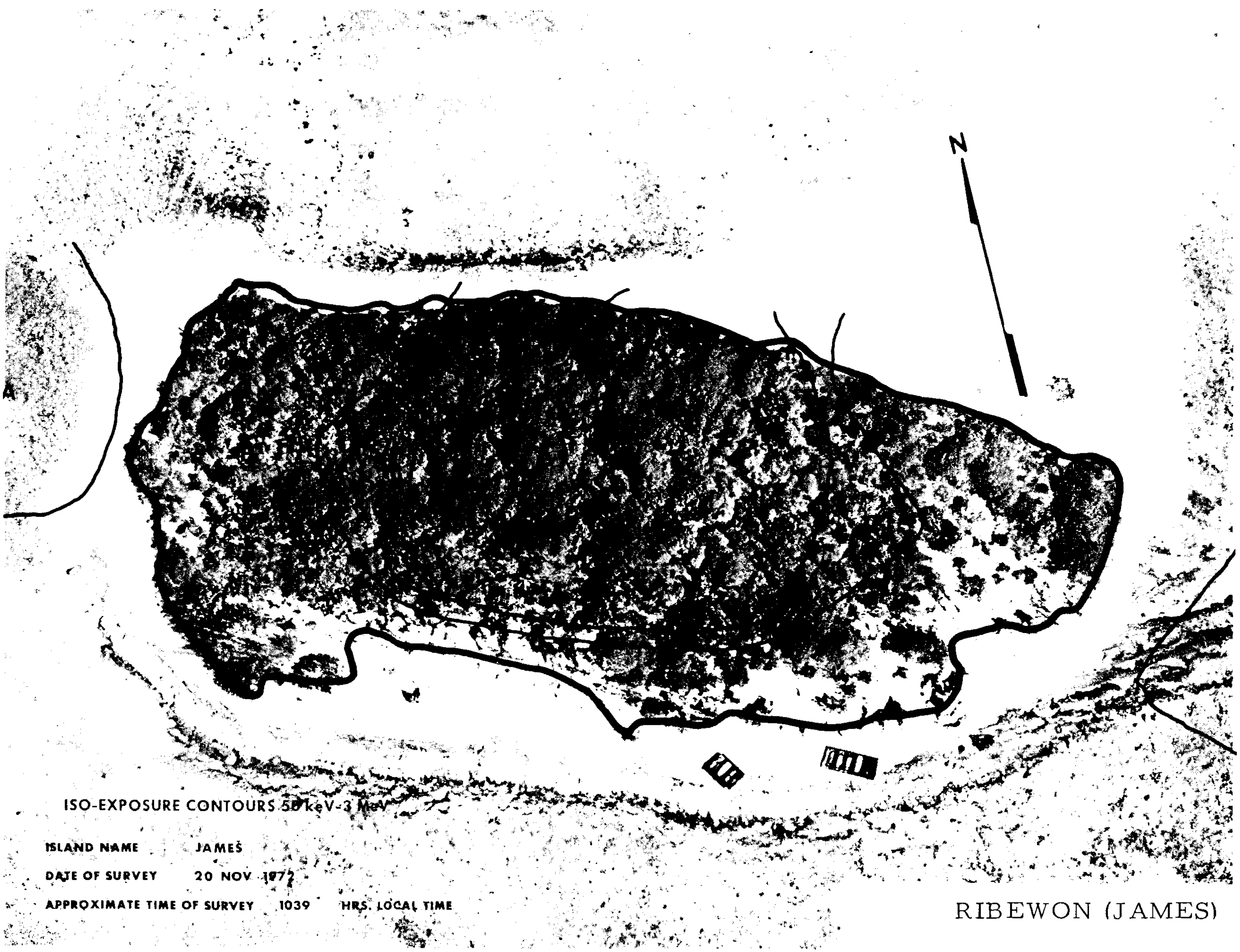
**DATE OF SURVEY** 18 NOV 1972

**APPROXIMATE TIME OF SURVEY** 1536 **HRS. LOCAL TIME**

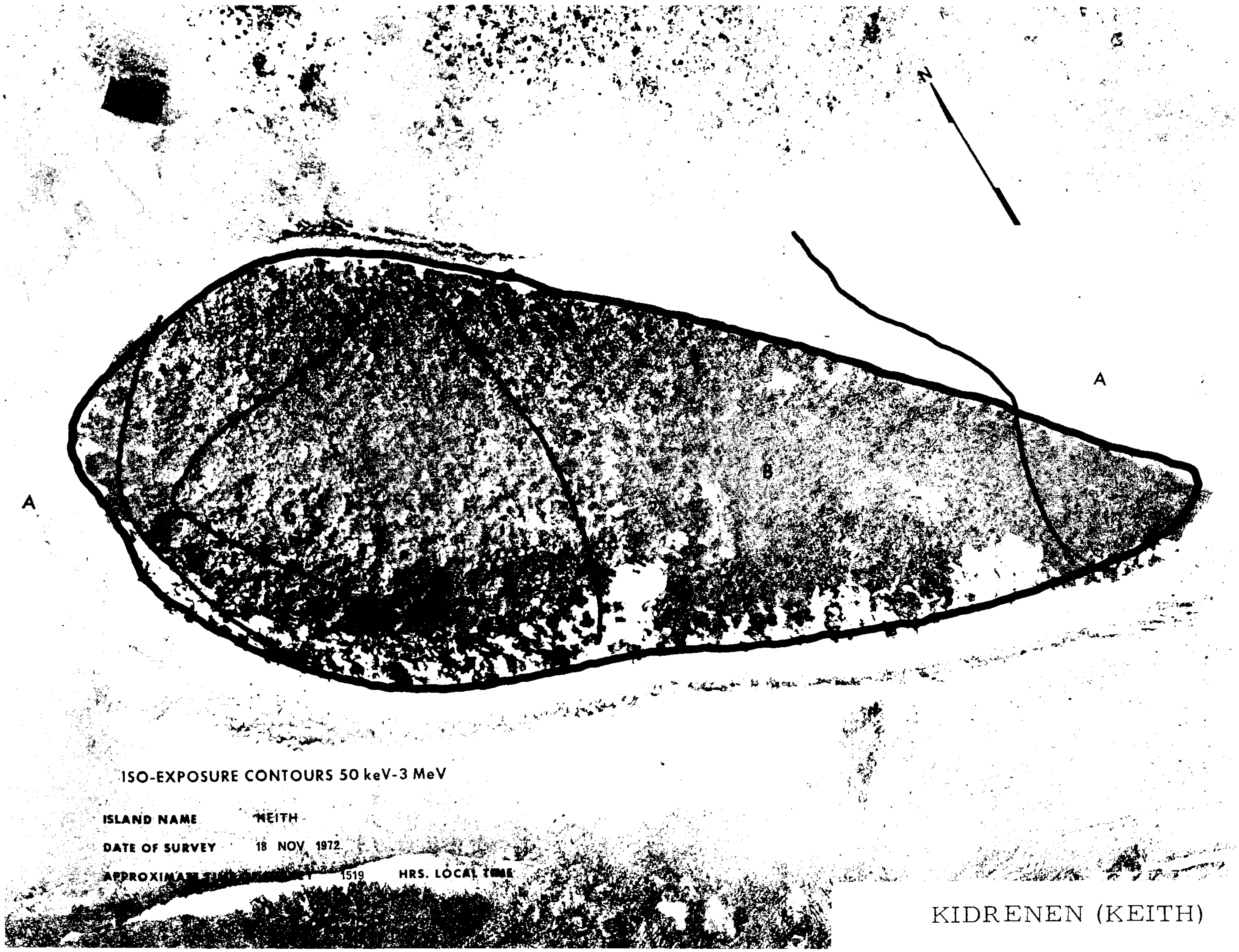
BOKEN (IRWIN) A



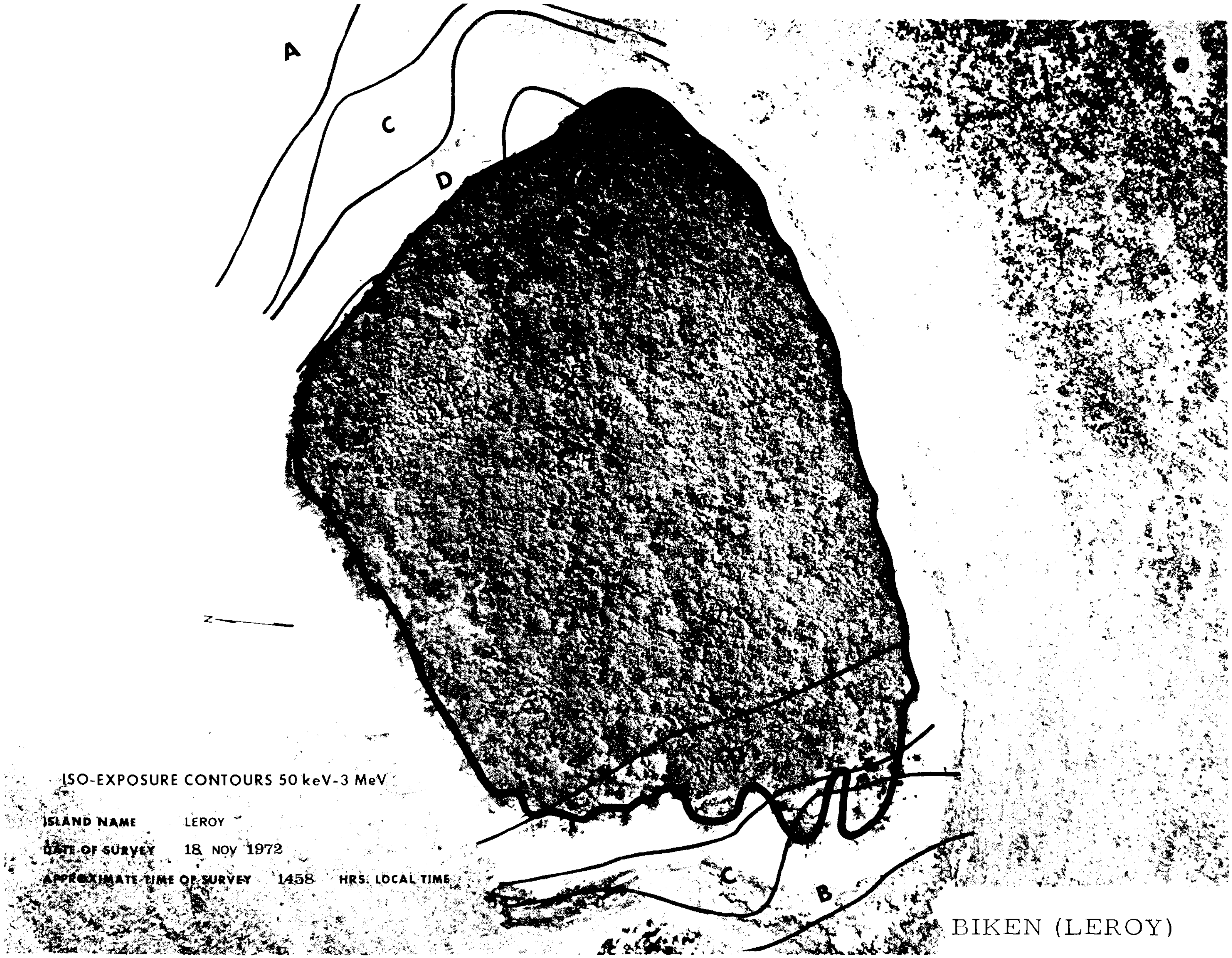

BOKEN (IRWIN) B




RIBEWON (JAMES)




KIDRENEN (KEITH)


A
C
D
B
C
N
ISO-EXPOSURE CONTOURS 50 keV-3 MeV
ISLAND NAME LEROY
DATE OF SURVEY 18 NOV 1972
APPROXIMATE TIME OF SURVEY 1458 HRS. LOCAL TIME

BIKEN (LEROY)


JEDROL (REX)

# REPORT BY

# THE AEC TASK GROUP ON RECOMMENDATIONS FOR

# CLEANUP AND REHABILITATION OF ENEWETAK ATOLL

June 19, 1974

ACKNOWLEDGEMENT

The Task Group wishes to thank all those who participated in development of input material for this report and particularly staff of the Environmental Protection Agency, Department of the Interior, and Defense Nuclear Agency for their comments and suggestions.

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## REPORT BY THE TASK GROUP ON RECOMMENDATIONS FOR CLEANUP AND REHABILITATION OF ENEWETAK ATOLL

### INTRODUCTION

On September 7, 1972, the Atomic Energy Commission (AEC) agreed to provide radiological criteria for cleanup and rehabilitation of Enewetak Atoll to the Department of Defense (DOD) and to the Department of Interior (DOI). AEC also agreed to conduct a comprehensive radiological survey. The purpose of the survey was to gain a sufficient understanding of the total radiological environment of Enewetak Atoll to support judgment as to whether all or any part of the atoll can safely be reinhabited and, if so, to describe cleanup actions to be taken by DOD and any constraints. These tasks are identical to those performed for cleanup and rehabilitation of Bikini Atoll and that experience has greatly aided the development of recommendations for Enewetak.

Radiological survey field operations were conducted between mid-October 1972 and mid-February 1973. Samples taken in the field have been analyzed and complete results of the survey have been published as a Nevada Operations Office document (NVO-140), Enewetak Radiological Survey, Vols. I, II, III. An abstract of NVO-140 is presented as Appendix I of this report, and the "Summary of Findings" chapter is reproduced here in Appendix II.

In July 1973, a Task Group was established to review the survey findings and to prepare cleanup and rehabilitation recommendations for consideration by the Commission. Members of this Task Group are: Mr. T. McCraw (AEC/OS), Dr. W. Nervik (LLL), Dr. D. Wilson (LLL), and Mr. W. Schroebel (AEC/DBER). Advisors and consultants to the Task Group have included Dr. E. Held (AEC/REG), Dr. R. Conard (BNL), Dr. H. Soule (AEC/WMT), Dr. N. Barr (AEC/DBER), Dr. R. Maxwell (AEC/DBER), Mr. L. J. Deal (AEC/OS), and Mr. R. Ray (AEC/NVO). Staff liaison representatives from DNA, EPA, and DOI attended Task Group meetings.

The job of the Task Group is to recommend for consideration by the Commission, radiological criteria for cleanup and rehabilitation of Enewetak Atoll and to recommend those remedial measures and actions needed to reduce exposures of the Enewetak people to levels within these criteria. The objective is to keep exposures as low as practicable. The Task Group, advisors, and consultants have carefully reviewed the AEC Radiological Survey results; current information on the life style, diet, and rehabilitation preferences of the Enewetak people; applicable radiation protection guidance established by various national and international radiation standards setting bodies; and current laws and regulations pertaining to disposal of radioactive waste materials.

The recommendations that were developed are those that, in the judgment of the Task Group, advisors, and consultants, are most appropriate for the U.S. Government to take to provide a radiologically acceptable environment for the Enewetak people considering they will be long-term residents on the Atoll. Recommended measures for Enewetak Atoll are very simular to those that guided cleanup and rehabilitation of Bikini Atoll.

TASK GROUP STATEMENT CONCERNING THE RADIOLOGICAL SURVEY RESULTS

After thorough review of the Radiological Survey Report, the Task Group makes the following observations:

- The survey provides an exceptionally complete data base for estimating radiation doses. It includes the results of an aerial gamma radiation survey of land area plus radiochemical data from the analysis of over 4500 samples of air, soil, vegetation, sediment, water, and marine and land animals.

- The survey report, plus the Master Plan for Rehabilitation and resettlement of Enewetak Atoll*, provide information on possible living patterns and diet of the Enewetak people.
- Several important components of the Enewetakese diet are either not now available on the Atoll, or are available in quantities which are small compared to the needs of the people. Pigs and chickens are not available at all, but will be reintroduced. No breadfruit is growing now; pandanus and tacca are growing only in scattered locations; and coconut is growing in quantity only on the southern islands. Breadfruit, pandanus, tacca, and coconut must be planted and will begin to produce crops after about 8 years. Radiation dose estimates for these foods have had to be based on correlations with plants and animals now present on the Atoll and on inferences drawn from earlier surveys on Bikini and Rongelap. There are many data points, and these correlations provide the best method currently available for estimating internal exposures. Nevertheless, the method is not as reliable as direct measurement of the foods produced in the areas of concern.
- Air sampling at Enewetak, accomplished largely during a 3 week period in December 1972 on uninhabited northern islands, showed extremely low levels if airborne radioactivity. Comprehensive air sampling during 12 consecutive months under conditions closely approximating human habitation and soil disturbance would provide more accurate data on which to base inhalation exposure estimates.

*The report, "Enewetak Atoll Master Plan for Island Rehabilitation and Resettlement," (3 Vols.), Holmes and Narver, Inc., Nov. 1973, contains information on the preferred living pattern for resettlement of Atoll obtained prior to completion of the AEC evaluation of radiological survey findings. The people are to be given another opportunity to express their views on the remedial actions under consideration by the AEC after they have been informed of radiological conditions in the Atoll, and the subjects of radiation exposure, radiation standards, radiation protection objectives, and remedial measures and their effectiveness have been discussed.

- The Enewetak people advise that catchment rainwater is the customary principal source of water for human consumption. Except in emergencies, water from underground lenses is not consumed. Samples of underground water were not obtained during the survey, and radiochemical analytical data on lens water is limited to that obtained from a few samples taken on JANET in 1971. A thorough lens water sampling, analysis, and assessment program requires sampling through a full rain-dry season cycle, 12 consecutive months at a minimum. Arrangements for sampling fresh water lenses are being made. This work will be done by AEC.
- It is the opinion of the Task Group that the results of additional air sampling or lens water sampling probably would not significantly change the dose estimates in NVO-140 nor change the recommendations of this Task Group.

RADIATION CRITERIA RECOMMENDED BY THE TASK GROUP

A review of the radiation protection standards and guides considered by the Task Group to be applicable to Enewetak is presented in Appendix III. This review indicates that the numerical standards and radiation protection philosophy of both national and international standards bodies are similar. Summarizing that appendix, the specific guidance and criteria used by the Task Group in its assessment of the data and recommended for cleanup and rehabilitation of the Atoll, are as follows:

- The population dose to the Enewetak people should be kept to the minimum practicable level.
- The Federal Radiation Council (FRC) Radiation Protection Guides (RPG) for individual and gonadal exposures are recommended as the criteria to be used in evaluating the various radiation exposure

options. The numerical guidance therein should be reduced by the factors of 50 percent for individual exposure and 20 percent for gonadal exposure considering that exposures cannot be precisely predicted. The detailed rationale for these reductions is provided in Appendix III. The resulting guides for planning cleanup actions will then be:

| | |
|---|---|
| Whole body and bone marrow - | 0.25 Rem/yr |
| Thyroid - | 0.75 Rem/yr |
| Bone - | 0.75 Rem/yr |
| Gonads - | 4 Rem in 30 yr |

- Since there is no adequate scientific information which would support general guidance for cleanup of plutonium contaminated soil, guidance can only be developed on a case-by-case basis using conservative assumptions and safety factors. With this in mind, the Task Group recommends the following for use in making decisions concerning $^{239}Pu$ cleanup operations at Enewetak:

  a. < 40 pCi/gm of soil - corrective action not required.

  b. 40 to 400 pCi/gm of soil - corrective action determined on a case-by-case basis* considering all radiological conditions.

  c. > 400 pCi/gm of soil - corrective action required.

ASSESSMENT OF DOSES AND THE RESULTS OF ALTERNATIVE CORRECTIVE ACTIONS

The Task Group approach for development of judgments and recommendations for the radiological cleanup and rehabitation of Enewetak was to consider a number of alternatives for exposure reduction that may be feasible. Basically, the procedure involved four steps:

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*See Appendix III for additional guidance.

- Assessment of doses for a population living on the Atoll in its current radiological condition.
- Assessment of dose reductions that might be expected due to modification of the diet.
- Assessment of dose reductions that might be expected due to removal of contaminated soil.
- Comparison of these dose assessment matrices with the population dose guidelines used by the Task Group.

The Enewetak Radiological Survey Report (NVO-140) contains estimates for average population doses on the Atoll for 5, 10, 30, and 70 years in its current radiological condition and for six living patterns covering a range of exposure conditions and including the pattern considered to be most representative of the Enewetak people's desired life style after they return. See Table 1 for the six living patterns assumed. In addition, dose estimates are made for each of these living patterns for each of the following corrective actions:

- Gravel the village area and plow the village island.
- Import pandanus and breadfruit from the southern islands (ALVIN-KEITH) for inhabitants of the northern islands.
- Import pandanus, breadfruit, coconut and tacca from the southern islands.
- Import pandanus, breadfruit, coconut, tacca, and domestic meat from the southern islands.

The estimates for 30 year whole body doses in the Survey Report are summarized in Table 1 of the Task Group report, and 30-year-bone dose estimates are summarized in Table 2. Note that the option for "Gravel Village Area - Plow Village Island," achieves a minimal reduction in radiation exposure of whole body and bone for all living patterns, and those living on JANET would have to import most foods to avoid exceeding a whole body exposure of 4 rems in 30 years.

Population dose guidelines used by the Task Group include annual dose rates as well as 30 year integrals for genetic doses. Appendix IV provides a detailed description of the calculations leading to estimates of maximum annual exposure for the critical organ of the segment of the population expected to receive the highest exposure. A detailed assessment of dose was made considering dietary changes that can be expected to occur with time and with age as these would influence dose to the fetus, the newborn, to children, and to adults. Estimates are developed both for persons who are adults when they return and for children born after return of their parents to the Atoll. Dynamic situations were evaluated such that exposures in the highest year are predicted. These estimates are not therefore average annual values applicable over a period of time, and exposures in other years should be lower than the predicted dose.

Conservative values have been selected for variables in models for assessment of expected doses. Though conservative, the estimates are not considered ultra conservative and do not constitute the theoretical maximum credible or worst case exposure. These conservative estimates of expected maximum annual exposure presented in Appendix IV are considered by the Task Group to be applicable to individuals in the Enewetak population. There will be few persons within this population at any one time who are fetus, newborn, or infants, believed to be the most sensitive members. Therefore, the predicted exposures are judged suitable for comparison with FRC exposure guides for individuals within an exposed population. Tables 3 and 4 show estimates of the maximum annual whole body and bone dose.

In considering the reduction in exposure that may be achievable through removal of contaminated soil, the Task Group has taken the position that these predicted exposures are approximations only. The effectiveness of such actions to reduce internal exposures that come through the food chain must be confirmed through analysis of test plantings. The Task Group does not favor soil removal as a dependable or feasible exposure reduction action for the dietary pathway. However, such action is reviewed in the Task Group Report in order to present a complete picture of the various possiblities considered.

In its assessment of dose reductions that might be possible due to removal of contaminated soil, the Task Group posed the following question: "Given the dose estimates of Tables 1-4, and the dose reductions that can be expected due to the indicated actions, can equivalent dose reductions be achieved by removal of soil and, if so, what volume of soil would have to be removed from contaminated islands?" In order to address this question one must know or have estimates of the areas to be used for housing and villages, for growing pandanus and breadfruit, for growing coconut, and for raising domestic animals.

Figure 1 shows the Enewetak Atoll Land Use Plan as presented in the Enewetak Atoll Master Plan. Of the northern islands only Enjebi (JANET) would be used as a residence and agricultural island if this were feasible. Aej (OLIVE), Lujor (PEARL), Amon (SALLY), Bijile (TILDA), Lojwa (URSULA), and Alamebel (VERA) are intended to be used as agricultural islands, and the remainder (ALICE, BELLE, CLARA, DAISY, IRENE, KATE, LUCY, MARY, NANCY, and WILMA) as food gathering and picnic islands.

Figure 2 shows the land use plan for Enjebi Island (JANET), including 14 housing areas (560,000 $ft^2$, assuming an average housing area to be 200' x 200' in size), a community center (200,000 $ft^2$), subsistence agricultural areas (1,100,000 $ft^2$), and commercial agricultural areas (7,300,000 $ft^2$).

In order to get an approximation of the amount of soil that would have to be removed to bring about a given dose reduction, one needs to determine the three dimensional distribution of the radioactive contamination. Figure 3 shows the average $^{90}Sr$ activities (pCi/gm) in soil samples collected to a depth of 15 cm on JANET. Similar figures for $^{137}Cs$, $^{60}Co$, and $^{239}Pu$ may be found in Appendix II of NVO-140. In addition to the 15 cm deep samples, radioactivity distribution as a function of depth ("profile samples") was measured in fourteen locations on JANET. Data from these profiles are presented in Figs. B.8.2.a-n of Appendix II of NVO-140. Inspection of these profiles indicates that, on the average, about 40 cm of soil would have to be removed to reduce the activity in the top 2 cm layer by a factor of 10. In addition, as the depth increases the slope of the activity-vs-depth curve tends to decrease, i.e., the activity levels do not go to zero, even at depths greater than 100 cm. Table 5 shows pertinent data for $^{90}Sr$.

In an attempt to quantify this distribution and obtain an approximation of the "average profile" for calculational purposes, $^{90}Sr$ and $^{137}Cs$ data for each of the fourteen profile samples have been reproduced in Tables 6 and 7. The average values for $^{90}Sr$ for each sampling depth are plotted in Fig. 4. It is apparent that from the surface to about 30 cm the $^{90}Sr$ specific activity is decreasing with a "soil half thickness" of 8.4 cm, while in the 30 to 85 cm depth range the half thickness increases to 22 cm. The levels do not get as low as those found on the southern islands ($\sim$0.5 pCi/gm) at any depth down to 180 cm. Those profile samples which lie in or closest to the subsistence agriculture areas of Figure 2 have been averaged and plotted in Fig. 5. In this set, the half thickness is only 4 cm from the surface to 10 cm, but increases to 25.5 cm in the 10 to 85 cm depth range. Similar treatment of the $^{137}Cs$ data is plotted in Figs. 6 and 7. In Fig. 6, where all samples are averaged, the half thickness is 4.5 cm down to about 10 cm, and 12 cm from 10 to 85 cm. Levels equal to those found on the southern islands (~0.2 pCi/gm) are found at depths below about 100 cm. In Fig. 7, the subsistence agriculture case gives a half thickness of 2.7 cm down to 10 cm, and 17.8 cm from 10 to 85 cm.

For both $^{90}Sr$ and $^{137}Cs$ it is apparent that the profile averaged over all samples is more conservative than is the profile for subsistence agricultural areas for estimating the effects of soil removal; therefore, the Task Group has used Figs. 4 and 6 for estimating dose reductions that might occur due to removal of soil.

In making these dose reduction approximations, one must keep two things in mind; first, that the NVO-140 dose estimates for terrestrial foods grown on an island such as JANET are based on correlations between certain indicator plants and average soil concentrations in the 0-15 cm samples (Fig. 3) since foods such as pandanus and breadfruit were not found on JANET and, second, that these concentrations are averaged over the 0-15 cm depth of Figs. 4 and 6. Estimates of dose reductions to be expected due to removal of soil to a given depth, therefore, require an estimate of the ratio of the average concentration of the nuclides of concern in the 0-15 cm depth of the newly exposed surface to that for the surface which is present now. This approach does not consider the radioactivity in the soils deeper than 15 cm which may be important, particularly for plants with roots that penetrate deeply into the soil. Table 8 presents these average concentrations and ratios for $^{90}Sr$ and $^{137}Cs$ for each 15 cm increment from the present surface down to 105 cm as derived from Figs. 4 and 6. These estimates indicate, for example, that removal of 15 cm of soil may reduce the terrestrial food dose due to $^{90}Sr$ by a factor of 3.3 and that due to $^{137}Cs$ by 3.2. However, such reduction may or may not be actually achieved. The Task Group believes that subsistence crops should not be planted on an island if use of the food produced is questionable. Measurements of radionuclide content of fruit from test plantings would be needed to determine the effectiveness of soil removal actions.

Using the data of Table 8, one may assess the dose reductions that might occur due to specific cleanup actions on JANET. Table 9 shows the doses that might occur due to seven different conditions. Case DI represents the contributors to the 80 Rem bone dose of Table 2 using values for $^{90}Sr$ and $^{137}Cs$ averaged over all of JANET. Case DI-1 indicates that if subsistence agriculture is limited to the area shown in Fig. 2 (i.e., along the lagoon shore) the $^{90}Sr$ and $^{137}Cs$ levels may be reduced to such an extent that the resulting 30-yr-bone dose becomes 57 Rem. Removal of a half-thickness of $^{137}Cs$ (4.5 cm) in the residential areas has little effect since that action influences only the external gamma dose. Removal of successive 15 cm layers of soil in the subsistence agricultural areas, however, may reduce the bone dose by significant amounts. Removal of the top 15 cm layer, for example, may reduce the 30-year-bone dose from 57 Rem to 19 Rem, while removal of an additional 15 cm may bring the dose down to 10.7 Rem.

Since soil removal-vs-bone dose reduction would possibly be most effective for pandanus and breadfruit, a variation on the estimates of Table 9 may be obtained by preferentially stripping soil in areas where these trees are to be grown. For case DI-1, for example, if pandanus and breadfruit are grown in the subsistence agricultural areas only in sections from which 15 cm of soil have been removed, the resulting bone dose may drop from 57 Rem to 29.7 Rem (i.e., 57-39.1 + 11.8). If an additional 15 cm layer is removed, the dose may drop to 23.7 Rem.

Another action that would achieve the maximum dose reduction that can be expected is through importation of clean soil from the southern islands or from outside the Atoll. $^{90}Sr$ concentrations in the average profile (Table 6) do not get as low as those on the southern islands even at a depth of 180 cm. To achieve this maximum effect, however, sufficient clean soil has to be imported to encompass the entire root system of the mature trees and the water supply for these crops must not have $^{90}Sr$ levels higher than those found in the southern islands. Any replacement soil should be coarse and granular. Such soil is less likely to blow away or wash away. Given these conditions, the 57 Rem bone dose of case DI-1 may be reduced to 18.9 Rem (57-39.1 + 2.1 (0.45) (the 2.1 Rem from Table 241 and 0.45 from Table 243 of NVO-140).

As to the question of whether equivalent dose reductions (equivalent to reductions obtained through modification of the diet) could be obtained through removal of contaminated soil, the Task Group holds the opinion that some reduction is possible. However, the magnitude of this reduction is uncertain and can only be determined reliably through measurement of the radionuclide content of the important food items such as pandanus and breadfruit grown in the modified condition. This would require a research effort to grow test plantings of the various food crops in the soil removal and replacement areas using various fertilizers and trace minerals, and analysis of radionuclide content of the fruit produced. There is the possibility that radioactivity in the fruit could be reliably predicted from analysis of stems and leaves of young and as yet unproductive plants. This would require additional study.

In the commercial agriculture areas of JANET and the other northern islands the item of concern is the radioactivity level of coconuts i.e., "Can the Enewetakese sell their copra?" Data in NVO-140 (pg 560-562) indicate that $^{137}Cs$ is the principal man-made radionuclide found in coconut meat, with the relationship $^{137}Cs$ (copra) = 1.33 $^{137}Cs$ (soil) at $^{137}Cs$ soil concentrations greater than 4.7 pCi/gm. NVO-140 also indicates that $^{40}K$ is found in copra at an average concentration of 6.8 pCi/gm. Since $^{40}K$ is a naturally occurring gamma emitter that has always been present in copra, one way to judge the acceptability of copra grown in Enewetak Islands is on the basis of its $^{137}Cs$ content relative to the naturally occurring $^{40}K$. If the $^{137}Cs$ content in soil is less than 5.2 pCi/gm, for example, the $^{137}Cs$ content of the copra produced may be less than its $^{40}K$ content. One could hold the position that marketability should not be affected if the fission product radioactivity makes less contribution to consumer exposure than naturally occuring radioactivity in the product. Table 10 shows the mean $^{137}Cs$ soil concentration and soil removal actions that may reduce the $^{137}Cs$ concentration in copra to values equal to and twice that of the natural $^{40}K$ for all northern islands (average profile data for PEARL, ALICE, BELLE, and CLARA, plotted in Figs. 8-11 and included in Table 8, were used in the calculations for each of these islands).

On JANET, for example, the commercial agriculture area in its current condition should yield copra with an average $^{137}Cs/^{40}K$ concentration ratio of about three. Removal of a 6 cm thick layer of soil may reduce this value to two, and removal of 14 cm may result in copra with equal concentrations of $^{137}Cs$ and $^{40}K$. Note that for islands planned to be used for commercial agriculture, it is possible that only JANET and PEARL have $^{137}Cs$ soil values high enough to yield copra with a $^{137}Cs/^{40}K$ ratio greater than 2. Test plantings of coconut would be needed in areas where removal of soil has been conducted and the level of $^{137}Cs$ in coconut meat analyzed before any commitment is made for planting of coconut trees in commercial quantities. As previously noted, it may be possible to predict the level of $^{137}Cs$ in coconut meat through analysis of stems and leaves of immature trees. This would save time.

The Task Group points out that measurable quantities of tests related radioactivity will be found in copra from all islands in the atoll, the highest levels from the nothern islands. No quarantee can be given for a level of $^{137}Cs$ acceptable in the market place, however, the level of natural $^{40}K$ appears to be a reasonable guidepost since there has been no requirement to reduce the level of naturally occuring radioactivity in copra.

DISPOSAL OF CONTAMINATED MATERIAL

For disposal of contaminated material, there appear to be several categories, each requiring separate consideration:

1. Contaminated scrap, non-plutonium.
2. Contaminated soil, non-plutonium.
3. Contaminated scrap, plutonium.
4. Contaminated soil, plutonium.
5. Pieces of plutonium metal.

Some of the above are below the ground surface such as in burial sites. Some is near the surface such as the pieces of plutonium metal on YVONNE. With regard to disposal, the Task Group considers it appropriate to cite the objectives for disposal, to list possible approaches for disposal, and to suggest possible interim measures where appropriate.

Table 12 and the associated discussion in NV-140, Vol. I, contains information on known or suspected burial sites for radioactive debris. The Holmes and Narver "Engineering Study For A Cleanup Plan, Enewetak Atoll-Marshall Islands," Hn.-1348.1, contains information on the location and quantity of other above ground contaminated scrap.

Considering the relative short radiological halftimes for the fission products and induced radioactivity found on such scrap and debris, the Task Group suggests that the objective for disposal is to make this debris, particularly scrap metal, unavailable to the people when they return. Possible approaches for disposal are:

1. Disposal in water filled and underwater craters.
2. Shallow land burial wherein the radiation level of the scrap is not significantly greater than the radiation level on land.
3. Disposal in deeper portions of the lagoon. It is expected that this would be a modest addition to similar material already there from past test operations.

For contaminated soil, other than plutonium, the Task Group has not included removal of such soil in its recommendations and therefore there would be no requirement to select a method of disposal. If such disposal were required, the objective would be to assure that there would be no pathway for any exposure of the Enewetak people to this radioactivity and a minimal follow-up requirement to insure that this situation continues after disposal.

The Task Group view is that because of its extremely long half-life, disposal of plutonium in the form of contaiminated soil and scrap is a problem of greater magnitude than for fission products and induced activity. In its deliberations, the Task Group has assumed that the disposition of such material will be such that there is no potential for exposure of the residents of the Atoll once cleanup has been completed. This is then the objective for cleanup.

Recommmendations which follow will treat the questions of how to approach recovery of quantities of finely divided plutonium in the form of contaminated soil, contaminated scrap, and the pieces of plutonium metal where they have been found to occur. Appendix III of this report contains guidance on decisions to be made on whether removal of plutonium contaminated soil is justified on various islands. It is the view of the Task Group that as a minimum, cleanup must accomplish the recovery of the plutonium in the form of contaminated materials, soil and scrap, from the various islands including buried scrap. To maintain control of the materials and minimize the spread of contamination, the recovery operations should utilize as few stockpiles as necessary. YVONNE may be a suitable site for such a stockpile until proper disposal is accomplished. YVONNE is still under quarantine placed in effect in May 1972, as a result of an AEC survey that indicated pieces of metal containing milligrams quantities of $^{239}Pu$ were on or near the surface of the island.

It is the hope of the Task Group that deliberation and decisions on disposal of plutonium contaminated soil and scrap will not delay other cleanup and rehabilitation actions.

As for considering disposal, there appear to be two possibilities:

1. Disposal wherein there is an irrevocable commitment of the contaminant to the environment.
2. Disposal wherein, with some difficulty, a later decision could change the method of disposal.

The following ideas have been put forth regarding disposal of plutonium contaminated soil and scrap:

1. Disposal of plutonium contaminated scrap in the deep lagoon or deep ocean.
2. Make the contaminated soil into concrete blocks with disposal in deep ocean or through burial on land.
3. Disposal of contaminated soil in the form of cement poured into deep drill holes on land with the scrap added.
4. Disposal of soil and scrap in the water filled craters on YVONNE with a thick concrete cover.
5. Return of these materials for burial in the U.S. in packaged form or as concrete blocks.
6. An effort be made to find a way to reduce the volume and amount of material requiring disposal.

Any ocean disposal plans must conform with the specific provisions of applicable regulations governing such disposal and must be approved by the Environmental Protection Agency. Discussions with the Enewetak people and their representatives indicate they strongly oppose disposal of radioactive debris on the Atoll. Any plans for burial of contaminated debris within the Atoll should be discussed with the people.

It may be possible to reduce the amount of material requiring disposal by removal of the plutonium from the most highly contaminated soil. The Task Group does not have adequate information to determine whether this may be feasible. Research to determine whether this can be accomplished could be conducted with YVONNE used as the study site.

## TASK GROUP OBSERVATIONS AND CONCLUSIONS

In the radiologically complex Enewetak Atoll environment there are a large number of options that may be considered for cleanup and rehabilitation of various islands. The Task Group has considered as many of these as possible and has attempted to arrive at a consensus of opinion among the drafting group and its technical advisors. Comments on draft material have been solicited from staff of several Federal agencies. Their suggestions have influenced the development of recommendations. Regarding each option, the following have been considered.

1. Determination of the radiological exposure to be expected and comparison of predicted exposures with accepted radiation exposure criteria.
2. The feasibility of actions or restrictions inherent in the option.
3. The effectiveness of the option in bringing exposures within the criteria and any uncertainties regarding the effectiveness.
4. The possible impact on the Enewetak people and on the environment.

Choice of the best overall method for reduction of exposures to the lowest practicable level is a matter of judgment and opinion. The Task Group has deliberated whether actions of an engineering nature, such as soil removal, are preferable to actions that would restrict use of certain islands for permanent habitation and food production. The adverse impact of engineering actions on the Atoll environment and the uncertainties regarding effectiveness have been viewed on the one hand, and the question of the extent to which the Enewetak people would comply with restrictions on the other.

NVO-140 and this Task Group report present the radiation doses that may be associated with a broad range of options and provide data for calculating doses for other options for anyone who wishes to do so. The dose reduction expected for one option can be compared with that of another. Dollar cost estimates should be prepared by DNA for the remedial measures recommended by AEC; and the impact and acceptability of restrictions can be evaluated through discussions with the Enewetak Council.

In NVO-140, and in the previous section of this report, dose estimates - and therefore options - were considered in matrix form (e.g., living pattern vs. diet, or diet source vs. amount of soil removed). While these matrices serve to indicate in detail the range of conditions to be found on the Atoll, the Task Group feels that its analyses and recommendations are presented more effectively in narrative form.

There are three basic questions to be addressed: 1)"Is the radiation environment acceptable or can it be made acceptable for the Enewetak people to return to their atoll," 2)"Is the radiation environment on Enjebi acceptable or can it be made acceptable for the people to return," and 3)"Are there islands which are not acceptable for people to conduct their normal agricultural and social activities, and, if so, are there any actions that could be taken or restrictions imposed that would keep exposures within acceptable criteria?"

Within this framework of data and basic questions, the Task Group has focused attention on the following options (see Fig. 146, page II-3 Appendix II):

Option I

a. No return of the Enewetak people.

b. No radiological cleanup.

This clearly represents a no-cost, no-radiation-dose option. Just as clearly, it runs contrary to the expressed wishes of the Enewetak people. In addition, choice of this option cannot be defended using current radiation protection philosophy and standards since the predicted exposures for persons living on the southern islands and using agriculture only on these islands are well within acceptable standards.

Option II

a. Return to the southern islands (ALVIN-KEITH).

b. Agriculture limited to the southern islands.

c. Travel restricted to the southern islands.

d. No restrictions on fishing.

e. No radiological cleanup.

This option (Row A of Tables 1-4) has a zero cost for radiological cleanup that results in population doses well below the guides. It differs from later options in that it leaves the problems of contaminated scrap in many areas of the Atoll, and the Pu in soil on YVONNE, IRENE, and in the burial sites on SALLY, plus generally contaminated areas on ALICE, BELLE, CLARA, and PEARL, unresolved. Such a choice would establish the need for off-limits areas in perpetuity, at least for YVONNE, since the metallic Pu is expected to be present on the surface of the island indefinitely unless cleanup is performed. Under current conditions there is a potential for exposures exceeding Federal standards through the inhalation pathway and the possibility of spread of the contamination if access to the island is not controlled. This accounts for the current quarantine of the island. Limiting all agriculture to the southern islands is difficult to justify because some of the northern islands are lightly contaminated. From Tables 1-4, for example, it can be seen that limiting only the growth of pandanus and breadfruit to the southern islands would permit all other subsistence agricultural practices on JANET-WILMA without the radiation exposure criteria being exceeded. Similarly, it is difficult to justify limiting travel to the southern islands since the ambient gamma levels on the northern islands do not represent a significant external exposure potential for occasional visitation.

Option III

a. Return to the southern islands (ALVIN-KEITH).

b. Subsistence agriculture limited to the southern islands plus JANET-WILMA except that pandanus and breadfruit are limited to the southern islands.

c. No restrictions on travel.

d. No restrictions on fishing.

e. Remove Pu contamination on YVONNE, IRENE and the SALLY burial sites.

f. Remove radioactive scrap.

This is one of the less expensive options in that it requires removal of only the most seriously contaminated materials. In practical terms, it maximizes unrestricted use of areas of the Atoll having low radioactivity levels, leaves no hazardous legacies for the indefinite future, and permits living patterns which, with high confidence, are expected to result in population doses well below the recommended radiation criteria.

This option does not specify action against radioactivity in soil of the islands such as ALICE, BELLE, and CLARA, nor does it recommend that residences be built on JANET. By implication, therefore, resettlement of JANET would have to wait for radioactive decay and weathering processes to reduce contamination levels to acceptable values on these islands. Since the predominant isotopes, $^{137}Cs$ and $^{90}Sr$, each have half-lives of 30 years, the waiting period could be slightly more than one human generation for each factor of two reduction in dose. On the other hand the reduction could proceed at a somewhat faster rate. On JANET, reducing the maximum annual child's bone marrow dose from 0.72 rem/yr (Table 4, Case D-I) to the guide level of 0.25 rem/yr through natural decay of the $^{90}Sr$ would theoretically require a wait of about 50 years considering only radiological decay. It is not expected that such a reduction will actually take that long.

Option IV

a. All of Option III a, c, d, e, and f, plus:

b. Return to JANET and build residences and community center in locations shown on the Master Plan.

c. Remove a minimum of 30 cm of soil in all areas where pandanus and breadfruit are to be grown on JANET; import clean soil in which to establish these plants; or import pandanus and breadfruit from the southern islands.

If these actions proved to be as effective as the theoretical predictions, this would permit return of the Enjebi people to their island. It should be emphasized, however, that even with the above actions, predicted doses are at or above the Task Group criteria for annual exposures and also well above the 30 year gonadal criteria. The levels are expected to be well above those of Option III.

Option IV c describes three ways in which essentially the same end can theoretically be achieved. Importation of food is the most dependable action but this imposes a long-term burden on the Enjebi people which they may find objectionable. Removal of soil alone is another alternative, but the effectiveness of the action is uncertain for reducing population dose since $^{90}Sr$ and $^{137}Cs$ are found so far below the surface on JANET. Importing soil for areas of subsistence crops such as pandanus and breadfruit would possibly reduce the dose from these foods to levels comparable to those found on the southern islands, provided that sufficient soil is imported to encompass the entire root system of the mature trees. The water supply for these crops must not have radioactivity levels higher than those in the southern islands. How this can be insured is not obvious at this time.

The Task Group considers Option IV a-c, by itself, to be unacceptable at this time. Even with the actions and restrictions indicated, exposures would be too high to provide an acceptable margin within the Task Group criteria. This is especially true for children born at about the time of rehabitation. Importation of food from the southern part of the Atoll or other sources is believed to represent an impractical solution to the problem of excessive internal exposure. Use of a layer of clean soil in areas for food production is not known to be effective and may be hard to regulate. Foods produced through experiments to determine the effectiveness of this measure should not be considered for use by people until the results are carefully evaluated. Use of clean soil for subsistence crops may have little effect on levels of radioactivity in domestic animals and coconut crabs, which range over the entire island.

Since Option IV a-c is expected to result in population doses near or slightly above the radiation criteria, further dose reduction may possibly be achieved by:

d. Removal of 15 cm of soil in the subsistence agricultural area of JANET.

e. Removal of 15 cm of soil in the commercial agricultural area of JANET.

These actions result in a theoretical reduction factor of 3 to 4 for $^{137}Cs$ and $^{90}Sr$ in the remaining top cm layer of soil - or have roughly the same theoretical effect as waiting 60 years for radioactive decay to take place. Whether food crops would show a similar reduction is uncertain. This action would possibly result in an ultimate finding that doses would be below the criteria but above that expected for people living on the southern islands.

Most significantly, however, implementation of Option IV a-e would remove a minimum of 15 cm of soil from essentially the entire island of JANET. Since the top soil on that island is charitably described as meager, such action would leave JANET a sand island. Heroic actions would be required to either reconstitute the remaining soil through use of fertilizers and other additives, or import topsoil sufficient to support subsistence and commercial agriculture. With any of these actions a period of time would be required to determine the effectiveness of the action. An additional period would be required after a decision to plant subsistence and commercial crops in quantity before the island could support its inhabitants.

Option V

a. All of Option IV a-e, plus:

b. Removal of a minimum of 10 cm of soil from PEARL.

c. Removal of a minimum of 47 cm of soil from ALICE, 14 cm from BELLE, and 10 cm from CLARA.

d. If pandanus and breadfruit are to be grown on northern islands other than JANET, the criteria of Option IV c should apply, i.e., plant in soil having a $^{90}Sr$ content of 4.6 pCi/gm or less, or bring clean soil to the island with a depth sufficient to contain the roots of these trees.

If these actions achieved a level of exposure reduction as large as the calculational result, this would permit use of the entire Atoll according to the Master Plan. This option is clearly much more expensive than other options since it requires removal of additional soil and requires reconstitution of soil in the cleared areas. Consideration of these actions as a viable option is clouded by uncertainties regarding the exposure reduction that can be achieved through partial soil removal and by selective soil replacement.

For comparative purposes, population dose estimates for Options I-V are presented in Table 11.

RECOMMENDATIONS

After careful review of all available radiological data the Task Group members' specific recommendations are as follows:

1. The people of Enewetak Atoll may be safety returned to their homeland provided certain actions are taken and precautions observed.
2. In the interest of achieving a minimum practicable radiation dose for the Enewetak people the Task Group recommends that:
   a. The first villages and residences be constructed on ELMER, FRED, DAVID, or on any of the southern islands (ALVIN-KEITH) that the Enewetak people choose.
   b. Growth of all subsistence crops such as pandanus, breadfruit, tacca, pigs, chickens, and all other terrestrial food stuffs except coconut be limited to islands ALVIN-KEITH.
   c. Subsistence and commercial coconut may be grown without remedial measures on any island in the Atoll except ALICE, BELLE, CLARA, DAISY, IRENE, JANET, and YVONNE.
   d. Fishing be permitted anywhere.
   e. Travel be unrestricted to all islands except YVONNE. When the Pu contamination on YVONNE is removed, the restriction of travel to that island can be lifted.
   f. Wild birds and bird's eggs be collected anywhere.
   g. Coconut crabs be collected only on the southern islands (ALVIN-KEITH).
   h. Wells which are intended to provide lens water for human consumption or for agricultural use be drilled only on the southern islands (ALVIN-KEITH). When drilled, water from each well should be checked for bacteria, salinity, and radioactivity content before the well is approved for use.

3. It is recognized that the people of Enjebi have a strong desire to return to live on that island. The island contains three ground zero locations from nuclear tests and was within about 3 miles of the Mike event that had a total yield of about 10 Megatons. According to the survey results presented in NV-140, Enjebi was the most heavily contaminated of the larger islands in the Atoll. The Task Group has been unable to determine any way in which radiation exposures can be brought within the acceptable criteria, that is both reliable and feasible, in order to resettle Enjebi at the same time as islands in the south of the Atoll. It is reasonable to expect that one day the island can be resettled. There appear to be two possible approaches:

   a. Soil removal followed by studies with test plantings to determine whether exposure for Enjebi residents would be within acceptable criteria.

   b. Conduct of studies using test plantings to determine when exposures would be within acceptable criteria but no soil removed.

   In either case, housing construction and planting of subsistence and commercial crops would be deferred until research with test plantings showed acceptably low levels of radioactivity. The Task Group recommends the second approach as one having minimal adverse impact on the island environment.

4. The research program in 3 above should also include a determination of radioactivity levels in coconut and other food crops produced on PEARL, CLARA, ALICE, and BELLE. YVONNE should also be included after removal of plutonium contaminated soil.

5. All radioactive scrap metal and contaminated debris identified during the Holmes and Narver Engineering Survey should be removed. If

additional contaminated debris is discovered in the course of cleanup and rehabilitation operations, it too should be removed. Specifically included in this recommendation are the three locations on SALLY and one on ELMER where contaminated debris is known to be buried. This debris should be exhumed and removed.

6. The quarantine of YVONNE, put into effect by the Air Force on May 26, 1972, should be continued in effect until the cleanup of plutonium contamination on that island has been completed. Should any Enewetak people return to the Atoll before cleanup is begun or before completion, an authority responsible for enforcement of the quarantine should be identified and should be in residence in the Atoll when people return.

7. The distribution of plutonium contamination on YVONNE is sufficiently complex that specific recommendations for cleanup cannot be presented. It is expected that the true picture of this contamination will unfold as the decontamination effort proceeds. The area observed to have pieces of plutonium and the highest soil concentrations is the interior and shoreline of the island beginning at a line drawn from the ocean reef to lagoon 60 meters north of the tower (Hardtack Station 1310) to CACTUS Crater. See Fig. 152, page II-17, Appendix II. Presented are some of the requirements and objectives that will establish a background from which plans can be made for recovery of plutonium on YVONNE.

   a. A team of experts should be assembled who can make and interpret field radiation and radioactivity measurements, advise on cleanup actions envolving plutonium and other radionuclides, and provide necessary health physics support including protection of workers, decontamination of workers and equipment, and packaging and handling of collected contaminated materials. A Public Health Service group, which is now part of the Enviromental Protection Agency, EPA, provided radiological assistance for cleanup of Bikini Atoll. Similar support should be sought from EPA for Enewetak Cleanup.

b. Decontamination of YVONNE is seen as an iterative process, namely, removal of soil, monitoring of radioactivity levels, and removal of more soil. This amounts to a search for the higher plutonium levels in soil with removal according to the guidance provided.

c. The objectives of the cleanup are two:

   (1) Recovery of the pieces of plutonium that have been observed on or near the island surface. Some contain milligram quantities of plutonium metal and are easily detected with field survey instruments such as the FIDLER.

   (2) Recovery of plutonium contaminated soil. To a first approximation, the location of the zones of higher Pu concentrations are shown in the survey profile samples.

d. Recovery of plutonium in soil at concentrations greater than 400 pCi/g $^{239,240}$Pu at any depth these levels are found. The justification is that plutonium at some depth may one day be at the surface. Also, recovery of contaminated soil sufficient to reduce surface levels to a value well below 40 pCi/g $^{239,240}$Pu. The justification is to keep air concentrations of resuspended plutonium to levels well within national and international standards. After soil removal, all areas should be resurveyed to ensure no pieces or hot spots of plutonium remain.

8. Plutonium contaminated soil on IRENE should be handled the same as on YVONNE and using the same general criteria for removal except it is not expected that pieces of plutonium metal will be found.

9. Since it is recommended that replanting of food crops be limited to certain islands, test plantings of pandanus, breadfruit, coconut, and arrowroot should be made, as soon as growth can be assured, on each of the islands indicated for such crops by the Enewetak people. As edible parts of these plants become available, their concentrations of $^{90}Sr$, $^{137}Cs$, $^{239,240}Pu$ and any other significant radionuclides should be measured and compared with the radiological survey predictions. These studies will provide for a determination to be made of the earliest time at which planting of food and commercial crops can be made on islands other than those listed in 2b. and 2c. above.

10. An underground lens water sampling and analysis program should be conducted in which samples are taken over a period of at least 12 calendar months. Bacterial content, salinity, and radionuclide content should be measured, but primary emphasis of the program should be placed on development of an understanding of processes which are operating - or which can be made to operate - to reduce the ecological half-life of $^{90}Sr$ and $^{137}Cs$ below the radioactive half-life on the northern islands, especially JANET.

11. A comprehensive air sampling program should be conducted over a period of 12 consecutive months under conditions closely approximating human habitation and expected soil disturbance. This would add to the body of available information on radioactivity levels in air. This program could be conducted coincident with and in support of cleanup operations.

12. Base-line surveys of body burdens and urine content of $^{137}Cs$ and $^{90}Sr$ should be made for the Enewetak people prior to return to Enewetak Atoll, after the first year of residence, and as appropriate thereafter. Resurveys of the environmental radiation and radioactivity levels should be made starting in the first year of return and repeated every other year. To be determined is the adequacy of the diet and the actual average daily dietary intake of radioactivity for various age groups for comparison with estimated levels and how radioactivity levels in water, air, soil, plants, and animals are changing with time. (Included should be measurements of radionuclide content of air and collection of information on the chemical and physical form and size distribution of particles in the air containing $^{239}Pu$.) Information from such surveys will provide a continuing check of the radiological status of the people and the environment and will assure that the exposure criteria is not being approached or exceeded.

13. Considering that the method of disposal of plutonium contaminated soil and scrap has not yet been decided, that not enough information is available to determine whether it is feasible to remove plutonium from the soil to reduce the amount of material requiring disposal, and not wanting such problems to delay cleanup and rehabililation of the Atoll, the Task Group recommends the following:

a. As a minimum, cleanup should accomplish the recovery of plutonium contaminated soil and scrap into storage on YVONNE.

b. The YVONNE quarantine should remain in effect with access controlled and all visitors and workers monitored as for a radiation control zone.

c. If disposal is deferred for further study, such study should be planned and conducted promptly.

14. The cleanup phase of rehabitation, i.e., removal and disposal of contaminated scrap, debris, and soil, should be carefully documented in a comprehensive final report from those conducting the cleanup operation.

15. The planning and conduct of cleanup, including radiological support for cleanup, should be similar to cleanup of Bikini Atoll and advantage taken of that experience. As Bikini people were given opportunity for employment during cleanup, an equal opportunity should be given Enewetak people if they desire.

TABLE 1. 30 Year Integral Whole Body Dose (Rem)

| Living Pattern | I<br>Current Condition (no corrective action) | II<br>Gravel Village Area - Plow Village Island | III<br>Import Pandanus and Breadfruit | IV<br>Import Pandanus, Breadfruit, Coconut, and Tacca | V<br>Import Pandanus, Breadfruit, Coconut, Tacca, and Meat |
|---|---|---|---|---|---|
| A | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| B | 4.4 | 4.4 | 2.2 | 1.9 | 1.3 |
| C | 5.7 | 4.4 | 2.7 | 2.4 | 1.8 |
| D | 11 | 8.9 | 4.4 | 3.7 | 1.9 |
| E | 14 | 13 | 6.6 | 5.7 | 3.3 |
| F | 31 | 24 | 11.3 | 9.1 | 3.5 |

| Living Pattern | | Village Island | Agriculture | Visitation |
|---|---|---|---|---|
| A | (1) | FRED/ELMER/DAVID | ALVIN through KEITH | Southern Islands |
| B | (2) | FRED/ELMER/DAVID | KATE through WILMA plus LeRoy | Northern Islands |
| C | (5) | JANET | KATE through WILMA plus LeRoy | Northern Islands |
| D | (3) | JANET | JANET | Northern Islands |
| E | (5) | JANET | ALICE through IRENE | Northern Islands |
| F | (4) | BELLE | BELLE | Northern Islands |

TABLE 2. 30 Year Integral Bone Dose (Rem)

| Living Pattern | I<br>Current Condition (no corrective action) | II<br>Gravel Village Area - Plow Village Island | III<br>Import Pandanus and Breadfruit | IV<br>Import Pandanus, Breadfruit, Coconut and Tacca | V<br>Import Pandanus, Breadfruit, Coconut, Tacca and Meat |
|---|---|---|---|---|---|
| A | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| B | 35 | 35 | 11.5 | 9.1 | 4.1 |
| C | 37 | 35 | 12 | 9.6 | 4.6 |
| D | 80 | 78 | 23 | 18 | 4.7 |
| E | 135 | 134 | 38 | 27 | 6.1 |
| F | 220 | 213 | 61 | 43 | 6.3 |

TABLE 3. Maximum Annual Whole Body Dose (Rem)

| Living Pattern | I<br>Current Condition (no corrective action) | II*<br>Gravel Village Area - Plow Village Island | III<br>Import Pandanus and Breadfruit | IV<br>Import Pandanus, Breadfruit, Coconut, Tacca | V<br>Import Pandanus, Breadfruit, Coconut, Tacca, and Meat |
|---|---|---|---|---|---|
| A | 0.039/0.039** | - | 0.039/0.039 | 0.039/0.039 | 0.039/0.039 |
| B | 0.234/0.236 | - | 0.125/0.128 | 0.091/0.122 | 0.090/0.083 |
| C | 0.237/0.241 | - | 0.128/0.133 | 0.093/0.127 | 0.089/0.094 |
| D | 0.540/0.542 | - | 0.245/0.252 | 0.146/0.187 | 0.087/0.097 |
| E | 0.749/0.761 | - | 0.350/0.367 | 0.246/0.328 | 0.182/0.211 |
| F | 1.56/1.55 | - | 0.662/0.663 | 0.357/0.475 | 0.192/0.191 |

*Values not significantly different from Column I

**Child/Adult - both starting Jan. 1974.

TABLE 4. Maximum Annual Bone Marrow Dose (Rem)

| Living Pattern | I<br>Current Condition (no corrective action) | II*<br>Gravel Village Area - Plow Village Island | III<br>Import Pandanus and Breadfruit | IV<br>Import Pandanus, Breadfruit, Coconut, Tacca | V<br>Import Pandanus, Breadfruit, Coconut, Tacca, and Meat |
|---|---|---|---|---|---|
| A | 0.047/0.045** | - | 0.047/0.045 | 0.047/0.045 | 0.047/0.045 |
| B | 0.314/0.294 | - | 0.148/0.149 | 0.122/0.130 | 0.097/0.091 |
| C | 0.317/0.300 | - | 0.151/0.178 | 0.121/0.135 | 0.096/0.096 |
| D | 0.718/0.677 | - | 0.293/0.294 | 0.168/0.204 | 0.094/0.094 |
| E | 1.06/0.989 | - | 0.428/0.437 | 0.253/0.354 | 0.184/0.213 |
| F | 2.08/1.92 | - | 0.786/0.774 | 0.415/0.516 | 0.199/0.193 |

*Values not significantly different from Column I.

**Child/Adult - both starting Jan. 1974.

TABLE 5. $^{90}Sr$ Profile Sample Data on JANET

| Profile Sample Number | Depth to Reduce Act. by Factor of 10 (cm) | $^{90}Sr$ Act. in Top 2 cm (pCi/gm) | $^{90}Sr$ Act. in Top 15 cm (pCi/gm) | $^{90}Sr$ Act. Below 100 cm Max. (pCi/gm) | "Av." |
|---|---|---|---|---|---|
| 100 | 7 | 360 | 150 | 11 (50 cm) | |
| 135 | 56 | 18 | 10 | 1.3 (100 cm) | 1 |
| 136 | > 100 | 14 | 17 | 3.6 (100 cm) | 3.6 |
| 137 | 15 | 34 | 16 | 2.1 (130 cm) | 0.4 |
| 138 | 9 | 100 | 28 | 1.3 (150 cm) | 0.4 |
| 139 | 12 | 410 | 220 | 5.4 (150 cm) | 0.9 |
| 140 | 66 | 54 | 95 | 4.8 (115 cm) | 2. |
| 141 | 12 | 100 | 39 | 4.8 (135 cm) | 2.5 |
| 142 | 60 | 90 | 95 | 46 (120 cm) | 10.5 |
| 143 | > 100 | 21 | 31 | 13 (100 cm) | 13 |
| 144 | 76 | 50 | 46 | 2.4 (100 cm) | 1 |
| 145 | 18 | 27 | 26 | 0.7 (100 cm) | 0.3 |
| 147 | 25 | 87 | 200 | 0.6 (160 cm) | 0.3 |
| 901 | 25 | 110 | 185 | 8.5 (40 cm) | -- |
| Av. | 42 cm | 105.4 | 82.7 | 7.1* | 3.0 |

*(No. 100 and No. 901 excluded)

Mean $^{90}Sr$ concentration in top 15 cm samples:

JANET: 44 pCi/gm

Southern islands:

DAVID, ELMER, FRED: 0.41 pCi/gm

All others except

LEROY: 0.52 pCi/gm

Table 6. $^{90}Sr$ Concentrations (pCi/gm) in Profile Samples Taken on JANET

| Profile No. | Sample Depth (cm) 0-2 | 2-5 | 5-10 | 10-15 | 15-25 | 25-35 | 35-45 | 45-55 | 55-65 | 65-75 | 75-85 | 85-95 | 95-105 | 105-115 | 115-125 | 125-135 | 135-145 | 145-155 | 155-165 | 165-175 | 175-185 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 * | 360 | 220 | 75 | 21 | 12 | 12 | 11 | 11 | 8.2 | | | | | | | | | | | | |
| 135 * | 18 | 16 | 7 | 8 | 5.5 | 5 | 5.2 | 3 | 1.3 | 1.3 | 1.5 | 1.3 | 1.3 | 1.0 | 0.85 | | | | | | |
| 136 * | 17 | 10 | 17 | 20 | 50 | | | 6.4 | 5.3 | 5 | 3.8 | 5.3 | 3.7 | | | | | | | | |
| 137 | 34 | 17 | 8.5 | 4.6 | 2.7 | 1.6 | 1.6 | 0.85 | 0.78 | 0.68 | 0.28 | 7.8 | 0.43 | 0.5 | 0.4 | 0.4 | 2.1 | 0.43 | 0.35 | 0.41 | 0.25 |
| 138 | 100 | 26 | 14 | 8 | 4.8 | 2.4 | 2.2 | 2.6 | 3.2 | 2.1 | 1.4 | 0.9 | 0.47 | 0.42 | 0.3 | - | 0.32 | 1.3 | 0.31 | 0.45 | 0.45 |
| 139 | 410 | 460 | 160 | 50 | 28 | 34 | 26 | 9.3 | 0.9 | 1.0 | 0.8 | 0.23 | 0.85 | 0.8 | 0.47 | 0.3 | 0.31 | 5.4 | 1.2 | 1.5 | |
| 140 * | 54 | 6 | 18 | 17 | 14 | 15 | 10 | 15 | 10 | 3.5 | 2.8 | 1.7 | 1.1 | 0.93 | 0.8 | 3.8 | | | | | |
| 141 * | 100 | 78 | 18 | 8 | 5.4 | 5.2 | 5.2 | 4.6 | 3.2 | 2.8 | 2.8 | 3.0 | 2.6 | 2.4 | 2.3 | 1.8 | 4.9 | 1.5 | | | |
| 142 | 90 | 95 | 120 | 110 | 78 | | | 14 | 12 | 8.2 | [illegible] | 5.6 | 4.8 | 4.1 | 46 | 22 | 4.3 | 3.5 | 3.3 | 2.9 | 2.7 |
| 143 * | 21 | 26 | 42 | 26 | 50 | 68 | 26 | 25 | 21 | 3.7 | 11 | 11 | 12.5 | | | | | | | | |
| 144 | 27 | 43 | 51 | 49 | 21 | 13 | 9 | 6.8 | 6.8 | 5.8 | 5.4 | 4.0 | 2.9 | 2.0 | 1.6 | 1.5 | 1.2 | 0.86 | 0.62 | 0.54 | 0.67 |
| 145 | 27 | 22 | 27 | 27 | 3.4 | 0.3 | 0.45 | 0.3 | 0.3 | 0.31 | 0.3 | 0.43 | 0.74 | 0.27 | 0.26 | 0.33 | 0.29 | 0.31 | 0.26 | 0.31 | 0.31 |
| 147 | 87 | 35 | 24 | 50 | 19 | 5.8 | 1.5 | 0.35 | 0.55 | 0.4 | 0.4 | 0.26 | 0.20 | 0.27 | 0.29 | 0.3 | 0.18 | 0.22 | 0.63 | 0.46 | 0.42 |
| [illegible] | 110 | 200 | 230 | 160 | 40 | 2.4 | 8.6 | | | | | | | | | | | | | | |
| Av.Composite | 103.9 | 90 | 58 | 40 | 23.8 | 13.7 | 8.9 | 7.6 | 5.6 | 2.9 | 3.1 | 3.5 | 2.7 | 1.3 | 5.3 | 3.8 | 1.7 | 1.7 | 0.95 | 0.94 | 0.8 |
| Av/Subsistence Agriculture Area (*Profiles) | 80 | 59.3 | 29.5 | 16.7 | 22.8 | 21. | 11.5 | 10.8 | 8.2 | 3.3 | 4.4 | 4.5 | 4.4 | 1.4 | 1.3 | 3.5 | 4.9 | 1.5 | | | |

Table 7. $^{137}Cs$ Concentrations (µCi/gm) in Profile Samples Taken on JANET.

| Profile No. | 0-2 | 2-5 | 5-10 | 10-15 | 15-25 | 25-35 | 35-45 | 45-55 | 55-65 | 65-75 | 75-85 | 85-95 | 95-105 | 105-115 | 115-125 | 125-135 | 135-145 | 145-155 | 155-165 | 165-175 | 175-185 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sample Depth (cm) | | | | | | | | | | | | | | | | | | | | |
| 100 * | 210 | 64 | 23 | 3.1 | 0.7 | 0.44 | 0.44 | 0.27 | 0.22 | | | | | | | | | | | | |
| 135 * | 5.7 | 7.7 | 2.8 | 3.2 | 1.6 | 0.9 | 0.66 | 0.14 | 0.29 | 0.027 | 0.037 | 0.082 | 0.072 | 0.039 | 0.026 | | | | | | |
| 136 * | 6 | 4.8 | 6 | 4.5 | 6.5 | 6.5 | 2.7 | 1.3 | 0.85 | 0.78 | 1.3 | 0.47 | 0.19 | | | | | | | | |
| 137 | 11 | 16 | 11 | 3.2 | 0.86 | 0.9 | 0.25 | 0.21 | 0.23 | 0.19 | 0.19 | 0.015 | 0.008 | 0.03 | 0.01 | 0.1 | 0.058 | 0.037 | 0.01 | 0.01 | 0.03 |
| 138 | 22 | 19 | 21 | 15 | 5.1 | 1.1 | 0.63 | 0.23 | 0.37 | 0.16 | 0.19 | 0.19 | 0.15 | 0.063 | 0.03 | - | 0.035 | 0.1 | 0.09 | 0.04 | 0.08 |
| 139 | 110 | 80 | 50 | 20 | 13 | 7 | 1.9 | 0.5 | 0.63 | 0.45 | 0.5 | 0.3 | 0.27 | 0.36 | 0.23 | 0.18 | 0.35 | 1.7 | 0.55 | 0.42 | |
| 140 * | 43 | 15 | 4 | 13 | 2.3 | 1 | 1.1 | 1.5 | 1.5 | 0.42 | 0.35 | 0.38 | 0.35 | 0.21 | 0.19 | 0.73 | | | | | |
| 141 * | 50 | 23 | 2.1 | 0.35 | 0.23 | 0.15 | 0.12 | 0.085 | 0.082 | 0.066 | 0.072 | 0.071 | 0.029 | 0.06 | 0.15 | 0.08 | 0.24 | 0.25 | | | |
| 142 | 100 | 63 | 42 | 49 | 53 | 26 | 1.5 | 0.72 | 0.45 | 0.23 | 0.21 | 0.27 | 0.35 | 0.29 | 0.18 | 0.17 | 0.15 | 0.34 | 0.39 | 0.53 | 0.52 |
| 143 * | 6.1 | 5 | 5.2 | 7 | 6.1 | 6 | 5 | 4.7 | 2.9 | 0.1 | 0.21 | 0.37 | 0.93 | | | | | | | | |
| 144 | 14 | 18 | 14 | 8 | 12 | 15 | 3.1 | 3.1 | 1.6 | 1.3 | 1.0 | 1.0 | 0.77 | 0.64 | 0.5 | 0.57 | 0.78 | 0.4 | 0.38 | 0.6 | 0.6 |
| 145 | 19 | 8 | 9.7 | 6.5 | 0.8 | 0.7 | 0.6 | 0.24 | 0.17 | 0.083 | 0.024 | 0.026 | 0.026 | 0.023 | 0.021 | 0.017 | 0.023 | 0.02 | 0.04 | 0.009 | 0.01 |
| 147 | 3.5 | 19 | 18 | 16 | 2.9 | 2.6 | 0.85 | 0.4 | 0.6 | 0.32 | 0.23 | 0.12 | 0.11 | 0.017 | 0.022 | 0.018 | 0.04 | 0.017 | 0.009 | 0.007 | 0.008 |
| 901 | 5.1 | 7 | 8.5 | 6.1 | 1.6 | 0.32 | 0.45 | | | | | | | | | | | | | | |
| Av. Composite | 43.2 | 25.0 | 15.5 | 11.1 | 7.62 | 4.9 | 1.38 | 1.03 | 0.76 | 0.34 | 0.37 | 0.27 | 0.27 | 0.17 | 0.14 | 0.23 | 0.021 | 0.36 | 0.21 | 0.23 | 0.21 |
| Av. Subsistence Agriculture | 53.5 | 19.9 | 7.2 | 5.2 | 2.9 | 2.5 | 1.67 | 1.33 | 0.97 | 0.28 | 0.39 | 0.27 | 0.31 | 0.10 | | | | | | | |

Table 8. Concentrations of $^{90}Sr$ and $^{137}Cs$ in each 15 cm increment below the surface for the "Average Profile Samples"

| | $^{90}Sr$ | | | $^{137}Cs$ | | |
|---|---|---|---|---|---|---|
| Depth cm | Av. $^{90}Sr$ conc. (pCi/gm) | Ratio to top 15 cm | 1/Ratio | Av. $^{137}Cs$ conc. (pCi/gm) | Ratio to top 15 cm | 1/Ratio |
| **JANET** | | | | | | |
| 0-15 | 67.7 | 1.0 | 1.0 | 19.6 | 1.0 | 1.0 |
| 15-30 | 20.2 | 0.30 | 3.3 | 6.26 | 0.311 | 3.22 |
| 30-45 | 10.2 | 0.15 | 6.7 | 3.63 | 0.164 | 6.09 |
| 45-60 | 6.36 | 0.094 | 10.6 | 1.11 | 0.055 | 18.1 |
| 60-75 | 3.96 | 0.059 | 17.1 | 0.464 | 0.023 | 43.3 |
| 75-90 | 2.82 | 0.042 | 24.0 | 0.277 | 0.014 | 72.6 |
| 90-105 | 2.34 | 0.035 | 28.9 | 0.249 | 0.0124 | 80.6 |
| **PEARL** | | | | | | |
| 0-15 | | | | 12.4 | 1.0 | 1.0 |
| 15-30 | | | | 3.4 | 0.276 | 3.6 |
| 30-45 | | | | 1.1 | 0.088 | 11.4 |
| **ALICE** | | | | | | |
| 0-15 | | | | 36 | 1.0 | 1.0 |
| 15-30 | | | | 24.5 | 0.68 | 1.47 |
| 30-45 | | | | 16.6 | 0.46 | 2.16 |
| 45-60 | | | | 11.2 | 0.31 | 3.19 |
| **BELLE** | | | | | | |
| 0-15 | | | | 48 | 1.0 | 1.0 |
| 15-30 | | | | 9.7 | 0.202 | 4.94 |
| 30-45 | | | | 2.0 | 0.041 | 24.5 |
| 45-60 | | | | 0.4 | 0.008 | 122 |
| **CLARA** | | | | | | |
| 0-15 | | | | 26 | 1.0 | 1.0 |
| 15-30 | | | | 6.5 | 0.25 | 4.0 |
| 30-45 | | | | 1.6 | 0.063 | 16 |
| 45-60 | | | | 0.42 | 0.016 | 64 |

Tabel 9. Effect of soil removal on 30 year integral bone dose on JANET, case DI, Table 2.

| Soil Removal Action | $^{90}$Sr Conc (pCi/gm) (15 cm aver.) | Soil Volume | Bone Dose (Rem) Due To: Pandanus Breadfruit | Bone Dose (Rem) Due To: Coconut Tacca | Bone Dose (Rem) Due To: Meat | Total Bone Dose | Av. Est. γ Exposure Rates | External | Marine | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DI Av. for JANET Current condition | 44 | 0 | 55.5 | 6.8 | 13.2 | 75 | 40 μR/hr | 4.0 | 0.84 | 80 |
| DI-1 Subsistance Agric. area | 31 | 0 | 39.1 | 4.8 | 9.3 | 53.2 | 28 | 3.3 | 0.84 | 57 |
| DI-2 Remove 4.5 cm in Residential area | 31 | $3.2 \times 10^3 m^3$ | 39.1 | 4.8 | | 52.8 | | 2.8 | 0.84 | 56.4 |
| DI-3a Remove 15 cm in Subsistence Agric.Area | 9.4 | $1.5 \times 10^4 m^3$ | 11.8 | 1.5 | 2.7 | 16 | | 2.2 | 0.84 | 19.0 |
| DI-3b Remove 30 cm | 4.6 | $3.0 \times 10^4$ | 5.8 | 0.7 | 1.3 | 7.8 | | 2.1 | 0.84 | 10.7 |
| DI-3c Remove 45 cm | 2.9 | $4.5 \times 10^4$ | 3.7 | 0.4 | 0.8 | 4.9 | | 2.0 | 0.84 | 7.7 |
| Dl-3d Remove 60 cm | 1.8 | $6.0 \times 10^4$ | 2.3 | 0.3 | 0.5 | 3.1 | | 2.0 | 0.84 | 5.9 |

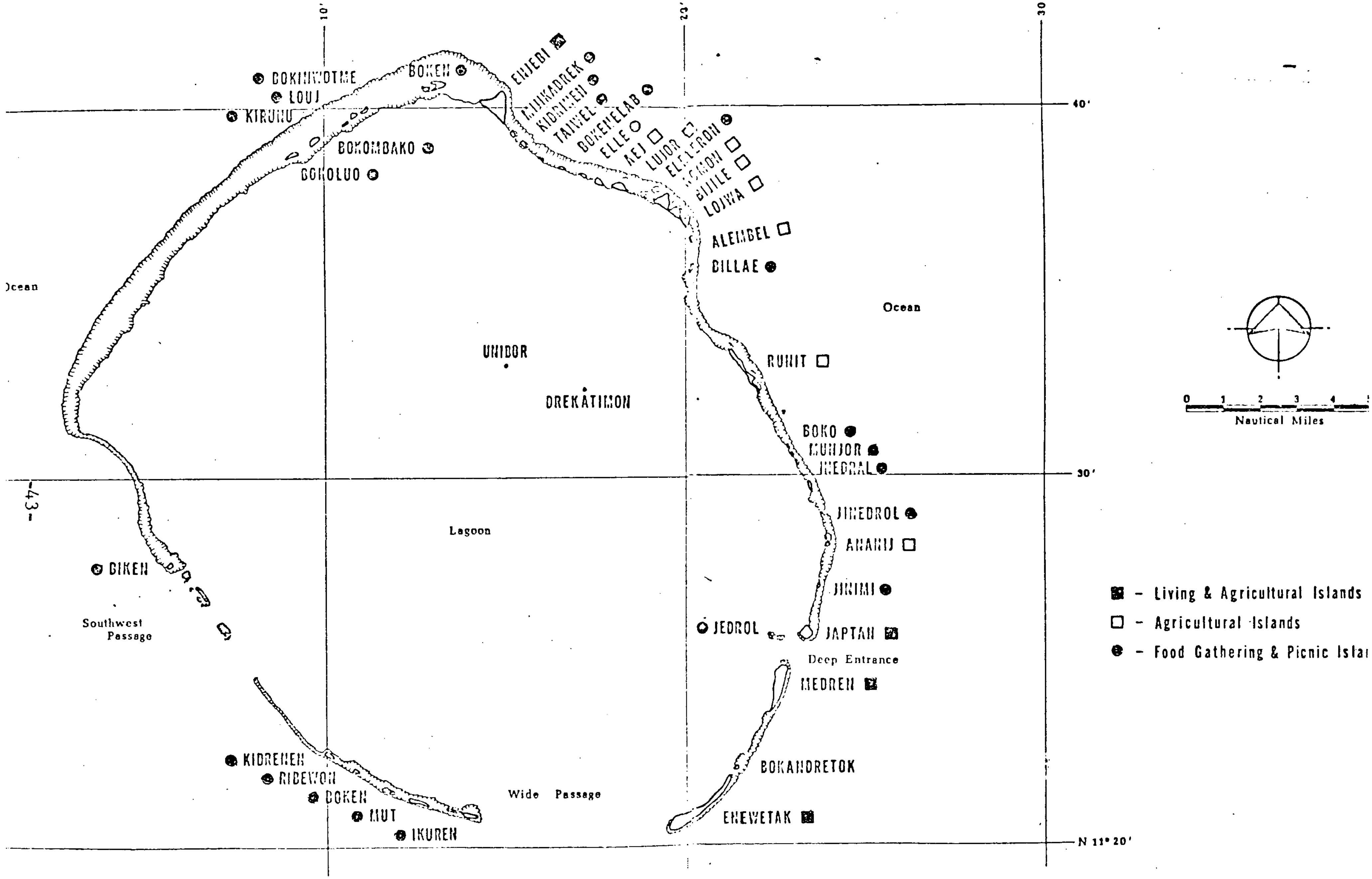
Table 10. Soil removal actions to reduce $^{137}Cs$ concentrations in copra

| Island Comm. Agr. | Mean current $^{137}Cs$ conc. in soil (pCi/gm in 15 cm samples) | | Soil to be removed to achieve: 10.4 pCi/gm | | 5.2 pCi/gm | |
|---|---|---|---|---|---|---|
| | | Area | Thickness | Volume | Thickness | Volume |
| JANET | 16 | $6.9x10^5$ m$^2$ | 6 cm | $4.1x10^4$ m$^3$ | 14 cm | $9.7x10^4$ m$^3$ |
| OLIVE | 7.65 | $1.1x10^5$ | 0 | | 5 cm | $0.55x10^4$ m$^3$ |
| PEARL | 12.4 | $1.5x10^5$ | 2 cm | $0.30x10^4$ | 10 cm | $1.5x10^4$ |
| SALLY | 3.0 | - | 0 | | 0 | |
| TILDA | 4.2 | - | 0 | | 0 | |
| URSULA | 1.7 | - | 0 | | 0 | |
| VERA | 2.0 | - | 0 | | 0 | |
| Food Gathering and Picnicing | | | | | | |
| ALICE | 36 | $9.3x10^4$ m$^2$ | 47 cm | $4.4x10^4$ m$^3$ | 74 cm | $6.9x10^4$ m$^3$ |
| BELLE | 48 | 18.6 | 14 | $2.6x10^4$ m$^3$ | 21 cm | $3.9x10^4$ |
| CLARA | 26 | 1.9 | 10 | $0.19x10^4$ | 17 cm | $0.32x10^4$ |
| DAISY | 11 | 5.6 | 0 | - | 9 cm | $0.5x10^4$ |
| IRENE | 3.2 | - | 0 | - | 0 | - |
| KATE | 13.1 | 7.4 | 3 cm | $0.22x10^4$ | 12 cm | $0.89x10^4$ |
| LUCY | 11 | 9.8 | 0 | - | 9 cm | $0.89x10^4$ |
| MARY | 9.9 | 5.6 | 0 | - | 8 cm | $0.45x10^4$ |
| NANCY | 12 | 8.4 | 2 cm | $0.17x10^4$ | 11 cm | $0.92x10^4$ |
| WILMA | 1.3 | - | 0 | - | 0 | - |

Table 11. Population Dose Estimates for Various Cleanup and Rehabilitation Options on Enewetak Atoll.

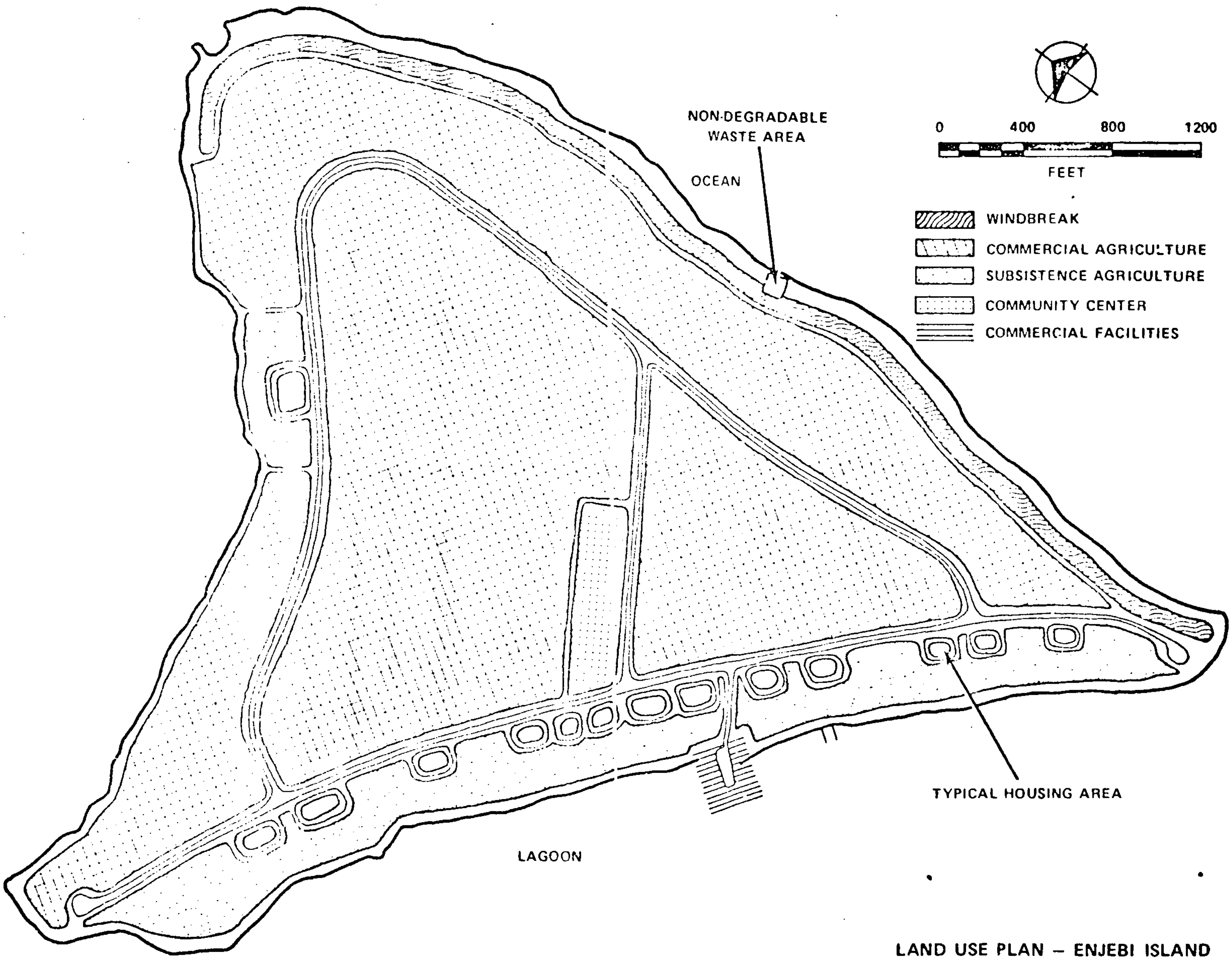
| OPTION | 30 yr whole body dose (Rem) | 30 yr integral bone dose (Rem) | Max annual whole body dose (Rem) | Max annual dose to red bone marrow (Rem) |
|---|---|---|---|---|
| I a, b | ≤ 1.0 | ≤ 3.8 | ≤ (0.039/0.039)* | ≤ (0.047/0.045)* |
| II a, b, c, d, e | 1.0 | 3.8 | 0.039/0.039 | 0.047/0.045 |
| III a, b, c, d, e, f | 2.2 | 11.5 | 0.125/0.128 | 0.148/0.149 |
| IV a, b, c | 5.6 | 23 | 0.245/0.252 | 0.293/0.294 |
| d | 3.6 | 13 | 0.16/ 0.16 | 0.17/ 0.17 |
| e | 1.6 | 11 | 0.07/ 0.07 | 0.14/ 0.14 |
| V a, b, c, d | (same as IV e) | | | |

*(Child/Adult)



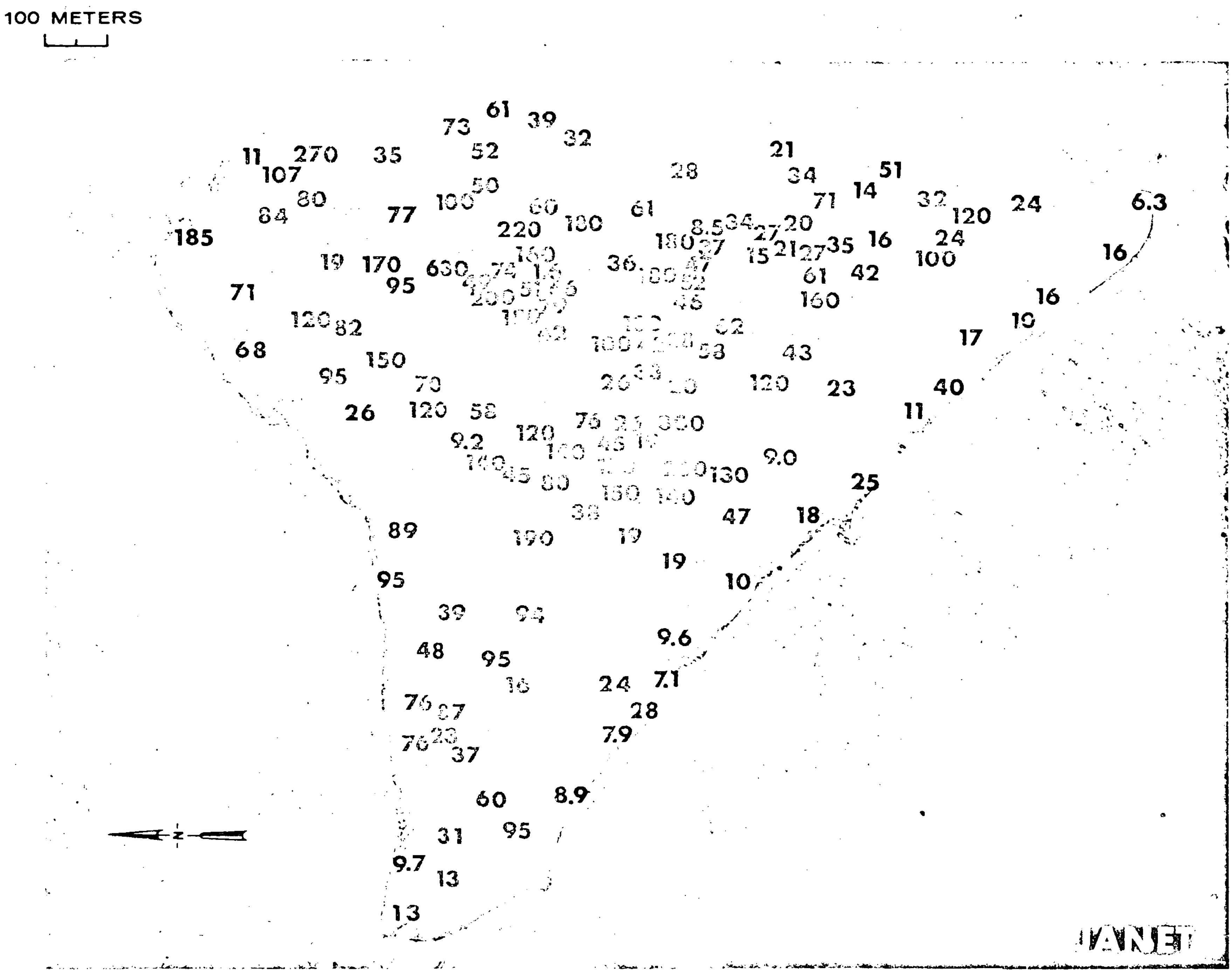
10'
20'
30'
40'
30'
N 11° 20'
BOKINWOTME
LOUJ
KIRUNU
BOKEN
ENJEBI
BOKOMBAKO
BOKOLUO
ELLE
AEJ
LUJOR
BILLAE
ALEMBEL
LOJWA
Ocean
UNIDOR
DREKATIMON
RUNIT
BOKO
Lagoon
GIKEN
Southwest Passage
JINEDROL
ANANIJ
JEDROL
JAPTAN
Deep Entrance
MEDREN
KIDRENEN
RIBEWON
BOKEN
MUT
IKUREN
Wide Passage
BOKANDRETOK
ENEWETAK
0
1
2
3
4
Nautical Miles
- Living & Agricultural Islands
- Agricultural Islands


Fig. 1.




**LAND USE PLAN – ENJEBI ISLAND**

Fig. 2.




The average $^{90}Sr$ activities (pCi/gm) in soil samples collected to a depth of 15 cm.

Fig. 3

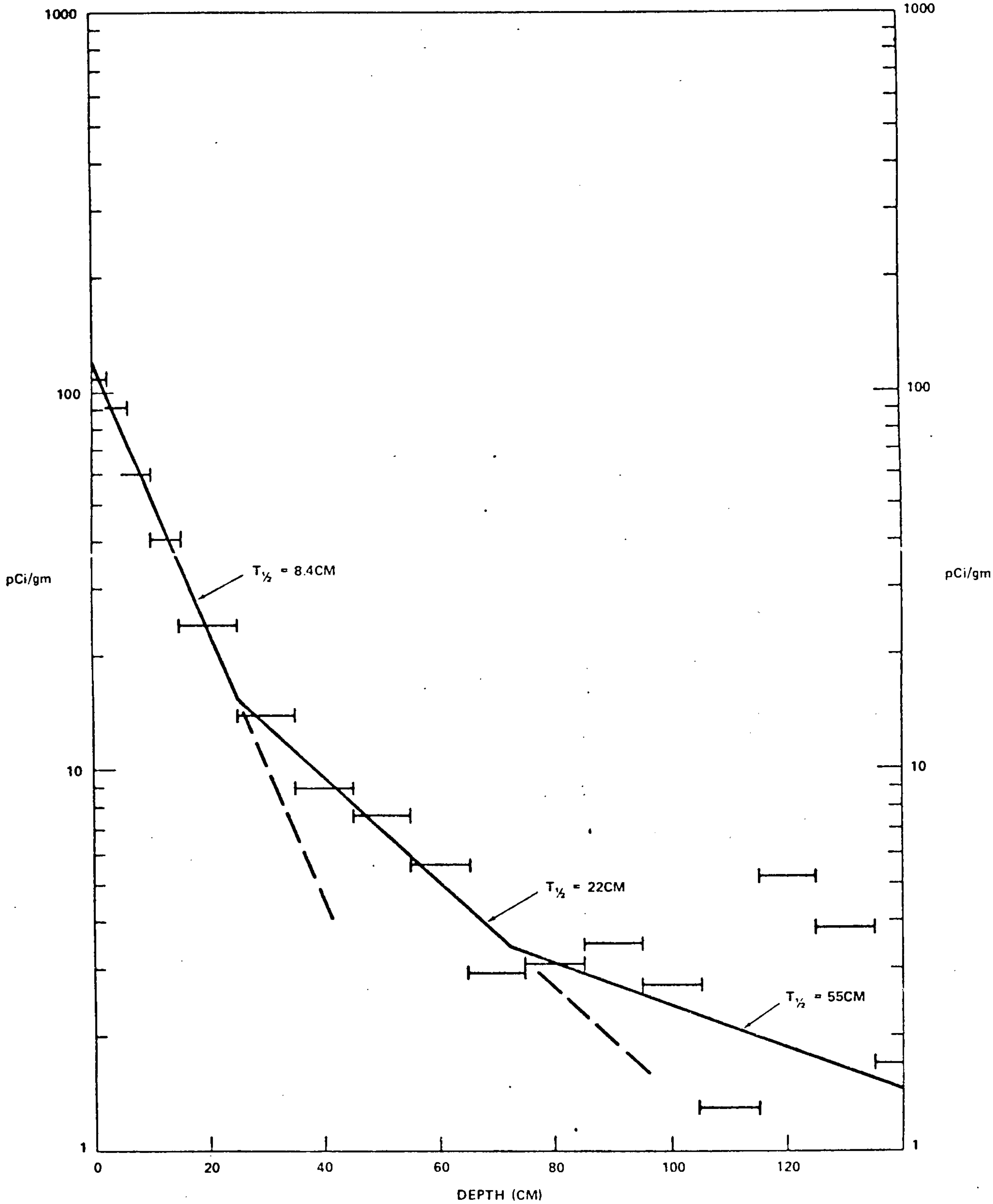



**FIG 4.** $^{90}Sr$ (AVERAGE OF ALL PROFILE SAMPLES ON JANET)

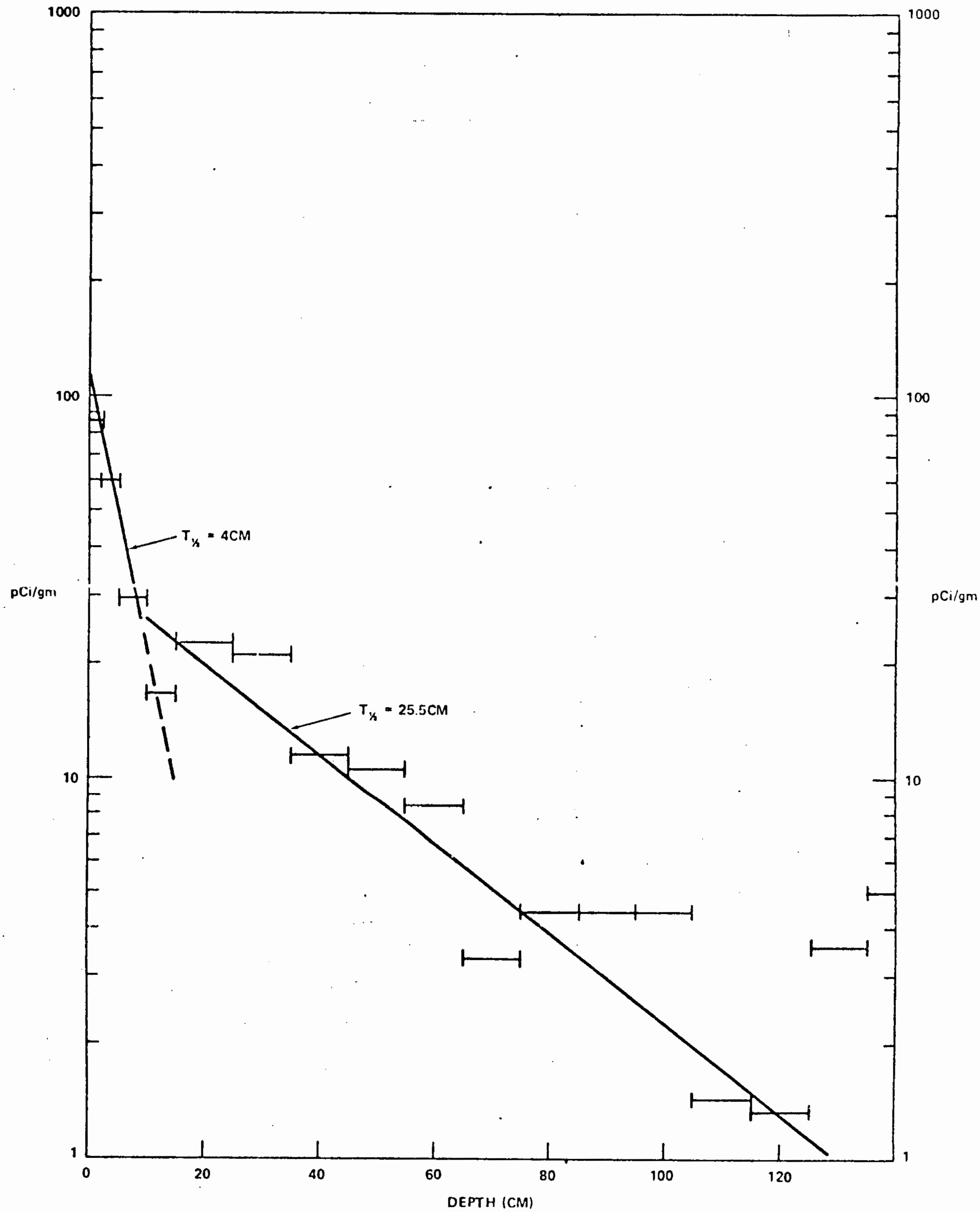



FIG 5. $^{90}$Sr (AVERAGE OF "SUBSISTENCE AGRICULTURE" PROFILE SAMPLES ON JANET)

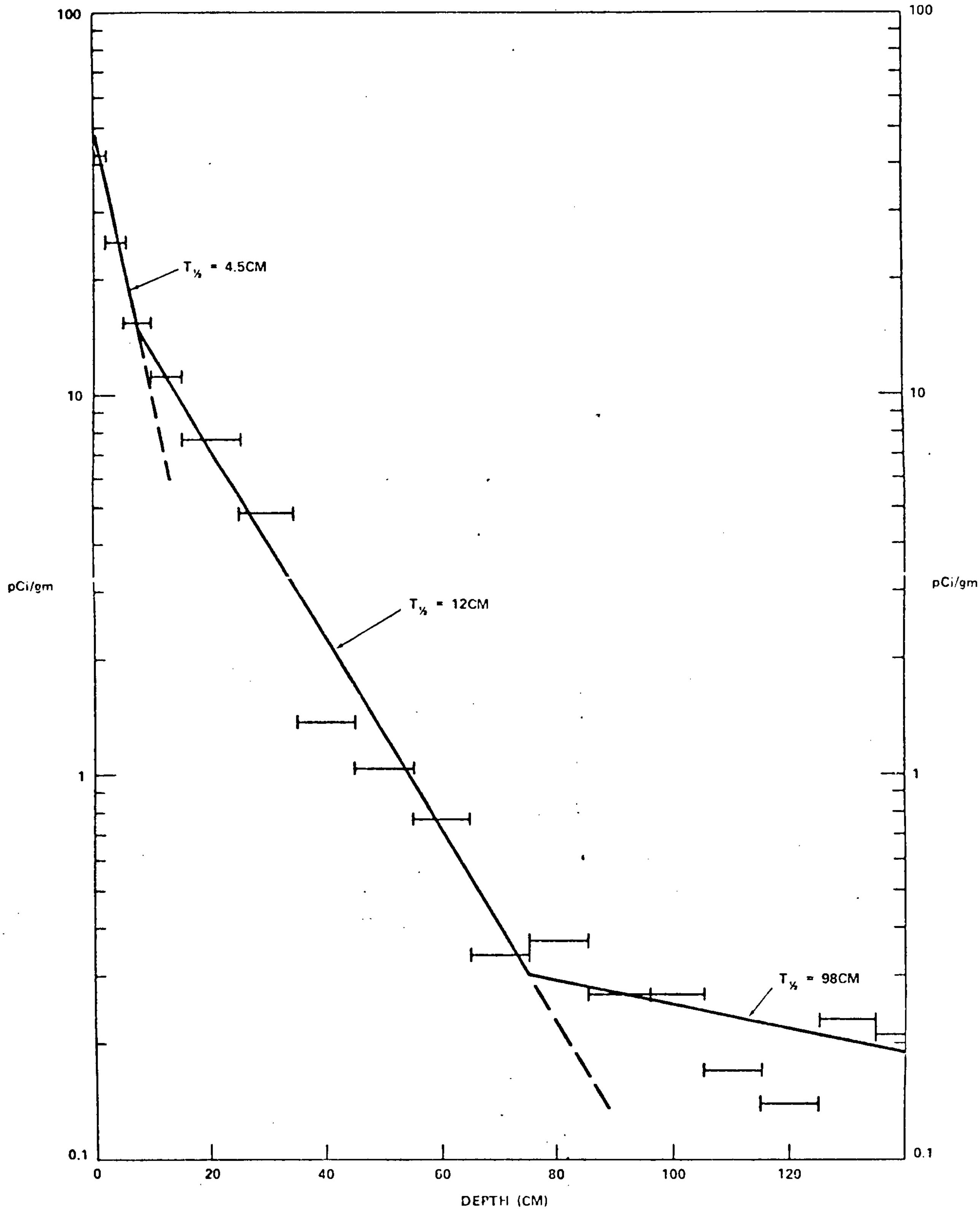



FIG 6. $^{137}Cs$ (AVERAGE OF ALL PROFILE SAMPLES ON JANET)

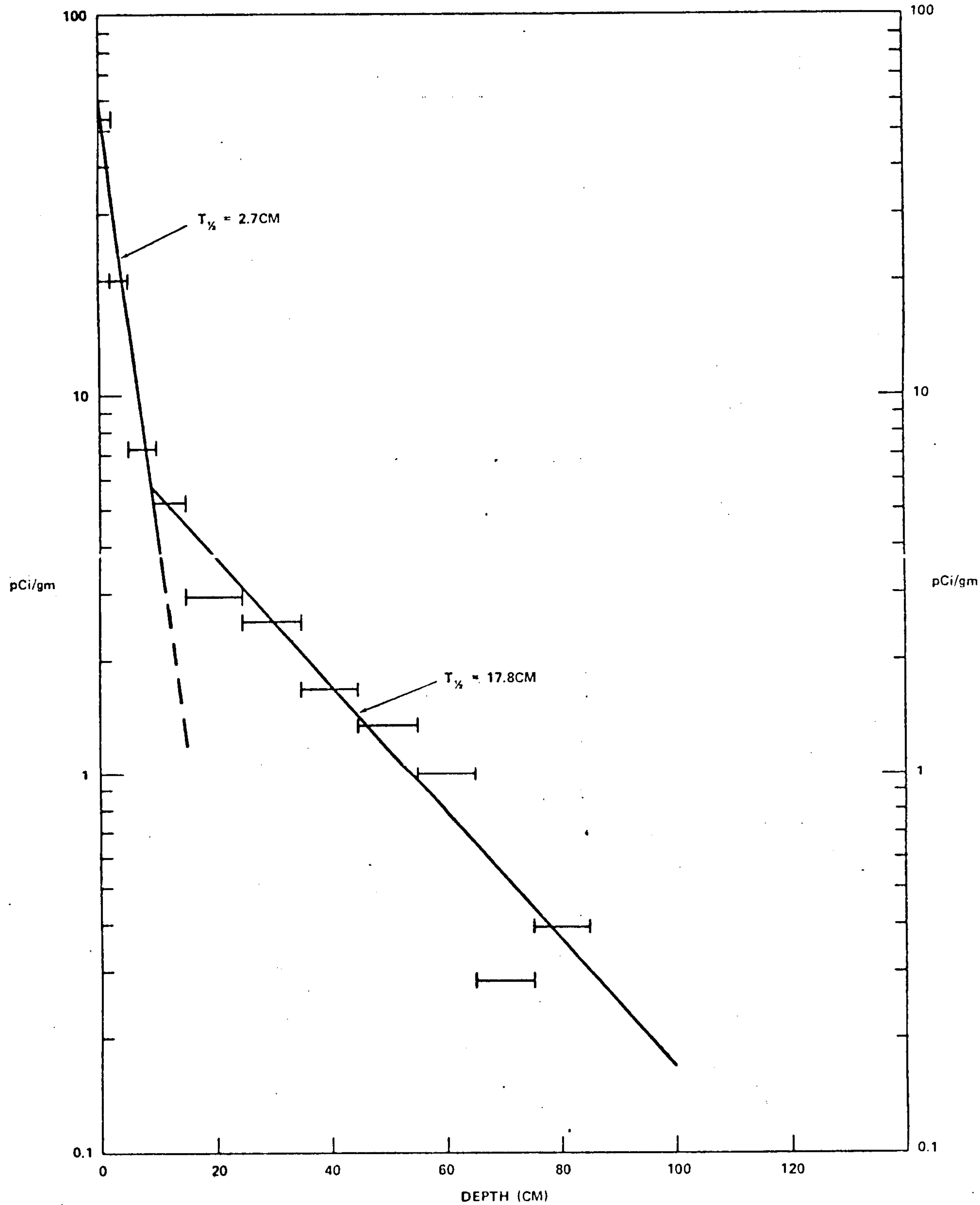



FIG 7. $^{137}Cs$ (AVERAGE OF "SUBSISTENCE AGRICULTURE" PROFILE SAMPLES ON JANET)

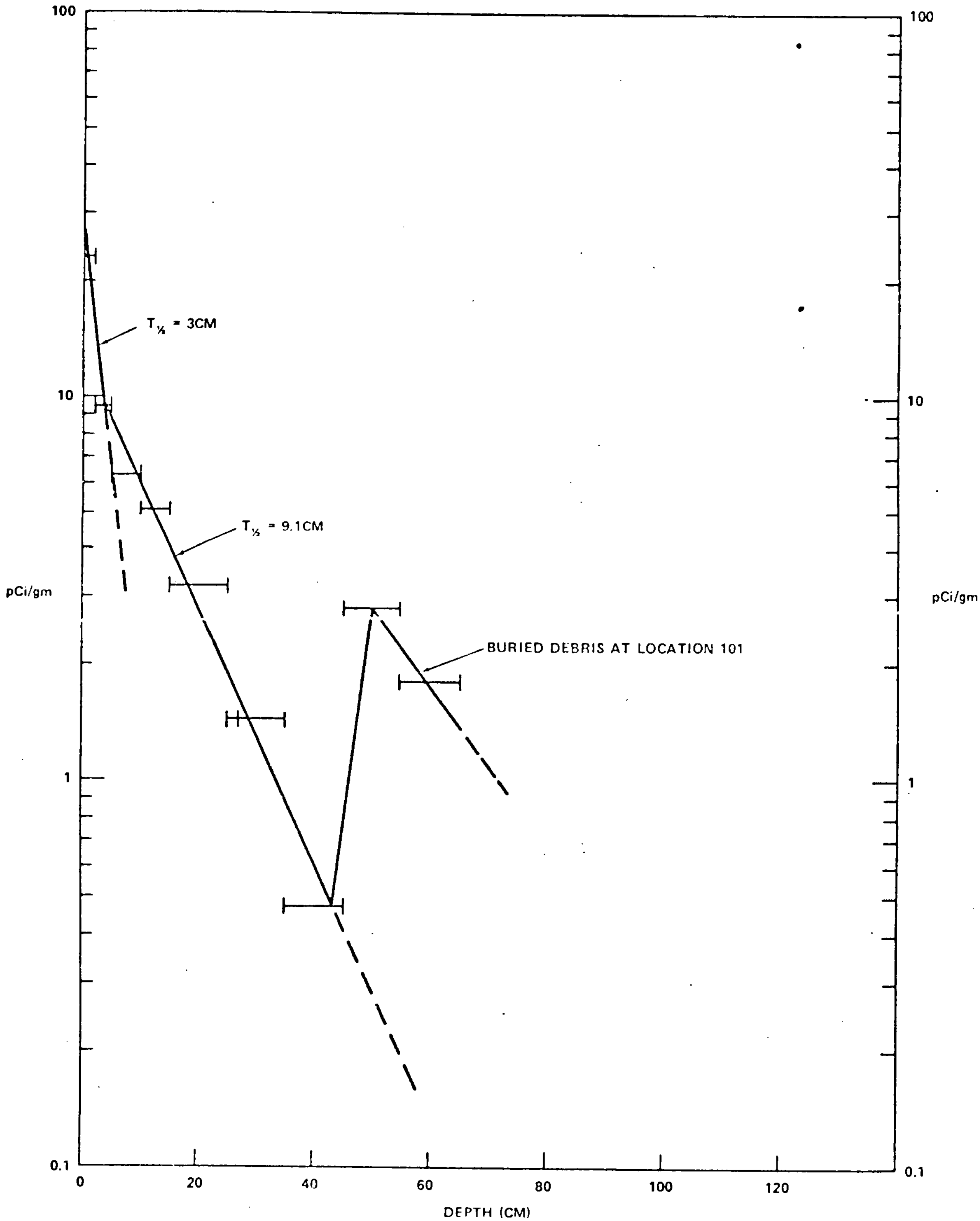



FIG 8. $^{137}Cs$ (AVERAGE OF ALL PROFILE SAMPLES ON PEARL)

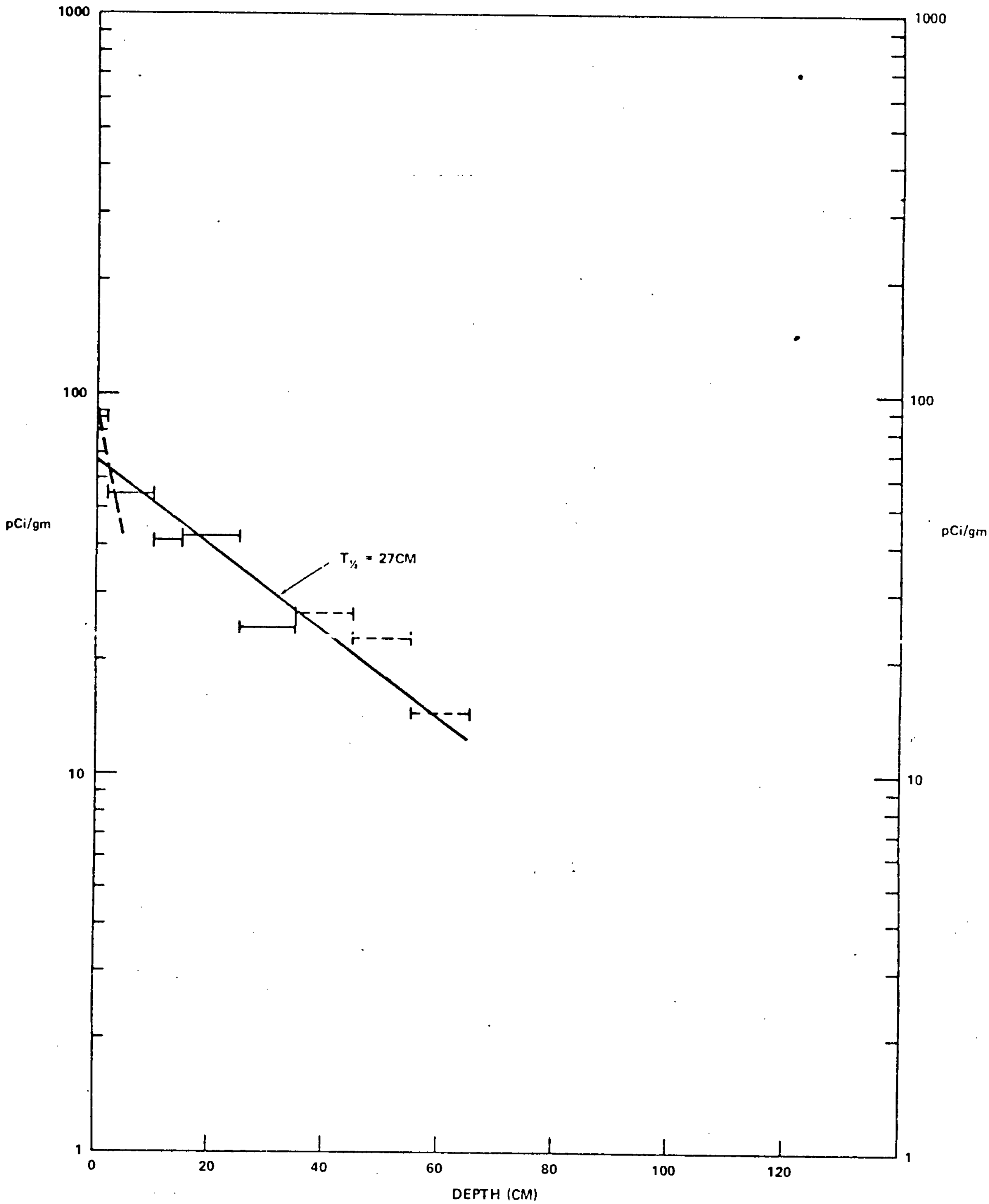



FIG 9. $^{137}$Cs (AVERAGE OF ALL PROFILE SAMPLES ON ALICE)

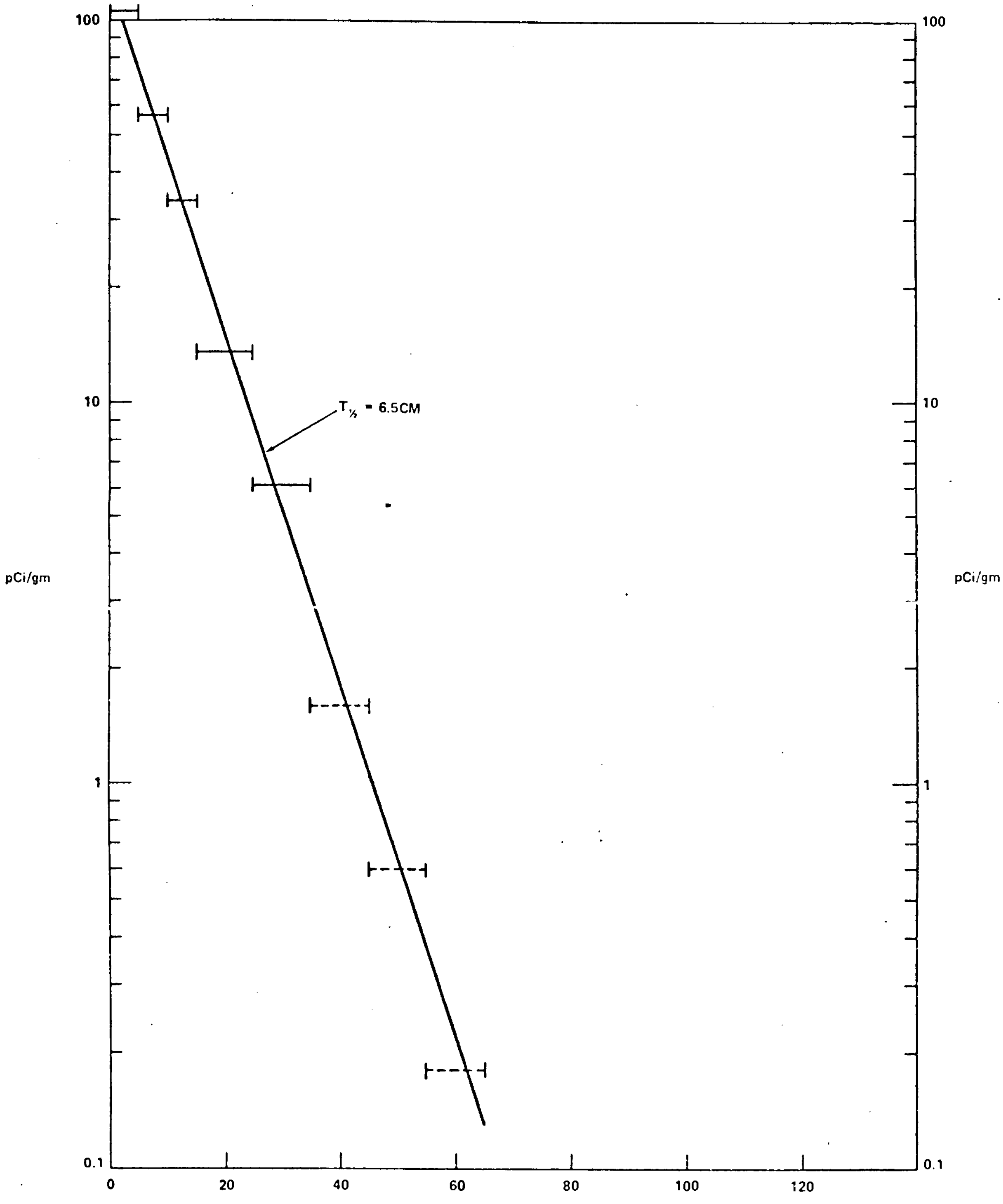



FIG 10. $^{137}Cs$ (AVERAGE OF ALL PROFILE SAMPLES ON BELLE)

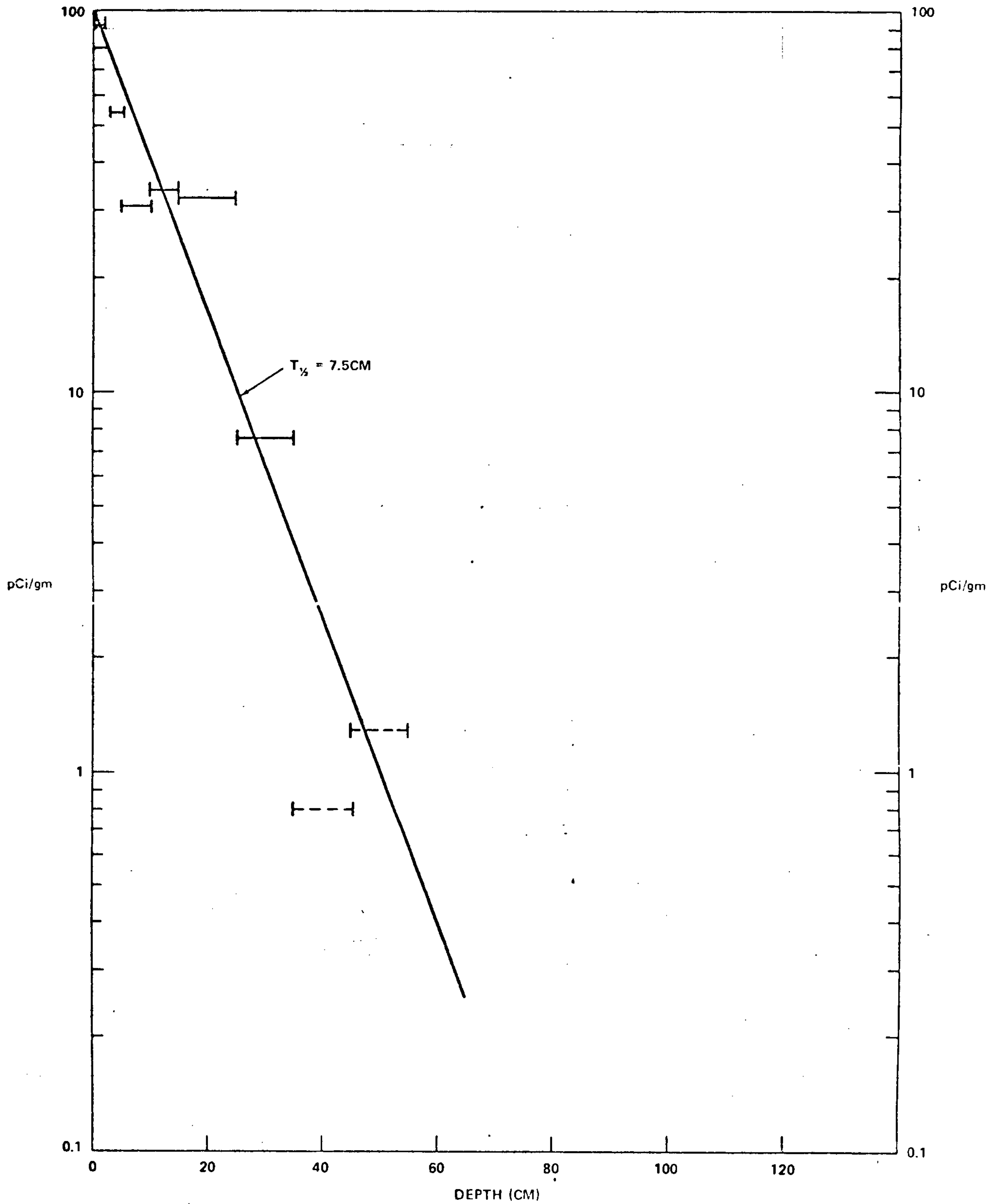



FIG 11. $^{137}Cs$ (AVERAGE OF ALL PROFILE SAMPLES ON CLARA)

# Appendix I
# Enewetak Radiological Survey Report

## Abstract


The AEC has conducted a survey of the total radiological environment of Enewetak Atoll in order to provide data for judgments as to whether or not all or any part of the Atoll can be safely reinhabited. More than 4500 samples from all parts of the marine, terrestrial, and atmospheric components of the Atoll environment were analyzed by instrumental and radiochemical methods. In addition, an aerial survey for gamma-radiation levels was conducted over all land areas.

$^{90}$Sr, $^{137}$Cs, $^{60}$Co, and $^{239}$Pu are the predominant radioactive isotopes now present, but their distribution is far from uniform. Islands on the southern half of the Atoll from ALVIN to KEITH have levels of contamination comparable to or less than those due to world-wide fallout in the United States. On the northern half, islands ALICE to IRENE are most heavily contaminated, KATE to WILMA are least contaminated, and JANET is at an intermediate level.

These radiological data have been combined with the best information currently available on the expected diet of the Enewetak people to estimate potential whole-body and bone doses to the population for six living patterns at 5-, 10-, 30-, and 70-yr intervals after return. Thirty-year integral dose estimates for unmodified (i.e., current) conditions are shown in Table A.


Table A. The 30-yr integral dose for six living patterns, assuming unmodified conditions.

30-year integral dose, rem
Unmodified conditions

| Living pattern | Inhalation | | | External | Terrestrial | | Marine | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bone | Lung | Liver | Bone, W. B. | W. B. | Bone | W. B. | Bone | W. B. | Bone |
| I | 7(-4) | 9(-4) | 4(-4) | 0.83 | 0.14 | 2.1 | 0.053 | 0.84 | 1.0 | 3.8 |
| II | 0.029 | 0.036 | 0.016 | 1.6 | 2.7 | 33 | 0.053 | 0.84 | 4.4 | 35 |
| III | 0.10 | 0.13 | 0.056 | 4.0 | 6.1 | 75 | 0.053 | 0.84 | 11 | 80 |
| IV | 0.47 | 0.59 | 0.24 | 10 | 21 | 210 | 0.053 | 0.84 | 31 | 220 |
| V | 0.11 | 0.13 | 0.058 | 2.9 | 2.7 | 33 | 0.053 | 0.84 | 5.7 | 37 |
| VI | 0.090 | 0.11 | 0.049 | 4.4 | 9.6 | 130 | 0.053 | 0.84 | 14 | 135 |

| Living pattern | Village island | Agriculture | Visitation |
|---|---|---|---|
| I | FRED/ELMER/DAVID | ALVIN through KEITH | Southern islands |
| II | FRED/ELMER/DAVID | KATE through WILMA plus LEROY | Northern islands |
| III | JANET | JANET | Northern islands |
| IV | BELLE | BELLE | Northern islands |
| V | JANET | KATE through WILMA plus LEROY | Northern islands |
| VI | JANET | ALICE through IRENE | Northern islands |

The main contribution to the population dose comes through the terrestrial food pathway, followed in decreasing order of significance by the external gamma dose, marine, and inhalation pathways. In the terrestrial food pathway, the main contribution to both whole-body and bone dose is due to pandanus and breadfruit. Percentage contributions to the 30-yr integral dose for each of the terrestrial food items for a population engaged in agriculture on JANET are shown in Table B.

Corrective actions to reduce population doses will be most beneficial if they are directed at the primary contributors, *i.e., pandanus* and breadfruit in the diet and external gamma dose in the residence areas. Since neither pandanus nor breadfruit are now growing on the Atoll in sufficient amounts to provide a significant dietary component, control of the location and manner in which they are reestablished will have a direct influence on the population doses from these fruits. If their growth were limited to the southern islands, for example, and the population living on JANET were to import them

Table B. Percentage of total 30-yr terrestrial food dose to a population engaged in agriculture on JANET.

| Food | $^{90}Sr$ dose to bone, % | $^{137}Cs$ dose to whole body, % |
|---|---|---|
| Domestic meat | 17 | 26 |
| Pandanus fruit | 40 | 35 |
| Breadfruit | 34 | 29 |
| Wild birds | 0.005 | 0.003 |
| Bird eggs | 0.05 | 0.002 |
| Arrowroot | 2 | 0.3 |
| Coconut meat | 6 | 9 |
| Coconut milk | 0.9 | 1 |

rather than grow them locally, the expected 30-yr bone dose would be reduced from 80 to 25 rem and the whole-body dose from 11 to 6.5 rem. Similar results would be obtained if uncontaminated soil were imported to JANET for the establishment of these plants. Attempts to obtain the same results by removal of $^{90}Sr$- and $^{137}Cs$-contaminated soil from JANET would require denuding of the entire island because of the relatively uniform distribution of these isotopes over the land surface.

Significant reduction of the external gamma dose may be achieved by placing a 2-in. layer of clean gravel in the village areas and by plowing the agricultural areas. On JANET, for example, use of these procedures reduces the expected 30-yr external dose from 4.0 to 1.7 rem.

Thus, from Table A it is clear that a very broad range of population doses may be expected, depending on village island, agricultural island, and living pattern. It is equally clear that substantial reductions of the higher doses can be achieved through relatively simple modification of the agricultural practices and of the soil. Table C summarizes the reduction that could be expected from these actions for a population living on JANET.

The island of YVONNE presents a unique hazard on Enewetak Atoll. Pure plutonium particles are present on or close to the ground surface, randomly scattered in "hot spots" over most of the area from the tower to CACTUS crater. Examination of these "hot spots" has revealed the presence of occasional milligram-size pieces of plutonium metal, as well as smaller pieces which are physically indistinguishable in size from the surrounding coral matrix. Given these current conditions, it must be assumed that pure plutonium particles of respirable size are now also present on the surface or may be present in the future as weathering effects oxidize and break down the larger particles. Lung dose assessments for this area, therefore, must be based on inhalation of pure plutonium particles rather than those having the average plutonium content of the soil.

The potential health hazard via the inhalation pathway is sufficiently great to dictate two basic alternatives for remedial action for this island: (1) Make the entire island an exclusion area—off limits to all people, or (2) conduct a cleanup campaign which will eliminate the "hot-spot" plutonium problem and remove whatever amount of soil is necessary to reduce the soil plutonium concentration to a level comparable to other northern islands. As an indication of the volumes of soil involved, removal of a 10-cm thick layer of topsoil in the area in which "hot spots" have been detected involves approximately 17,000 $m^3$ of material. Further removal of soil to reduce the maximum plutonium contamination levels to 50 pCi/g or less involves an additional 25,000 $m^3$ of material.

Table C. 30-yr integral doses from all pathways compared to U.S. external background dose.

| Location | 30-yr integral dose, rem[a] | | | |
|---|---|---|---|---|
| | Unmodified soil case | | Modified soil case[b] | |
| | W.B. | Bone | W.B. | Bone |
| Enewetak Atoll living pattern III (JANET-current conditions) | 11 | 80 | 8.9 | 78 |
| Enewetak Atoll living pattern III (JANET-pandanus and breadfruit imported) | 6.5 | 25 | 4.2 | 23 |
| Enewetak Atoll living pattern III (JANET-all agriculture confined to southern islands) | 4.2 | 7.0 | 1.9 | 4.7 |
| Enewetak Atoll living pattern I (southern islands) | 1.0 | 3.8 | 1.0 | 3.8 |
| U.S. background only[c] | 3.0 | 3.0 | 3.0 | 3.0 |

[a]Sum of all pathways for the Enewetak living patterns (i.e., external, inhalation, marine, and terrestrial).

[b]Soil modified by placing 2 in. of clean gravel in the village area and plowing the agricultural area.

[c]Based upon background of 100 mrem/yr at sea level.

# Appendix II
# Enewetak Radiological Survey Report
# Summary of Findings Chapter

W. Nervik, Lawrence Livermore Laboratory, Livermore, California

## INTRODUCTION

It has been the purpose of this survey to gain a sufficient understanding of the total radiological environment of Enewetak Atoll to permit judgments as to whether or not all or any part of the Atoll can safely be reinhabited and, if so, what preliminary steps toward cleanup should be taken and what post-rehabilitation constraints must be imposed.

Enewetak Atoll has an extremely broad range of radiological conditions in a small land mass. To gain an understanding of the details of this range of conditions, it has been necessary to obtain and analyze a very large number of samples from all components of the environment. To gain an equivalent understanding of the implications of this range of conditions for rehabilitation of the Enewetak people, it has been necessary to postulate population distributions, life styles, and dietary habits – an endeavor fraught with uncertainties under the best of circumstances, but particularly so for the current, rapidly changing Marshallese culture.

This section is a summary of the data obtained from the Survey, the postulates used, and the population dose assessments derived from data plus postulates. The reader is cautioned against expecting or using a "simple" description of the radiological condition of Enewetak Atoll, because no single value of any component of the radiological condition is applicable to the entire Atoll without being misleading.

## CURRENT RADIOLOGICAL CONDITION OF THE ATOLL

### External Gamma Radiation Levels

Three independent techniques were used to measure external gamma radiation levels on the Atoll:

- LiF and $CaF_2$ thermoluminescent dosimeters (TLDs) were exposed for 3½ months on seven of the northern islands.
- A measurement using a Baird-Atomic survey instrument was made at each soil-sampling location on each island.
- An aerial survey with NaI detectors was conducted over the entire surface area of every island.

All three techniques yield results which agree to within about 10%. $^{60}Co$ and $^{137}Cs$ contribute most of the total external gamma radiation, with the remainder due to small amounts of other gamma emitters such as $^{125}Sb$, $^{155}Eu$, and $^{241}Am$. The amount of $^{60}Co$ relative to $^{137}Cs$ varies throughout the Atoll, with a range of values from about 0.5 on JANET to greater than 14 on JAMES. Average values for each isotope on each island are given in Table 214. For reference, a map of the Atoll is shown in Fig. 146.

Southern islands (SAM to KEITH) are characterized by low and more or less uniformly distributed gamma-radiation levels over the area of each island. As exposure levels increase, exposure gradients become severe, with beaches

Table 214. Summary of average exposure rates for islands in Enewetak Atoll.

| Island | Average exposure rate, μR/hr at 1 m[a] | | | |
|---|---|---|---|---|
| | $^{137}Cs$ | $^{60}Co$ | Total γ (0-3 MeV) | Range[b] |
| ALICE | 42 | 36 | 81 | 4-170 |
| BELLE | 61 | 50 | 115 | 5-200 |
| CLARA | 20 | 19 | 42 | 5-100 |
| DAISY | 6.8 | 14.4 | 21.3 | 5-140 |
| EDNA | 2.8 | 2.4 | 6 | 5-8 |
| IRENE | 14 | 63 | 80 | 3-560 |
| JANET | 25 | 13 | 40 | 2-150 |
| KATE | 11 | 7 | 19 | 3-22 |
| LUCY | 6 | 7 | 14 | 1-20 |
| PERCY | 2 | 2 | 5 | 2-11 |
| MARY | 5.5 | 4 | 10 | 2-12 |
| NANCY | 6 | 5 | 12 | 1-50 |
| OLIVE | 6.5 | 4.5 | 11 | 1-15 |
| PEARL | 12 | 45 | 70 | 1-400 |
| RUBY | 2 | 12 | 14 | 1-42 |
| SALLY | 3.5 | 3 | 7 | 3-110 |
| TILDA | 4 | 2 | 6 | 2-11 |
| URSULA | 3 | 1.8 | 5 | 1-7 |
| VERA | 2.8 | 2 | 5 | 1-6 |
| WILMA | 1 | 1 | 2 | 1-3 |
| YVONNE | 5.6 | 22.4 | 33 | 1-750 |
| SAM | <0.3 (0.20) | <0.6 (0.11) | 10.9 | 0-1 |
| TOM | <0.3 (0.18) | <0.6 (0.13) | <0.9 | 0-1 |
| URIAH | <0.3 (0.06) | <0.6 (0.43) | <0.9 | 0-1 |
| VAN | <0.3 (0.08) | <0.6 (0.25) | <0.9 | 0-1 |
| ALVIN | N. D. (0.06) | <0.6 (0.25) | <0.9 | 0-1 |
| BRUCE | 0.4 (0.22) | 0.8 (0.34) | 1.2 | 0-1 |
| CLYDE | <0.3 (0.04) | <0.6 (0.11) | <0.9 | 0-1 |
| DAVID | N. D. (0.21) | N. D. (0.10) | <0.9 | 0-5 |
| REX | <0.3 (0.28) | <0.6 (0.25) | <0.9 | 0-1 |
| ELMER | N. D. (0.19) | N. D. (0.12) | <0.09 | 0-2 |
| WALT | <0.3 (0.08) | <0.6 (0.10) | <0.9 | 0-1 |
| FRED | N. D. (0.14) | N. D. (0.12) | <0.9 | 0-1 |
| GLENN | 0.4 (0.33) | <0.6 (0.20) | <0.9 | 0-1 |
| HENRY | <0.3 (0.14) | <0.6 (0.20) | <0.9 | 0-1 |
| IRWIN | <0.3 (0.08) | <0.6 (0.46) | <0.9 | 0-1 |
| JAMES | <0.3 (0.05) | 2.8 | 3.0 | 0-5 |
| KEITH | <0.3 (0.15) | <0.6 (0.49) | <0.9 | 0-2 |
| LEROY | 2.8 | 4.8 | 7.6 | 3-8 |

[a]Average dose rates given are derived from aerial survey data. On islands where activity levels are at the lower limit of sensitivity of the aerial survey equipment, dose rates derived from the soil sample data are given in parentheses.

[b]As measured with the Baird-Atomic instrument.

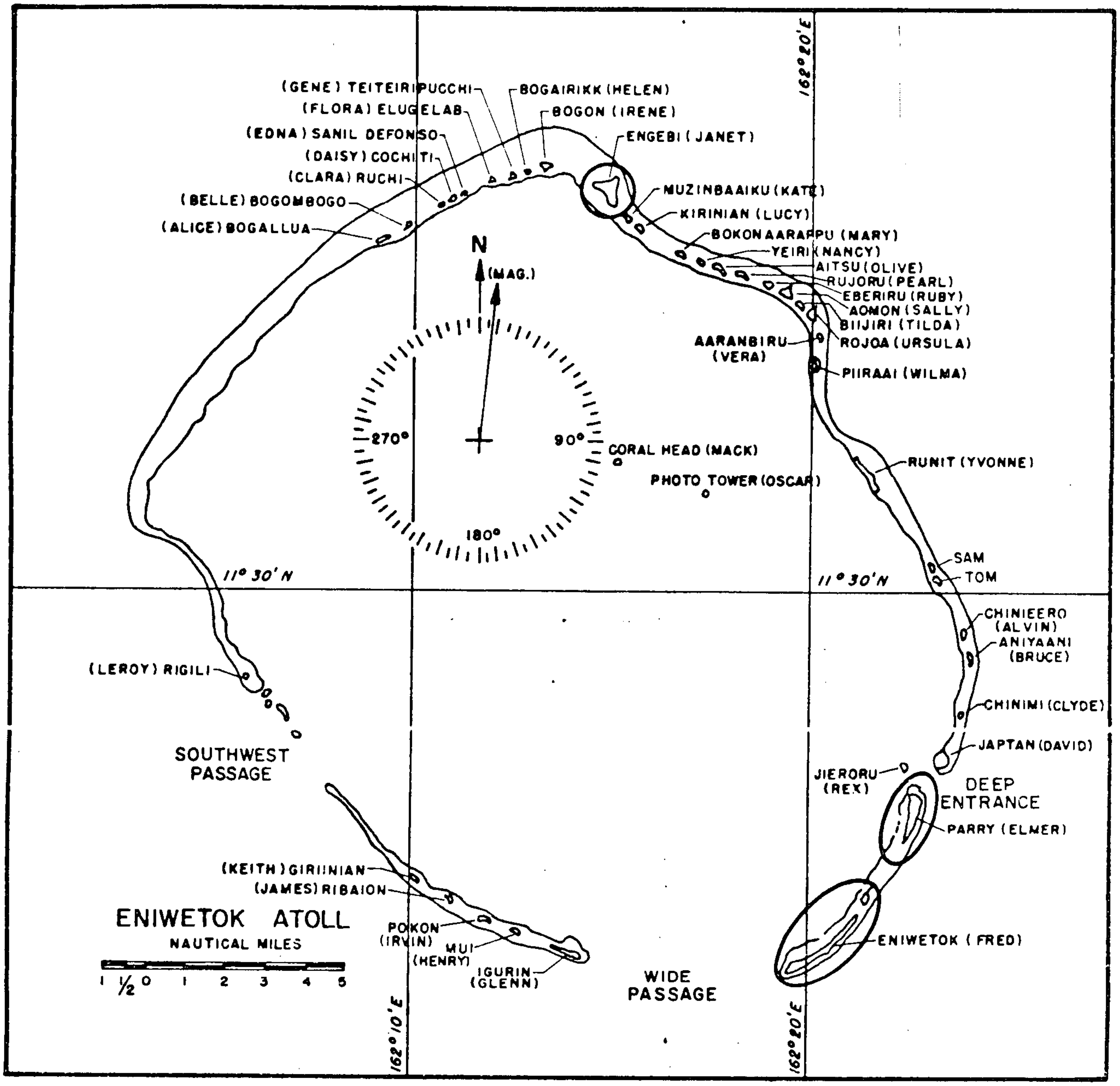



Fig. 146. Islands (those circled) requested as village locations by the Enewetak people.

generally at or very near expected background levels; the highest levels are found in heavy vegetation at island centers or near ground zero sites. "Average" values for islands with relatively high dose levels include a broad range of values for specific areas and should therefore be used with caution.

## Radioactivity Levels in Enewetak Soil

Approximately 3000 samples of Enewetak soil were analyzed by germanium gamma-spectroscopic (GeLi) and wet-chemistry techniques to determine the distribution of radioactive species on islands in the Atoll. Samples were taken on every island, but emphasis was given to – and proportionately larger numbers of samples taken on – those islands which were known to have been sites for nuclear testing activity or to have been subjected to large amounts of fallout from such activity.

Two types of soil samples were taken on each island: "surface" and "profile." At "surface" sampling locations, two samples were taken – one a 30-$cm^2$ × 15-cm-deep core, and the second a composite of two 30-$cm^2$ × 5-cm-deep cores. At "profile" sampling locations, 100-$cm^2$ samples were taken from the side wall of a trench dug for the purpose. Nominal depth increments for the profile samples were 0 to 2, 2 to 5, 5 to 10, 10 to 15, 15 to 25, and 25 to 35 cm, and at 10-cm increments to total depth. Total depth for profile samples varied from 35 to 185 cm, depending on the distribution expected from the testing history of the island being sampled.

In general, the predominant species found in the soil samples are $^{90}Sr$, $^{137}Cs$, $^{239}Pu$, and $^{60}Co$. $^{40}K$, $^{55}Fe$, $^{101}Rh$, $^{102m}Rh$, $^{125}Sb$, $^{133}Ba$, $^{134}Cs$, $^{152}Eu$, $^{154}Eu$, $^{155}Eu$, $^{207}Bi$, $^{226}Ra$, $^{235}U$, $^{238}Pu$, and $^{241}Am$ are also present in some or all of the samples. As was the case for external gamma levels, small amounts of radioactive species on the southern islands (SAM to KEITH) are distributed more or less uniformly over the entire land area. On islands where larger amounts of activity are present, the highest levels of all species are found at the island centers or in proximity to ground-zero sites, usually related in a direct way to the vegetation density in the immediate area. As an example of the kind of data obtained for each of the predominant isotopes on each of the islands, $^{90}Sr$ values for 0-15 cm core samples on JANET are plotted in Fig. 147.

Table 215 presents geometric mean values and ranges for the four predominant radionuclides on islands from ALICE through WILMA. On islands where there are significant differences in activity levels between densely and sparsely vegetated areas, data for both are given. Similar data for groups of southern islands are shown in Table 216.

"Profile" samples showed a wide range of activity distributions as a function of depth on different parts of the Atoll. Examples of the types found are given in Figs. 148-151. Although generalizations in this area are not very meaningful, Fig. 148 shows the profile distribution normally found on the southern islands. Here the activity levels are usually low through the full range of depths sampled. Some sampling locations show concentrations decreasing somewhat from the surface through the first 10 or 20 cm of soil. Figure 149 shows the type of distribution often found inland on islands subjected to fallout but not to construction or other ground-zero earthmoving activities – i. e., a rapid and fairly steady decrease of activity levels from the surface to total depth. Figure 150 shows the distribution found on beaches and exposed areas on these same islands – i. e., uniform or slowly decreasing activity levels from the surface to total depth. Figure 151 shows a distribution pattern found occasionally on islands which have been the sites for tests or have been subjected to construction and earthmoving activities (primarily IRENE, JANET, PEARL,

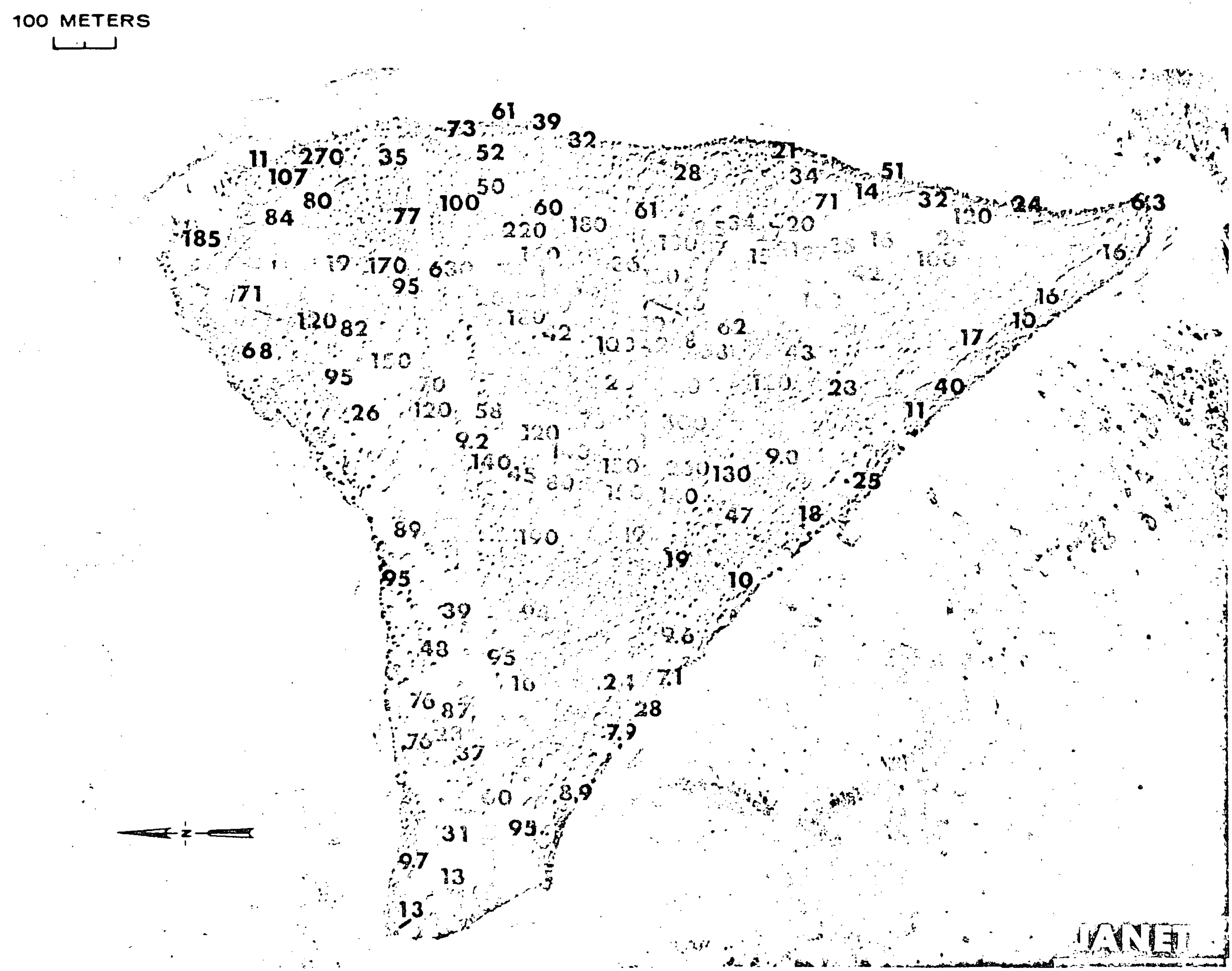



Fig. 147. The average $^{90}Sr$ activities (pCi/gm) in soil samples collected to a depth of 15 cm.

Table 215. Enewetak soil data, "northern islands" (pCi/g in top 15 cm).

| | | $^{90}Sr$ | | $^{137}Cs$ | | $^{239}Pu$ | | $^{60}Co$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| ALICE | | 80 | 14-430 | 36 | 5.6-141 | 12 | 3.9-68 | 5.9 | 1.4-33 |
| BELLE | Dense | 123 | 14-670 | 48 | 14-170 | 26 | 7.2-130 | 10 | 3.1-30 |
| | Sparse | 44 | 35-130 | 8.6 | 3.3-44 | 11 | 5.8-26 | 4.6 | 2.4-9.6 |
| CLARA | | 65 | 13-310 | 26 | 5.6-110 | 22 | 3.5-88 | 6.4 | 0.91-20 |
| DAISY | Dense | 190 | 100-380 | 11 | 3.4-33 | 41 | 22-98 | 11 | 6.4-26 |
| | Sparse | 32 | 16-120 | 3.8 | 0.86-9.0 | 15 | 3.8-33 | 0.85 | 0.37-7.4 |
| EDNA | | 46 | 30-220 | 4.2 | 2.7-6.4 | 18 | 13-24 | 0.43 | 0.33-0.63 |
| IRENE | | 30 | 5.9-570 | 3.2 | 0.22-41 | 11 | 2.4-280 | 5.4 | 0.12-520 |
| JANET | | 44 | 1.6-630 | 16 | 0.57-180 | 8.5 | 0.08-170 | 1.9 | 0.02-33 |
| KATE | Dense | 67 | 37-200 | 24 | 18-37 | 17 | 8.6-50 | 2.7 | 1.6-5.8 |
| | Sparse | 11 | 1.6-49 | 4.8 | 1.8-16 | 2.3 | 0.17-14 | 0.46 | 0.03-3.5 |
| LUCY | | 32 | 10-83 | 11 | 2.2-25 | 7.7 | 2.4-22 | 1.5 | 0.26-3.8 |
| MARY | | 29 | 11-140 | 9.9 | 5.6-26 | 8.0 | 2.0-35 | 1.5 | 0.74-4.8 |
| NANCY | | 36 | 16-110 | 12 | 6.0-28 | 9.1 | 2.3-28 | 1.6 | 0.56-5.3 |
| PERCY | | 13 | 3.6-73 | 0.94 | 0.12-17 | 3.5 | 1.5-23 | 0.47 | 0.08-2.9 |
| OLIVE | Dense | 22 | 4.6-70 | 8.5 | 3.5-28 | 7.7 | 2.2-30 | 1.5 | 0.65-4.1 |
| | Sparse | 4.5 | 2.0-11 | 0.16 | 0.07-11 | 2.8 | 1.9-4.1 | 0.11 | 0.05-0.31 |
| PEARL | Hot spot | 62 | 35-140 | 19 | 7.4-55 | 51 | 15-530 | 12 | 3.6-70 |
| | Remainder | 17 | 3.2-61 | 7.6 | 1.2-34 | 11 | 0.85-100 | 4.1 | 0.49-49 |
| RUBY | | 12 | 7.1-63 | 1.4 | 0.71-7.2 | 7.3 | 3.0-24 | 0.93 | 0.29-16 |
| SALLY | | 8.4 | 0.87-140 | 3.0 | 0.03-30 | 4.3 | 0.21-130 | 0.54 | 0.05-69 |
| TILDA | Dense | 27 | 17-54 | 8.4 | 3.5-20 | 7.6 | 1.4-17 | 1.2 | 0.61-1.9 |
| | Sparse | 8.7 | 2.2-47 | 1.0 | 0.04-5.3 | 2.5 | 1.1-34 | 0.37 | 0.21-1.7 |
| URSULA | | 6.8 | 2.0-19 | 1.7 | 0.13-7.8 | 1.3 | 0.26-7.3 | 0.31 | 0.05-1.7 |
| VERA | | 6.3 | 1.1-68 | 2.0 | 0.03-12 | 2.5 | 0.60-25 | 0.30 | 0.02-2.2 |
| WILMA | | 3.3 | 0.26-13 | 1.3 | 0.31-7.2 | 1.1 | 0.1-5.3 | 0.12 | 0.01-0.7 |
| Southern YVONNE | | 1.7 | 0.09-20 | 0.40 | 0.02-3.6 | 3.2 | 0.02-50 | 0.64 | 0.01-20 |
| Northern Beaches | | 6.4 | 1.2-30 | 0.30 | 0.03-9.0 | 2.7 | 0.34-18 | 0.13 | 0.03-1.6 |

YVONNE - Because of the complex distribution of activities on Northern YVONNE no single mean value for an isotope can be used for the island as a whole without being misleading. Readers should consult the YVONNE discussion in this section and the detailed data in Appendix II for information pertinent to their interests.

SALLY, and YVONNE). In these locations, activity levels below ground level are significantly higher than at the surface. Because of the observed variety of profile distributions, no "average vertical distribution" can be formulated which is applicable to the Atoll as a whole.

The land area which has the most severely nonuniform distribution of radioactive species on the Atoll is that

Table 216. Enewetak soil data, southern islands (pCi/g in top 15 cm).

| | $^{90}Sr$ | | $^{137}Cs$ | | $^{239}Pu$ | | $^{60}Co$ | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Group A (DAVID, ELMER, FRED) | 0.41 | 0.02-4.8 | 0.21 | 0.01-2.1 | 0.04 | 0.004-0.31 | 0.03 | 0.01-0.15 |
| Group B (All others except LEROY)[a] | 0.52 | 0.03-3.9 | 0.14 | 0.004-1.8 | 0.07 | 0.004-1.1 | 0.06 | 0.007-63 |
| Group C (LEROY) | 11 | 1.6-34 | 3.2 | 0.5-10 | 0.63 | 0.02-2.0 | 0.58 | 0.04-5.0 |

[a]SAM, TOM, URIAH, VAN, ALVIN, BRUCE, CLYDE, REX, WALT, GLENN, HENRY, IRWIN, JAMES and KEITH.

part of YVONNE which lies north of the tower (Sta. 1310). This area includes the highest external gamma levels found on the Atoll, with levels of 500-750 $\mu$R/hr found over a five-acre site just south of the CACTUS crater. In addition, pieces of plutonium metal weighing as much as several milligrams are randomly scattered on or near the ground surface over most of the area from CACTUS crater to a line drawn across the island, about 60 m north of the tower. Construction and earthmoving activities during the testing period, for which we have no reliable record, served to redistribute the radioactivity in such a way that it is essentially impossible to get an accurate, detailed, three-dimensional survey of radioactive species present in this area now. Four hundred meters north of the tower, for about 100 m along the ocean-side embankment, for example, there is a visible layer of dark soil roughly 20 cm thick, 10 to 20 cm below the surface, which contains high concentrations of plutonium (3200 pCi/g in one sample).

In an effort to obtain a reasonable estimate of the three-dimensional distribution of radioactive material in this area, 45 profile locations (shown in Fig. 152) were sampled to 150-cm depths. Plutonium data for the profiles along the center of the island, and across the island at the position of the plutonium-bearing layer, are shown in Figs. 153-156. Data from all of the profile samples lead to the following observations:

- There were no large plutonium particles analyzed in any of these samples since the maximum specific activity found was ~800 pCi/g.
- Except for the area in the general vicinity of the exposed plutonium layer, there were few profile sampling locations where plutonium concentrations exceeded 100 pCi/g at <u>any</u> depth. Of the four that did, two had the high concentration in the top 10 cm of soil. Profile sampling locations where plutonium concentrations greater than 100

pCi/g were found at any depth are enclosed in cross-hatched areas in Fig. 152.

Thus it seems likely that soil bearing high concentrations of plutonium – as opposed to pieces of plutonium – is largely limited to a band roughly 350 m wide across the island, centered on the visible plutonium soil layer. Within this band, plutonium concentrations are greatest on the ocean side, less on the lagoon side, and least in the island center – a finding consistent with historical data which indicate that debris was bulldozed away from the shot point toward both shorelines after the event which produced these plutonium particles.

Except for this band across the island, there is no evidence which indicates that plutonium particles on or near the ground surface in the larger area shown in Fig. 152 are also found at any significant depth below the surface. Because of the discrete nature and random distribution of these particles, of course, the only way that their distribution could be further established would be by analysis of very large volumes of soil.

## Radioactivity Levels in Enewetak Lagoon

Approximately 858 samples taken from the Enewetak lagoon environment were analyzed by germanium gamma-spectroscopic (GeLi) and wet-chemistry techniques to determine the distribution of radioactive species in the lagoon, including 345 sediment and bottom cores, 82 seawater and seawater filters, 21 algae, plankton, or coral, and 410 fish samples. Figure 157 shows the major sampling locations for this marine program.

Analysis of the sediment and core samples indicates the presence of $^{40}K$, $^{60}Co$, $^{90}Sr$, $^{101}Rh$, $^{102m}Rh$, $^{106}Ru$, $^{127}Sb$, $^{137}Cs$, $^{152}Eu$, $^{154}Eu$, $^{155}Eu$, $^{207}Bi$, $^{235}U$, $^{238}Pu$, $^{239,240}Pu$, and $^{241}Am$ in some, but not necessarily all of the samples. Each nuclide is non-uniformly distributed over the lagoon floor, with the highest levels generally found in the northwest part of the lagoon, 2-3 km southeast of the islands ALICE through IRENE; the next highest levels are found in the area southwest of YVONNE; and the lowest levels are found south of a line extending across the lagoon from the Southwest Passage to TOM. Figure 158, for example, shows the distribution pattern for $^{90}Sr$. Similar figures have been prepared for each of the predominant species found.

Many of the radionuclides found in the marine sediment and core samples were not detected in the water samples, including $^{102m}Rh$, $^{106}Ru$, $^{125}Sb$, $^{152}Eu$, and $^{235}U$. In only 15 samples from the northern part of the lagoon were $^{60}Co$, $^{155}Eu$, $^{207}Bi$, and $^{241}Am$ detected. $^{137}Cs$ and $^{239,240}Pu$ were positively identified in all samples. Table 217 gives the mean surface water concentration of $^{137}Cs$ and $^{239,240}Pu$ in the four quadrants of the lagoon, in the ocean close to the east side of the lagoon, and for several areas in other parts of the world for comparative purposes.

In the plankton samples, the most abundant isotopes observed were $^{90}Sr$ (av 0.86 pCi/g, wet wt) and $^{207}Bi$ (0.83 pCi/g), followed in decreasing order of abundance by $^{60}Co$ (0.68 pCi/g), $^{239,240}Pu$ (0.39 pCi/g), $^{155}Eu$ (0.24 pCi/g), $^{241}Am$ (0.23 pCi/g), and $^{137}Cs$

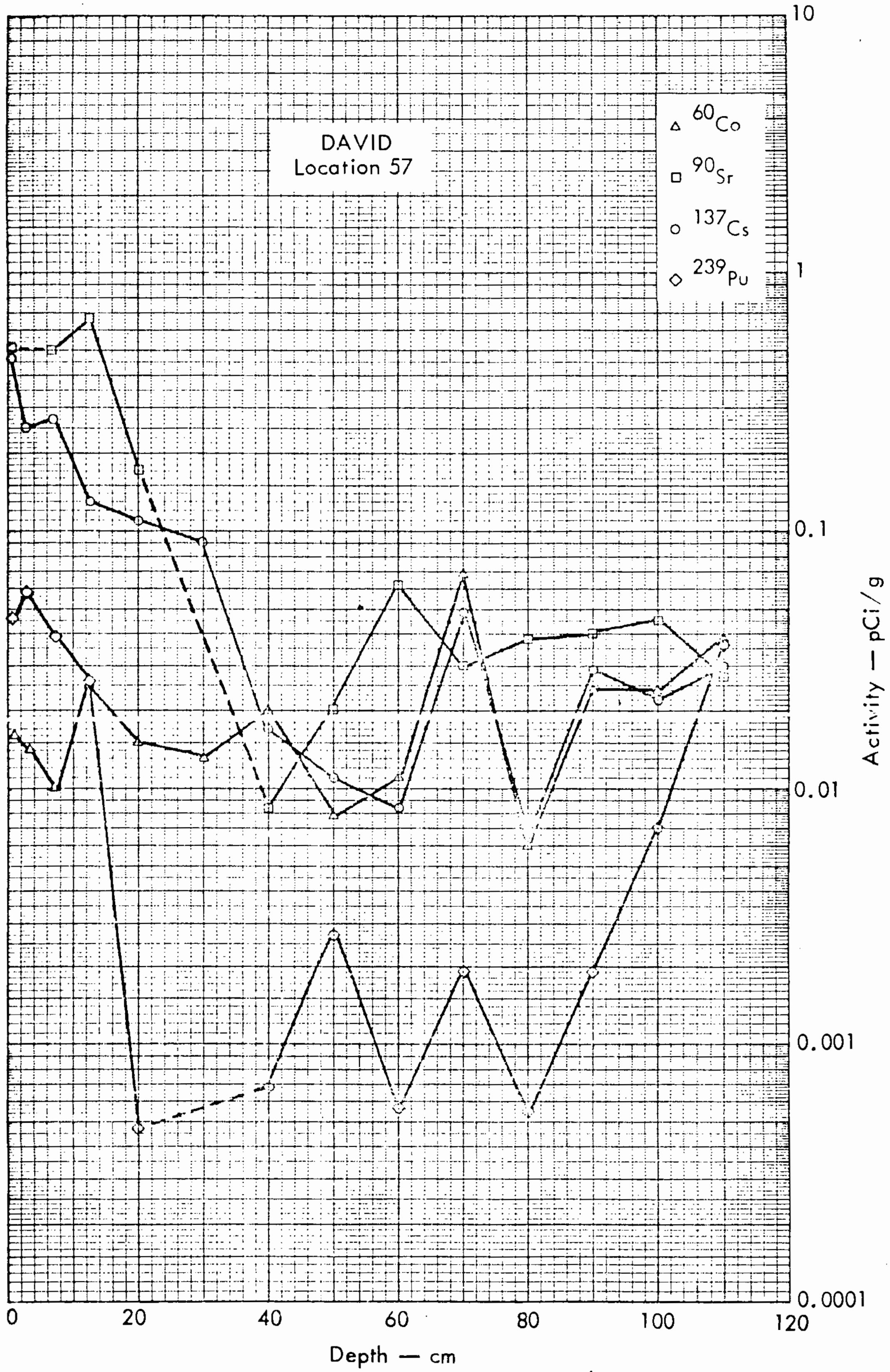



Fig. 148. Activities of selected radionuclides as a function of soil depth.

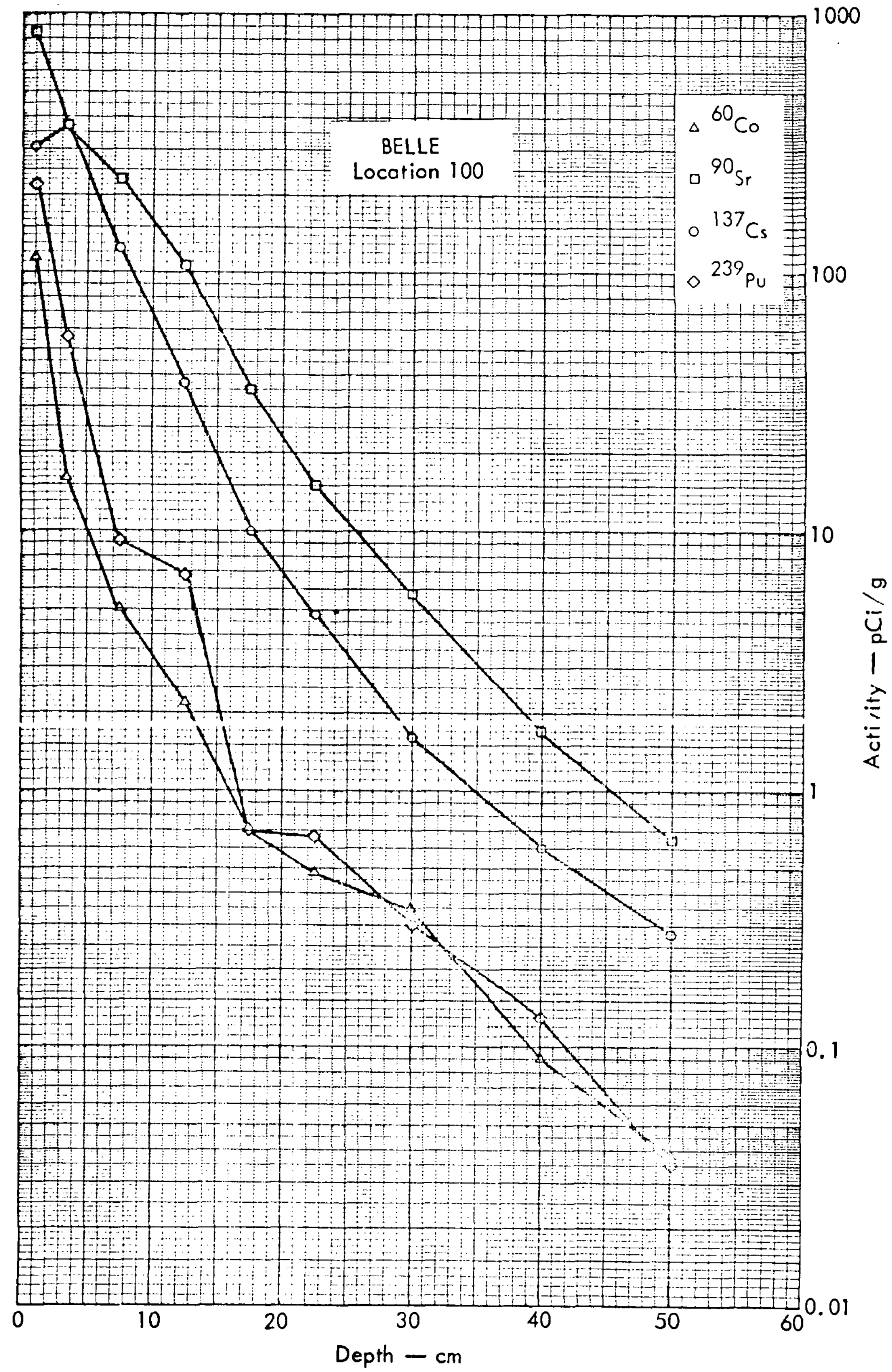



Fig. 149. Activities of selected radionuclides as a function of soil depth.

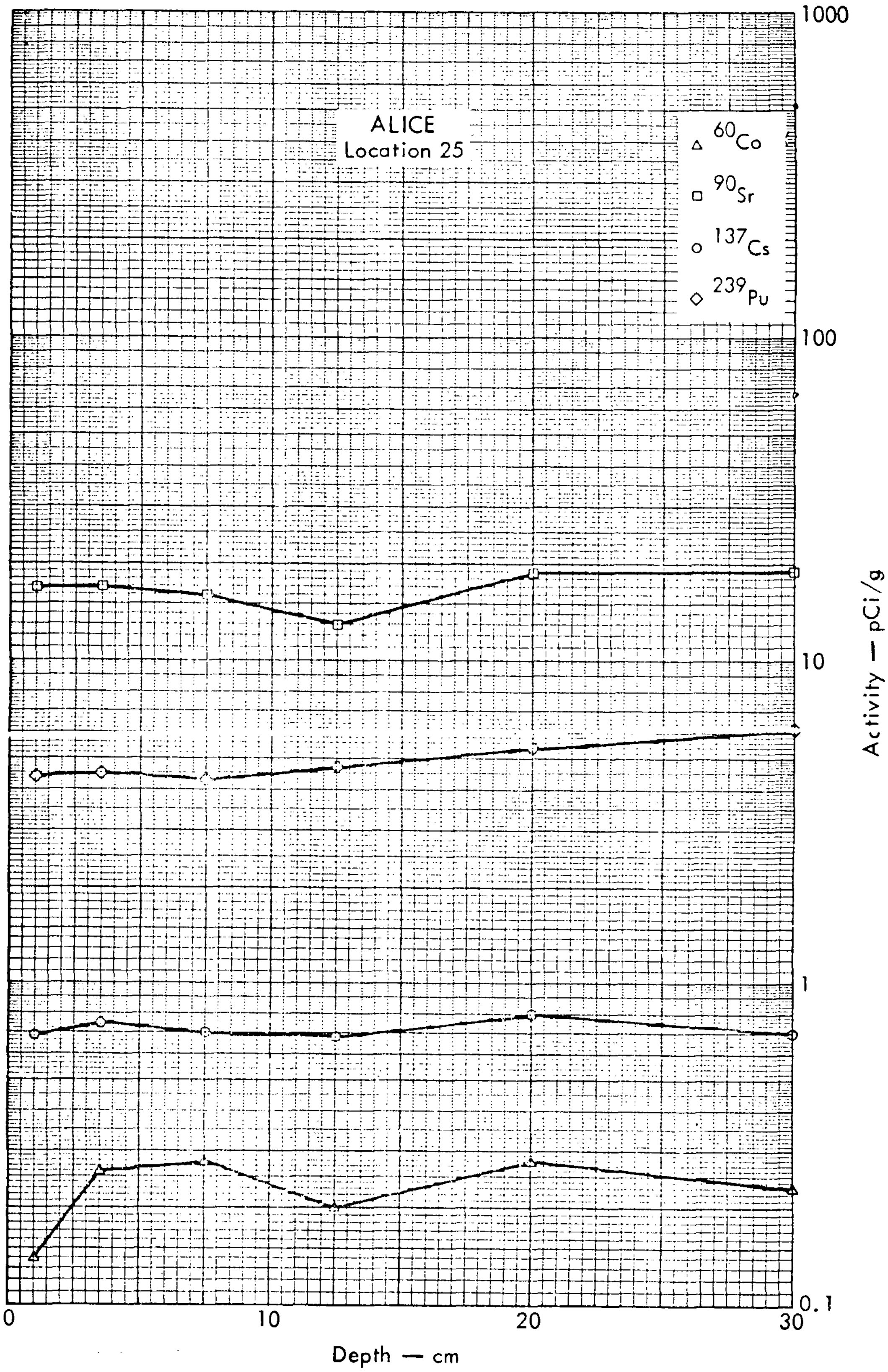



Fig. 150. Activities of selected radionuclides as a function of soil depth.

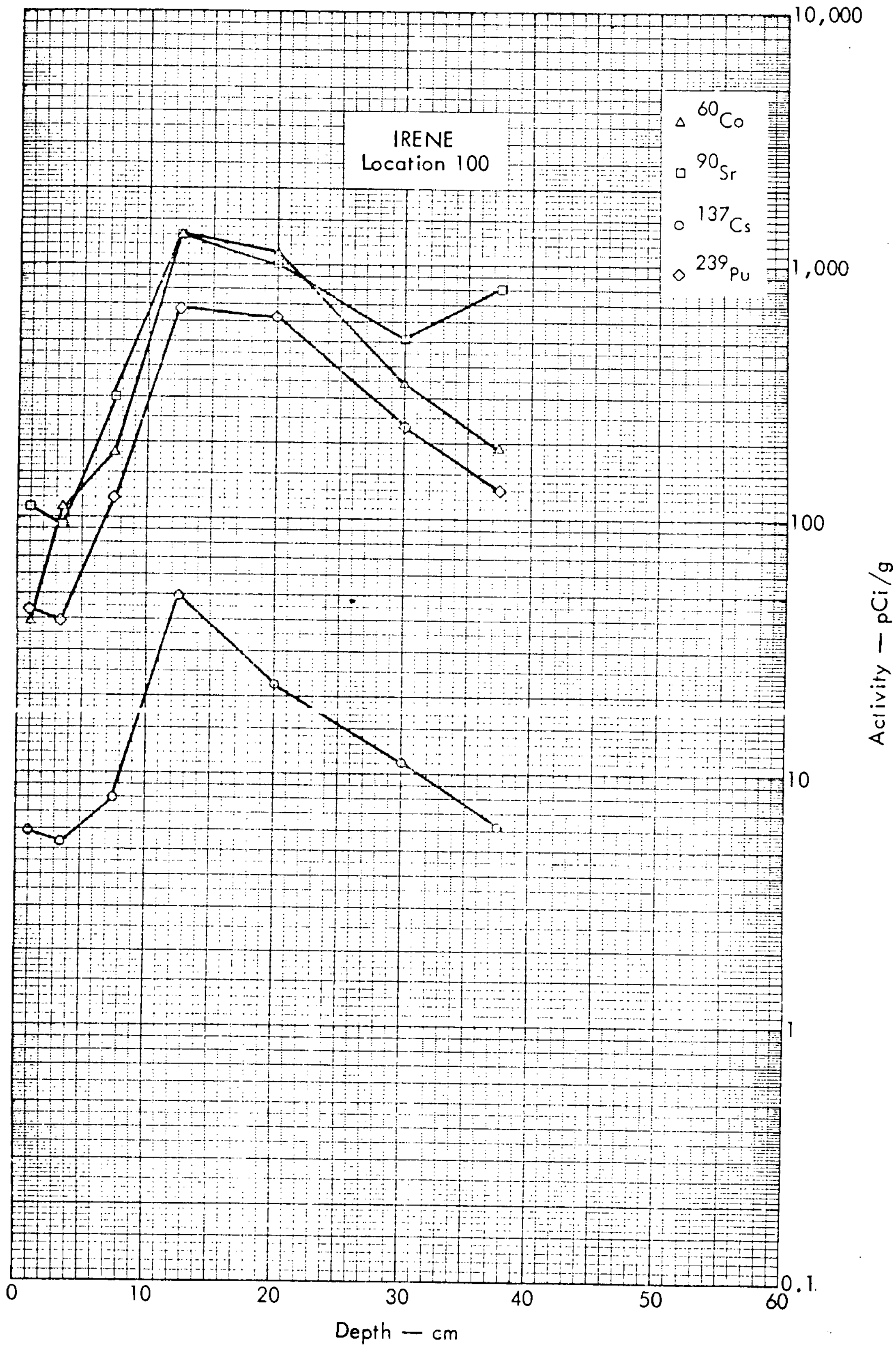



Fig. 151. Activities of selected radionuclides as a function of soil depth.

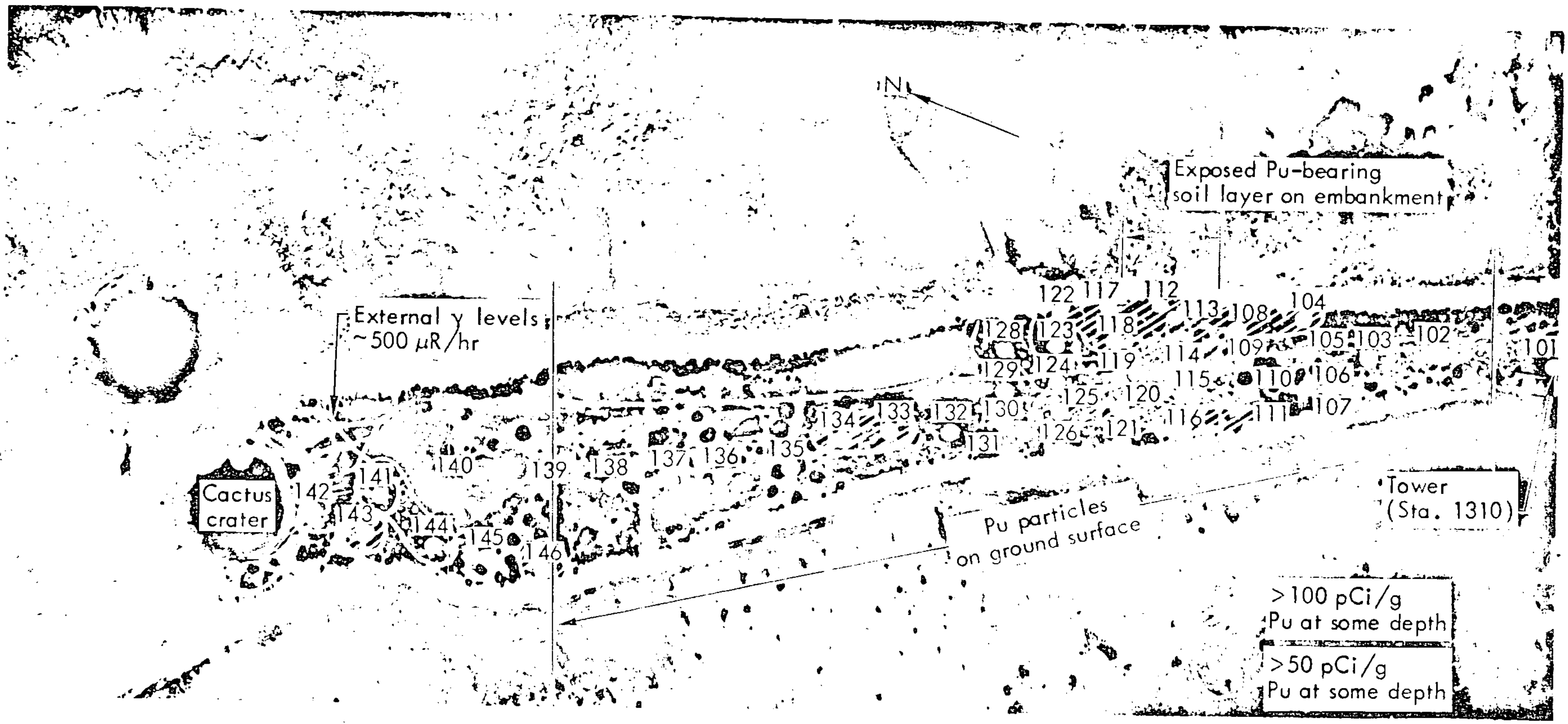



Fig. 152. Soil-profile locations which were sampled to 150-cm depths, YVONNE.

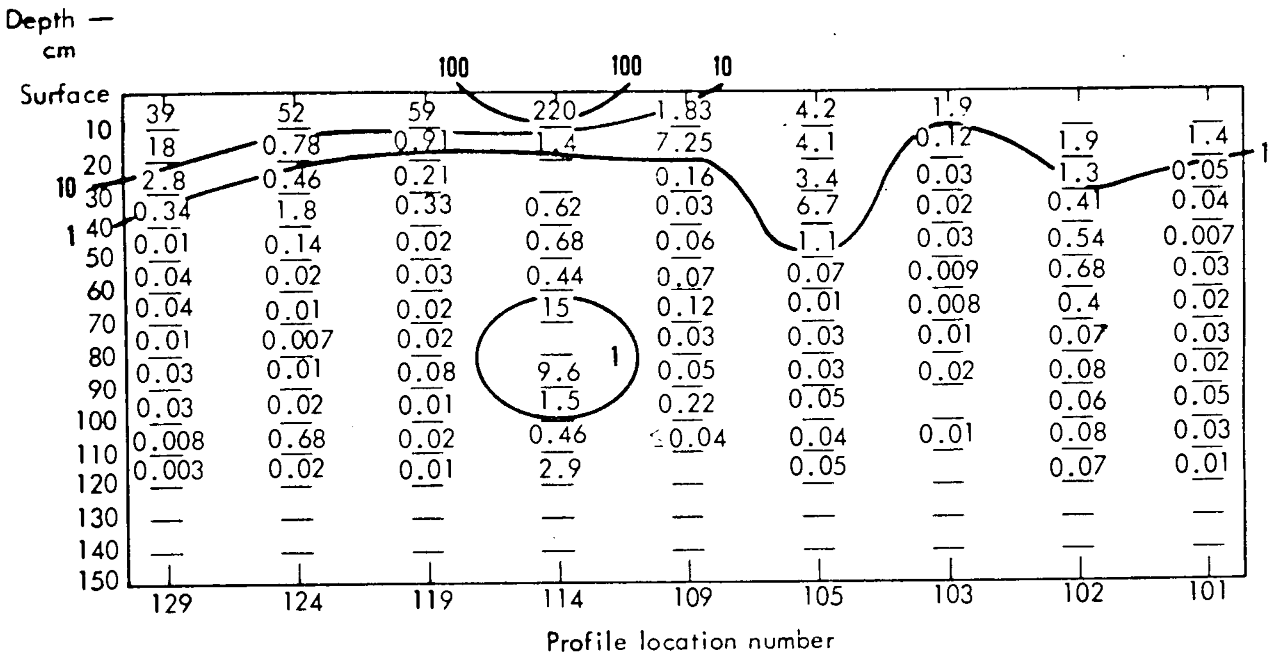


Fig. 153. Plutonium profile data, Locations 101-103, 105, 109, 114, 119, 124, and 129, YVONNE.

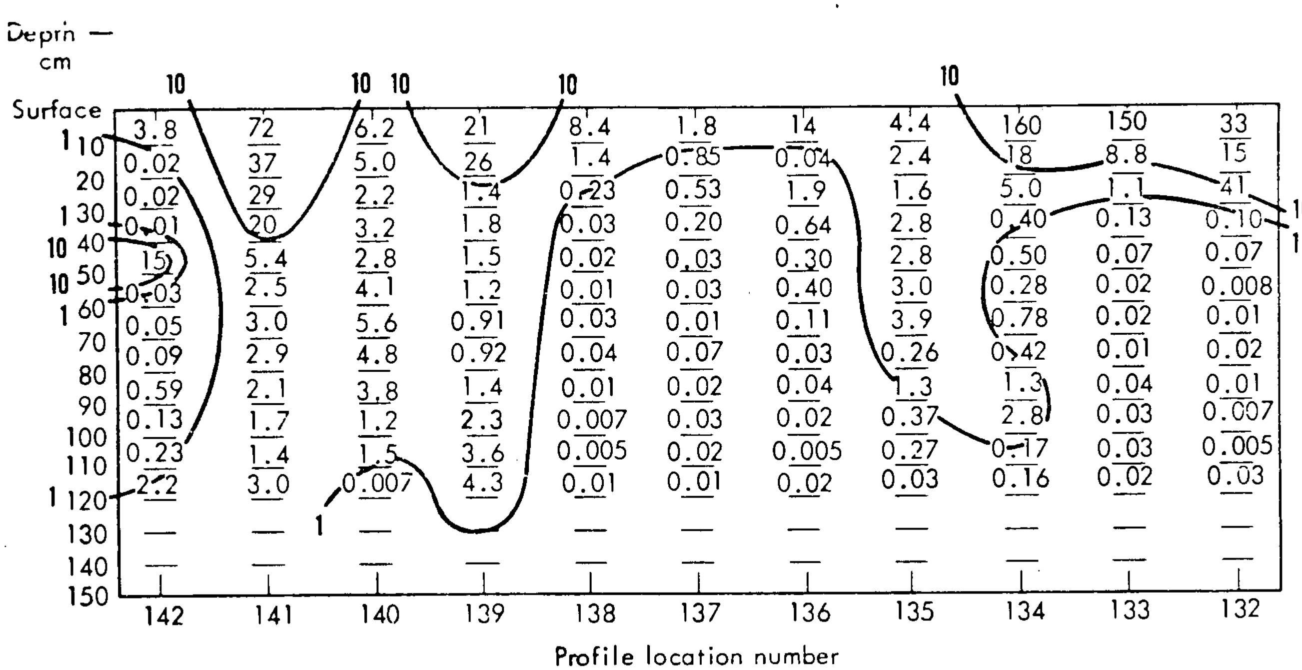


Fig. 154. Plutonium profile data, Locations 132-142, YVONNE.

(0.07 pCi/g). Comparison of these data with similar data obtained in 1964 indicates that, in addition to physical decay, $^{60}Co$ and $^{137}Cs$ are being lost from the lagoon with mean residence half-times of 3.3 and 4.1 yr, respectively, while $^{207}Bi$ appears to be decreasing at approximately its radioactive decay rate. $^{90}Sr$,

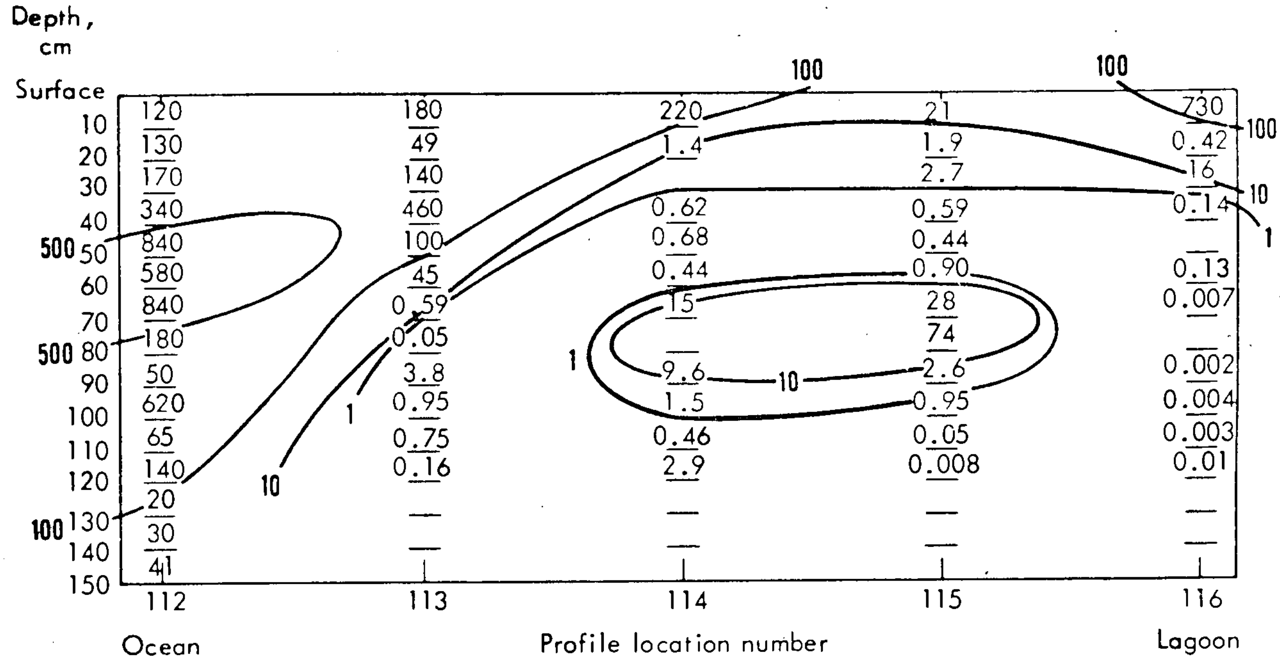


Fig. 155. Plutonium profile data, Locations 112-116, YVONNE.

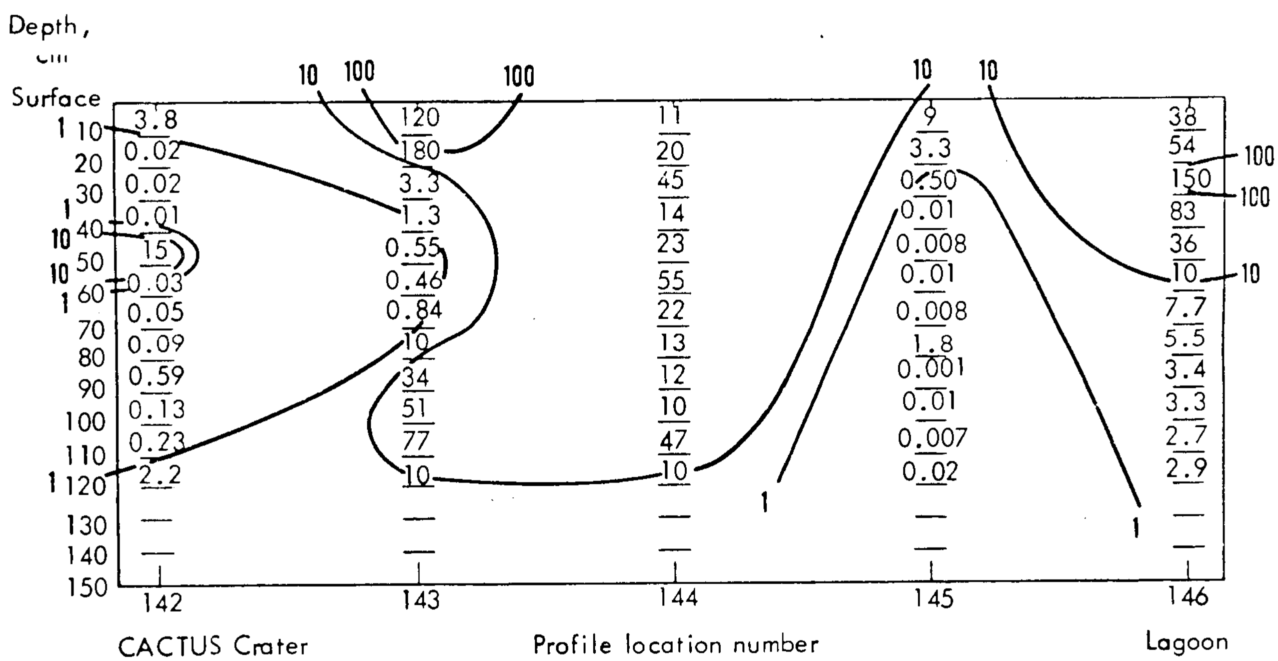


Fig. 156. Plutonium profile data, Locations 142-146, YVONNE.

$^{239,240}Pu$, $^{155}Eu$, and $^{241}Am$ were not reported in 1964.

Of the more than 700 species of fish at Enewetak Atoll, the species selected for this survey were chosen for one or more of the following reasons: (1) They are commonly eaten by the Marshallese; (2) they are relatively abundant at most of the

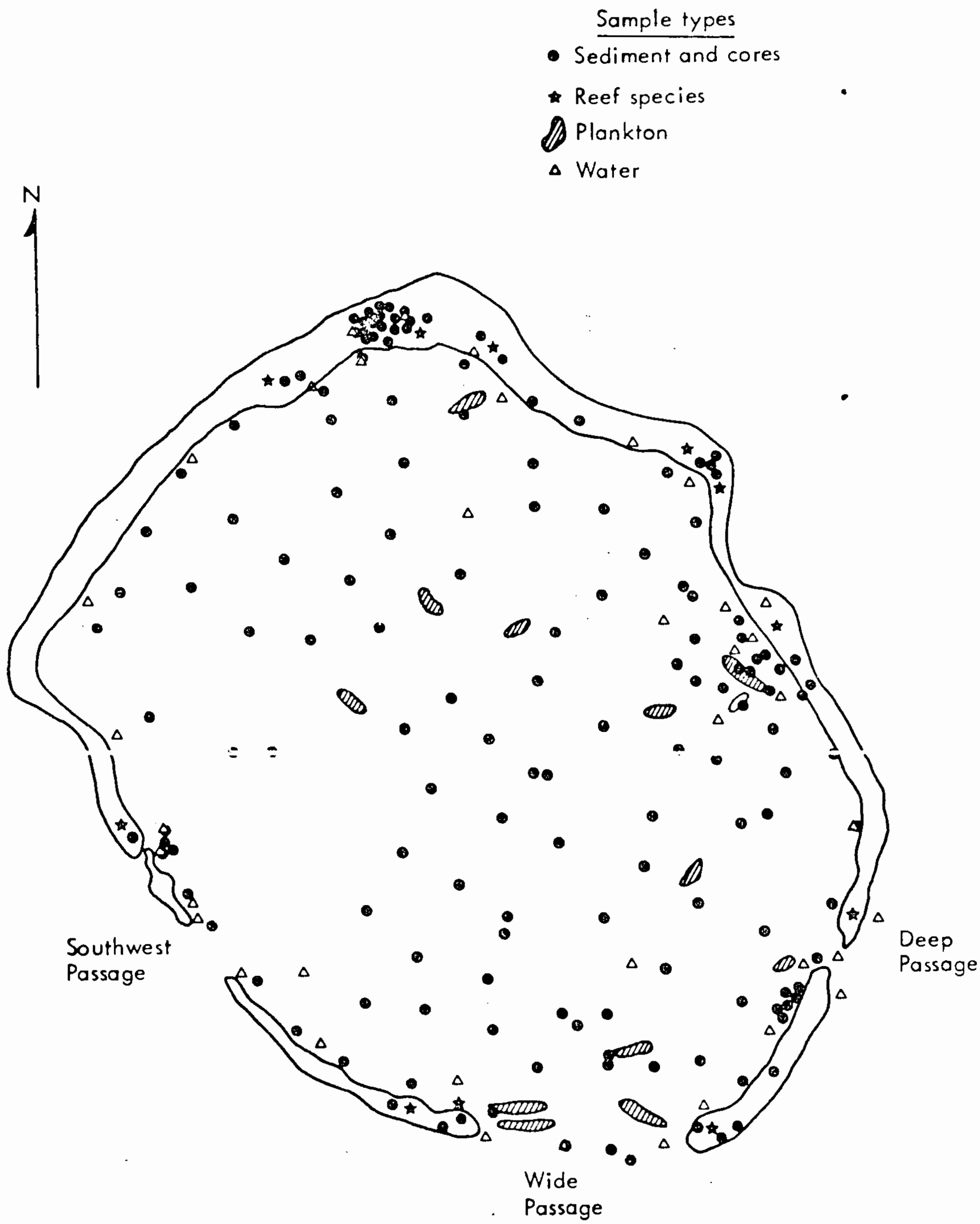



Fig. 157. Enewetak marine program sampling locations.

collection sites; (3) they are representative of a feeding habit; or (4) there is previous relevant radiometric information about the species. The species of reef fishes selected as being representative of feeding habits include the mullet (a plankton and detritus feeder), convict surgeon (a grazing herbivore), goatfish (a bottom-feeding carnivore), and parrotfish (a coral eater). The tunas, jacks, and dolphins – pelagic fish – and the snappers and groupers – benthic fish – which were also

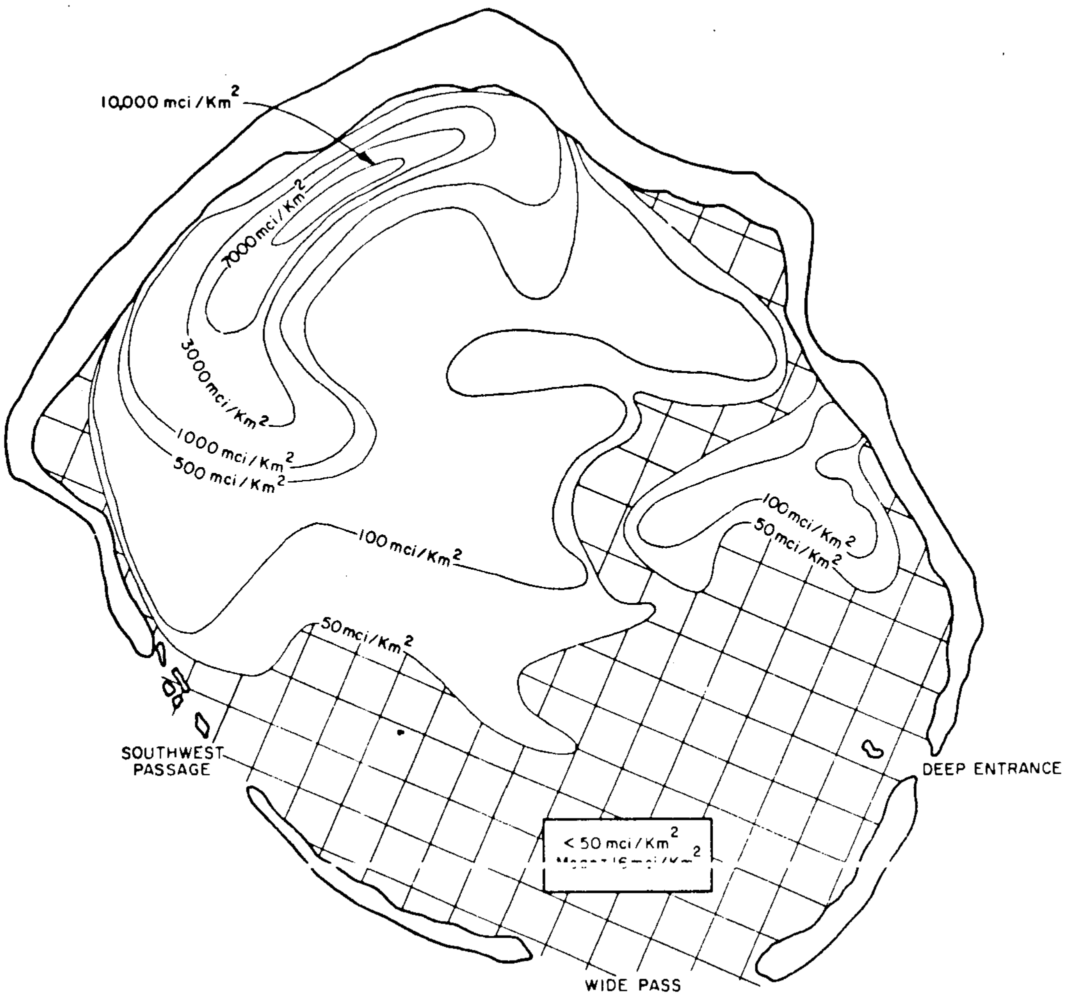



Fig. 158. Activity levels of $^{90}Sr$ deposited in the sediments of Enewetak Lagoon.

collected are carnivores of high order in the food chain leading to man.

The number and kind of marine organisms collected at near-shore sites at Enewetak Atoll and at Kwajalein Atoll, where "control" samples were taken, are shown in Table 218. Similar information for the carnivorous fish is given in Table 219.

$^{40}K$, $^{55}Fe$, and $^{60}Co$ were the predominant radioactive nuclides found in all fish, although $^{65}Zn$, $^{90}Sr$, $^{101}Rh$, $^{102m}Rh$, $^{108m}Ag$, $^{125}Sb$, $^{137}Cs$, $^{152}Eu$, $^{155}Eu$, $^{207}Bi$, $^{239,240}Pu$, and $^{241}Am$ were also present in some or all samples.

Table 217. Concentration of $^{137}Cs$ and $^{239}Pu$ in comparative, surface water samples.

| Location | Concentration, fCi/liter | |
|---|---|---|
| | $^{137}Cs$ | $^{239}Pu$ |
| Enewetak Lagoon | | |
| SE quadrant | 226 | 9.1 |
| NE quadrant | 334 | 42.6 |
| NW quadrant | 579 | 33.4 |
| SW quadrant | 332 | 21.6 |
| Ocean, east of Enewetak Atoll | 89 | 0.3 |
| Lake Michigan (1971) | 88 | 1.1 |
| Humboldt Bay, Calif. (1973) | 300 | |
| 14°N 180°W (1972) | 143 | 0.44 |
| 12°N 170°E (1972) | 170 | 0.35 |
| Windscale vicinity (1969) | 105,000 | |
| Mean surface, Atlantic 0-31°N (1968) | | 0.7 |

Table 218. Number of organisms collected at Enewetak Atoll and Kwajalein Atoll near-shore sites, October to December 1972.

| Collection site | Organism | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mullet | Goatfish | Convict surgeon | Parrot-fish | Other reef fish | Tridacna | Sea cucumber[a] | Other inverte-brates | Approx total |
| Enewetak Atoll | | | | | | | | | |
| GLENN-HENRY | ~25 | 11 | ~50 | 2 | 10 | 6 | 4 | 6[b] | 114 |
| LEROY | ~50 | 9 | 34 | 3 | 1 | 1 | 0 | ~10[c] | 108 |
| FRED | 0 | ~20 | ~50 | 9 | 7 | 3 | 2 | | 91 |
| DAVID | 0 | 25 | ~50 | 12 | 2 | 4 | 1 | | 94 |
| BELLE | ~50 | 3 | 30 | 1 | 3 | 10 | 0 | | 97 |
| IRENE | 2 | 3 | 12 | 0 | 8 | 0 | 0 | | 25 |
| JANET | ~50 | 3 | ~40 | 1 | 0 | 4 | 0 | | 98 |
| TILDA-URSULA | ~35 | 11 | ~50 | 2 | 3 | 3 | 3 | | 107 |
| YVONNE | 10 | ~15 | ~55 | 10 | 3 | 0 | 3 | 9[d] | 105 |
| Kwajalein Atoll | – | – | ~30 | 1 | 5 | 5 | | | 41 |
| Approximate Total | ~220 | ~100 | ~400 | 41 | 42 | 36 | 13 | 25 | 870 |

[a] The number given is the number of collections from a given site.

[b] Pencil urchins.

[c] Top snails.

[d] Spiny lobster.

Table 219. Number of carnivorous fish collected from the Enewetak and Kwajalein off-shore lagoon sites, October to December 1972.

| Collection site | Yellowfin tuna | Organism | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Skipjack | Mackerel | Dolphin | Snapper | Grouper | Ulua | |
| Enewetak | 2 | 9 | 3 | 2 | 8 | 8 | 8 | 40 |
| Kwajalein | 3 | 1 | | | | 2 | | 6 |
| Total | 5 | 10 | 3 | 2 | 8 | 10 | 8 | 46 |

Figures 159-161 show the average concentrations of predominant radionuclides found in convict surgeon samples taken at each of the collection sites around the lagoon. Similar data were obtained from the mullet, goatfish, and parrotfish samples.

Average radionuclide content of light muscle, dark muscle, and liver of skipjack collected in Enewetak lagoon are shown in Fig. 162. In general, $^{55}$Fe levels in the large pelagic fish were higher than levels found in other fish types, while other nuclides were present at levels comparable to or lower than those found in the reef fish.

Of the samples collected at Kwajalein, $^{40}$K was present at normal background

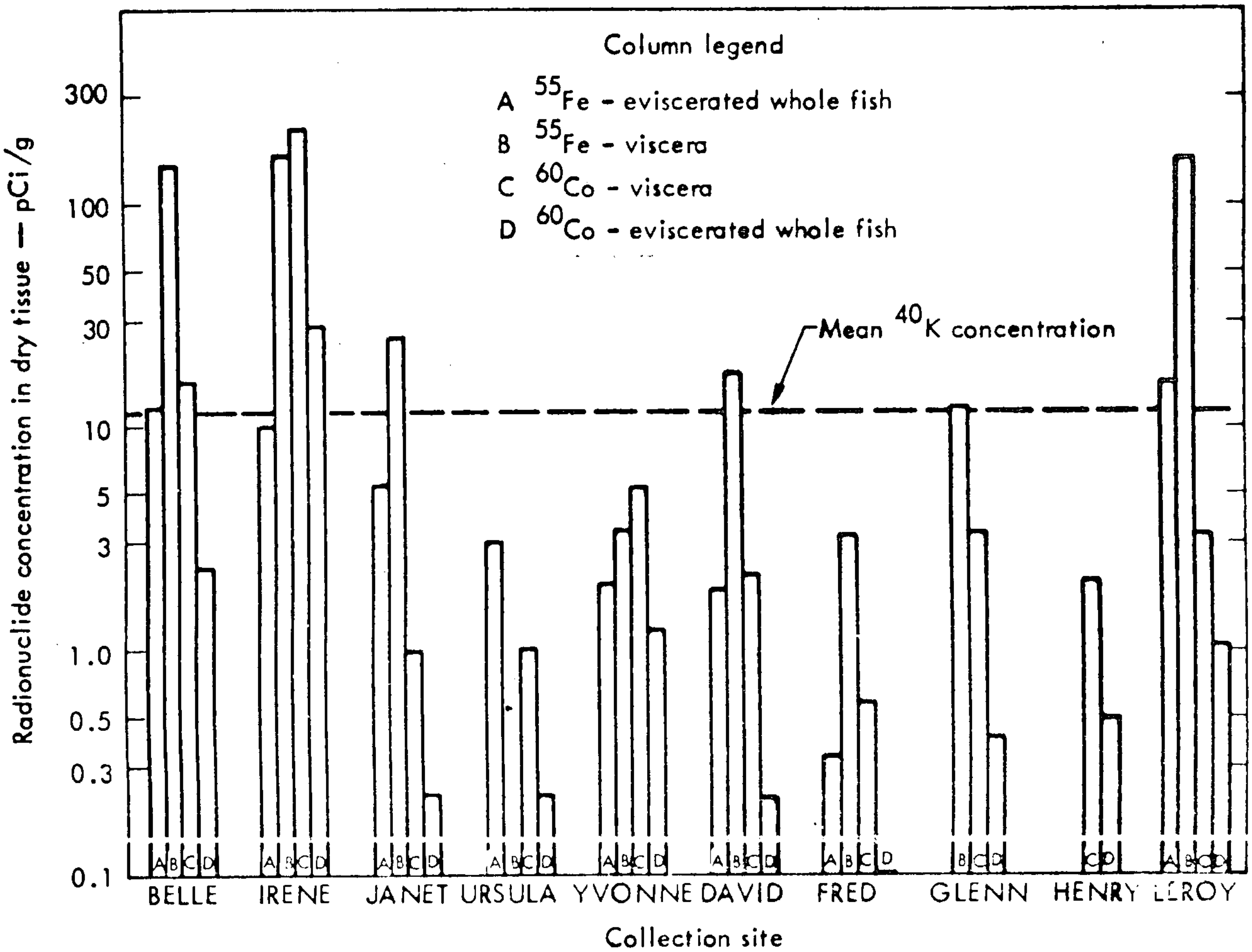



Fig. 159. Average $^{40}$K, $^{55}$Fe, $^{60}$Co concentration in convict surgeon from Enewetak Atoll, October to December, 1972. The $^{40}$K value is the mean for all convict surgeon samples.

Table 220. Comparison of $^{60}$Co and $^{207}$Bi in the viscera of convict surgeon collected in 1964 and 1972.

| Island | $^{60}$Co in pCi/g, dry | | | $^{207}$Bi in pCi/g, dry | | |
|---|---|---|---|---|---|---|
| | 1964 | 1972 | Fraction remaining | 1964 | 1972 | Fraction remaining |
| BELLE | 120 | 16 | 0.13 | 8.0 | 2.0 | 0.25 |
| JANET | 8.3 | 0.96 | 0.12 | 1.2 | 0.2 | 0.17 |
| GLENN | 19 | 3.3 | 0.17 | 2.6 | 0.7 | 0.27 |
| LEROY | 56 | 3.4 | 0.06 | 5.2 | 3.1 | 0.59 |
| YVONNE | 64 | 5.2 | 0.08 | – | – | – |
| Average | | | 0.11 | | | 0.32 |

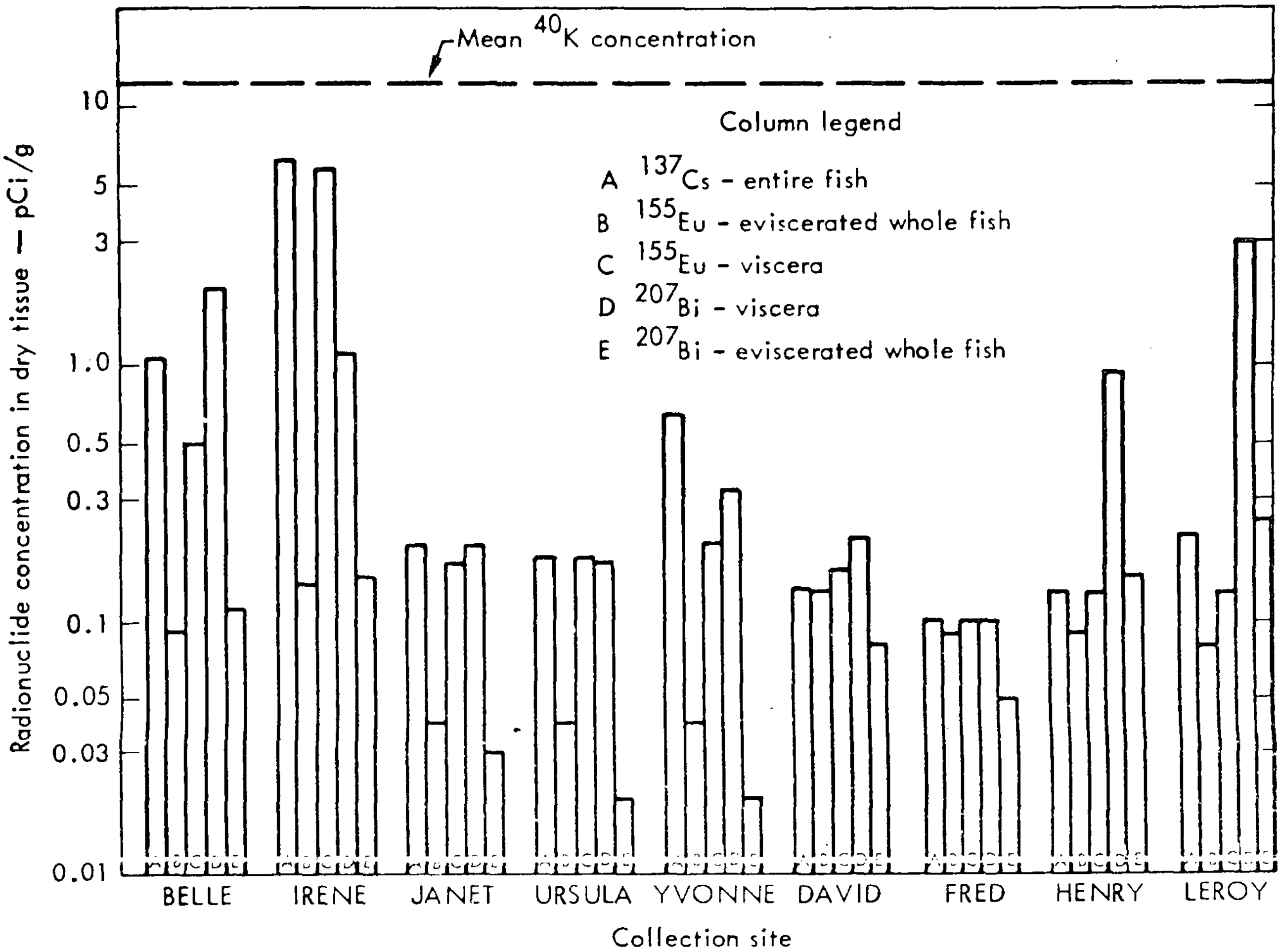



Fig. 160. Average $^{137}$Cs, $^{155}$Eu, and $^{207}$Bi concentration in convict surgeon from Enewetak Atoll, October to December, 1972. The $^{40}$K value is the mean for all convict surgeon samples.

levels (av 15 pCi/g). No $^{60}$Co, $^{207}$Bi, or $^{155}$Eu were observed, but $^{55}$Fe, $^{137}$Cs, $^{90}$Sr, and $^{239,240}$Pu were found in some or all of the samples, usually at levels comparable to the lower values found at Enewetak.

As with the plankton, comparison of data obtained from this survey with similar data from samples taken in 1964 indicates that, for some nuclides at least, there are processes operating to reduce concentrations in the lagoon faster than is expected from radioactive decay alone. Table 220, for example, presents a comparison of $^{60}$Co and $^{207}$Bi data for the two collection periods. The effective half-life of 2.7 yr for $^{60}$Co (radioactive decay half-life 5.24 yr) and 5.1 yr for $^{207}$Bi (radioactive decay half-life 30 yr) implies an effective half-life in the ecosystem for both isotopes of about 5-6 yr.

Of the marine invertebrates present at Enewetak, tridacna clams, sea cucumbers, spiny lobster, and top snails were collected and analyzed. In the tridacna, $^{60}$Co was the most abundant radioisotope found, and it was present in higher amounts in the kidney than in the viscera,

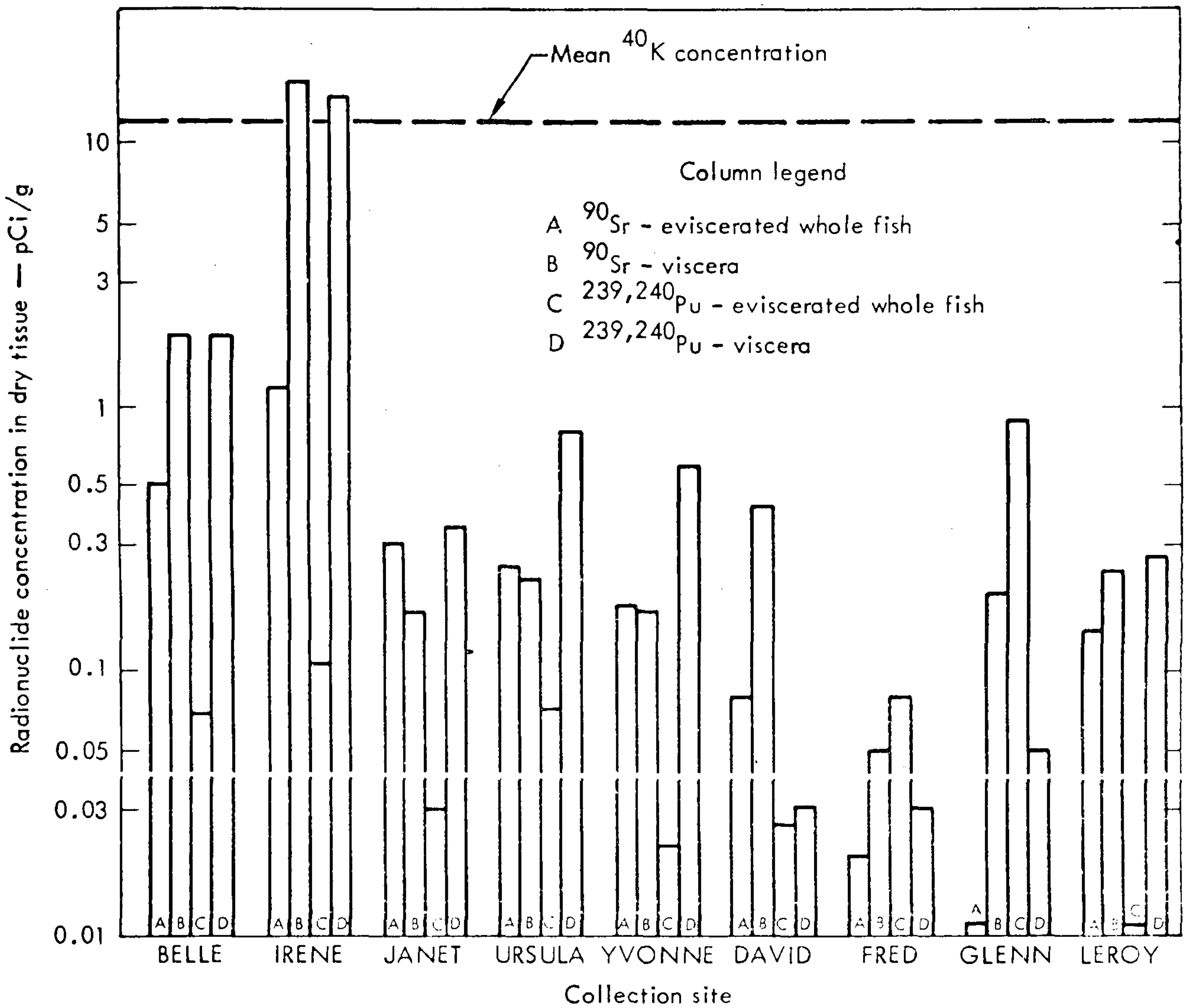



Fig. 161. Average $^{90}Sr$ and $^{239,240}Pu$ concentration in convict surgeon from Enewetak Atoll, October to December, 1972. The $^{40}K$ value is the mean for all convict surgeon samples.

mantle, or muscle. Figures 163-165 present the average radionuclide concentrations of these tissues for the Enewetak locations at which tridacna samples were taken.

Radionuclide distributions for sea cucumbers, spiny lobsters, and top snails were similar to those found for the tridacna, except that high concentrations were not observed in the kidney.

## Radioactivity Levels in Enewetak Terrestrial Biota

The terrestrial biota survey had as its objective the collection and analysis of all available terrestrial vegetation and animal species which could be used as a basis for estimating population doses through dietary pathways. Not all vegetable and animal components of the Enewetakese diet are currently available

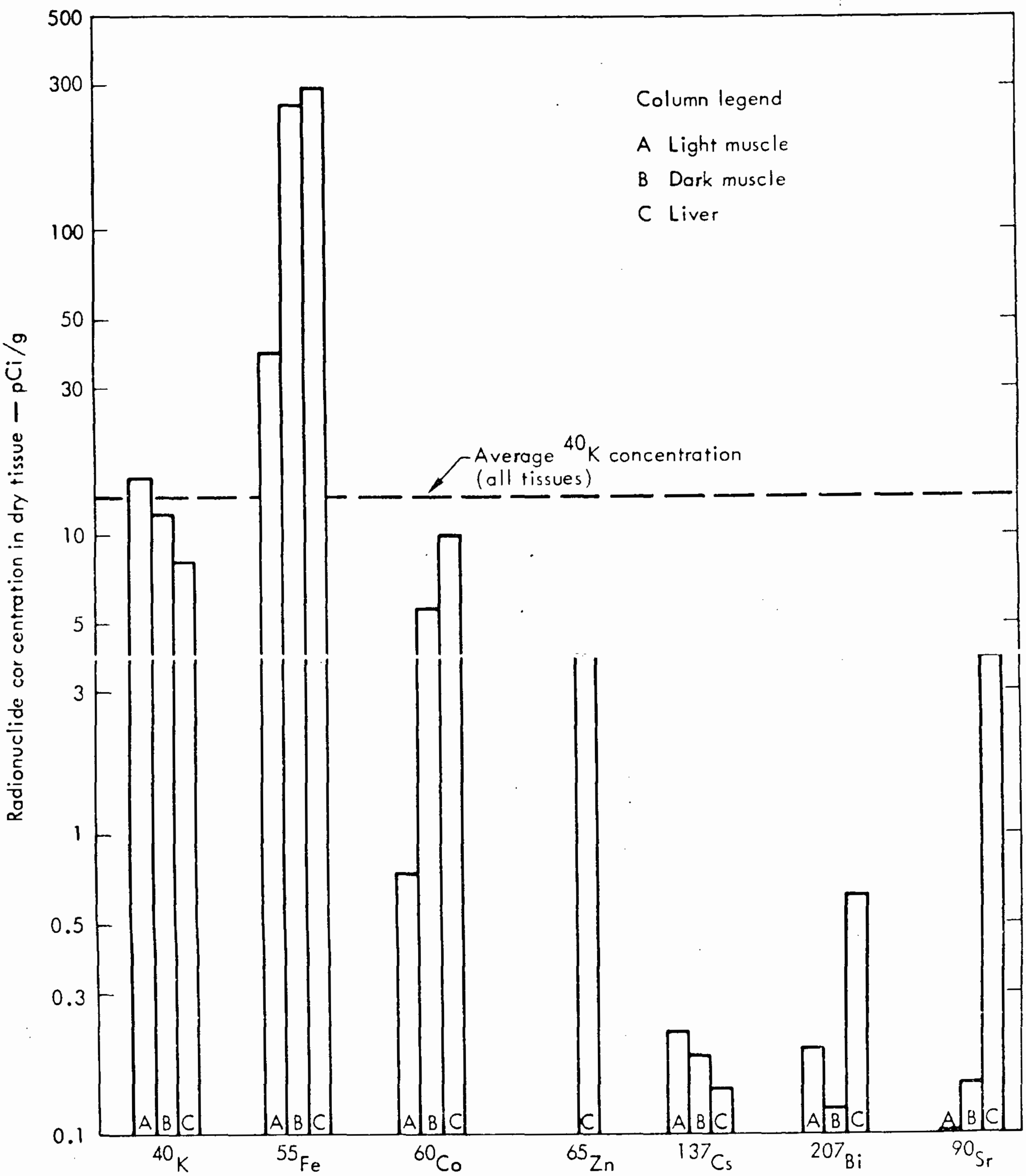



Fig. 162. Average concentration of seven radionuclides in the light muscle (A), dark muscle (B), and liver (C) of three skipjack from Enewetak Atoll, October to December, 1972.

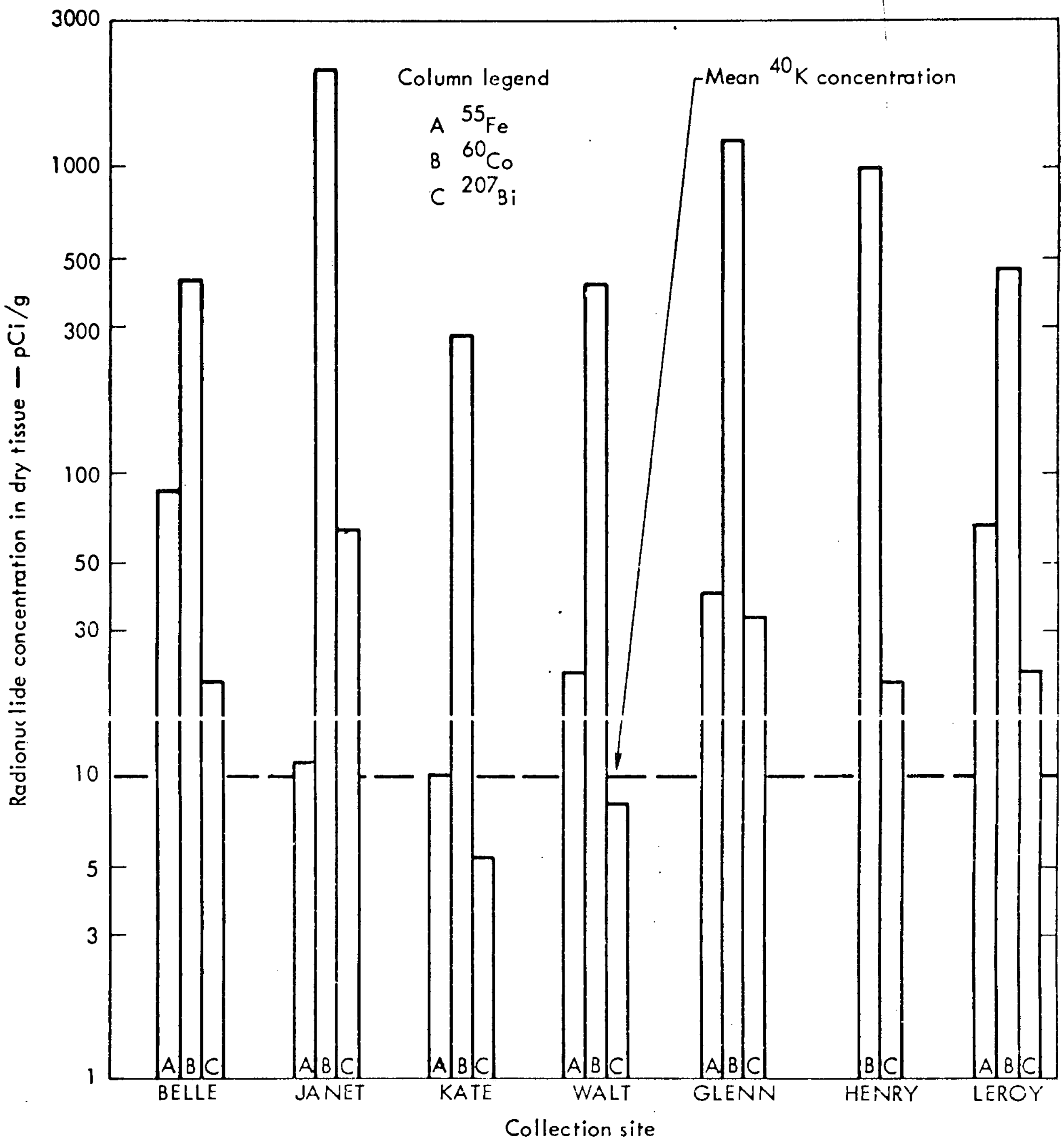



Fig. 163. Average $^{40}$K, $^{55}$Fe, $^{60}$Co, and $^{207}$Bi concentration in the kidney of Tridacna clams collected at Enewetak Atoll, October to December, 1972. The $^{40}$K value is the mean of all Tridacna samples.

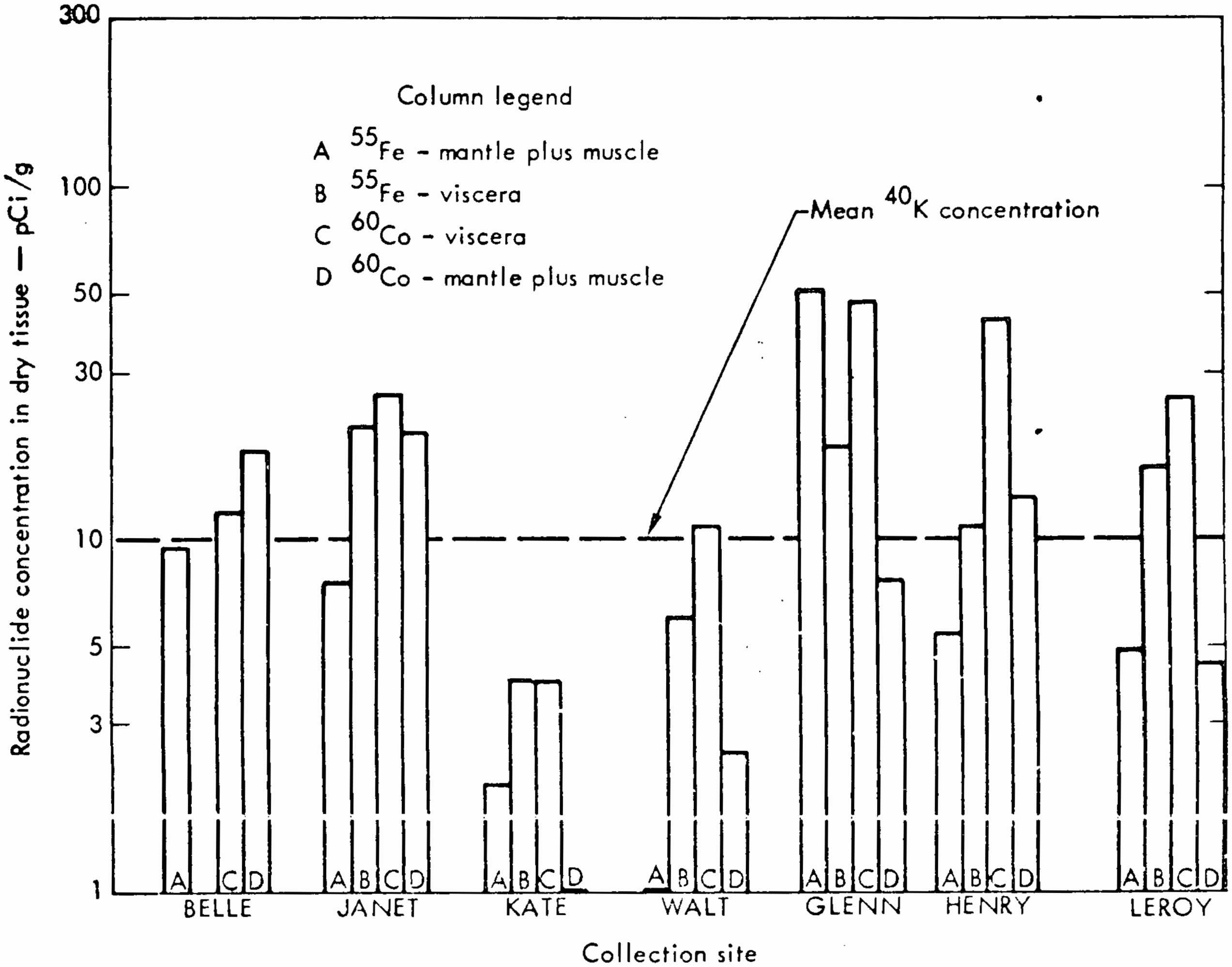



Fig. 164. Average $^{40}K$, $^{55}Fe$, and $^{60}Co$ concentration in the viscera, mantle, and muscle of Tridacna clams collected at Enewetak Atoll, October to December, 1972. The $^{40}K$ value is the mean of all Tridacna samples.

on the Atoll; of those that are, not all are available on every island.

A total of 1103 specimens were collected in the field as part of the terrestrial biota survey, distributed as follows:

| | |
|---|---|
| Soils | 42 |
| Plants | 208 |
| Birds | 116 |
| Eggs | 217 |
| Rats | 249 |
| Crabs | 271 |
| Total | 1103 |

The geographical distribution of specimen collection sites is shown in Fig. 166 and the types of edible sample collected on each island are listed in Table 221.

$^{90}Sr$ and $^{137}Cs$ were observed in essentially all of the plant, rat, and crab samples and in many of the bird and egg samples. $^{55}Fe$, $^{60}Co$, and $^{239,240}Pu$ were observed less frequently, and isotopes such as $^{207}Bi$, $^{152}Eu$, and $^{151}Sm$ were observed occasionally.

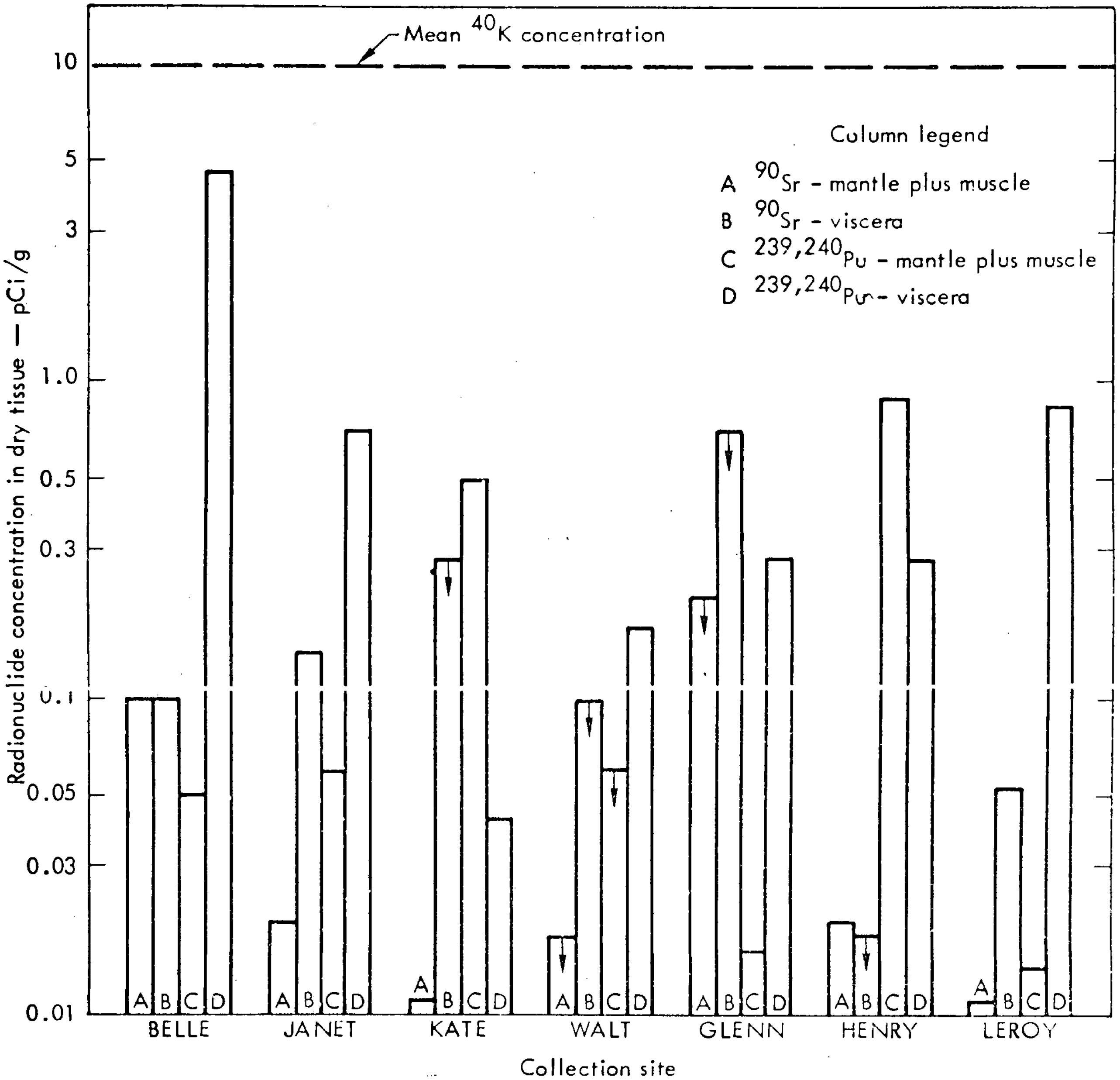



Fig. 165. Average $^{90}Sr$ and $^{239,240}Pu$ concentration in the viscera, mantle, and muscle of Tridacna clams collected at Enewetak Atoll, October to December, 1972. The $^{40}K$ value is the mean for all Tridacna samples.

Table 221. Terrestrial biota survey. Edible plants and edible animals sampled.

| Island No. | Island | Coconut meat | Coconut milk | Pandanus fruit | Pandanus leaves[a] | Tacca corm | Birds | Bird eggs | Coconut crab | Rat[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | ALICE | | | | | | x | | | |
| 2. | BELLE | | | x | x | | | | | |
| 4. | DAISY | x | x | | | | | | | |
| 9. | IRENE | x | x | | | | x | x | | |
| 10. | JANET | x | x | | x | | x | x | | x |
| 12. | LUCY | | | | | | x | | | |
| 14. | MARY | x | x | | | | x | | | |
| 15. | NANCY | x | x | | | | | | | |
| 16. | OLIVE | | | | | | x | | | |
| 17. | PEARL | | | | | | x | | | x |
| 19. | SALLY | | | | x | | x | x | | x |
| 20. | TILDA | | | | x | | | | | |
| 21. | URSULA | | | | | | | | | x |
| 22. | VERA | x | | | x | | | | | |
| 24. | YVONNE | x | | | | | x | x | | x |
| 29. | VAN | | | | | | x | | | |
| 30. | ALVIN | | | | | | x | | | |
| 31. | BRUCE | x | | | | | x | | x | |
| 32. | CLYDE | | | | | | x | x | | x |
| 33. | DAVID | x | x | | x | x | x | | | x |
| 34. | REX | | | | | | x | x | | |
| 35. | ELMER | x | | | x | | | | | x |
| 37. | FRED | x | | | x | | | | | |
| 38. | GLENN | x | | | | | | | x | x |
| 39. | HENRY | x | | | | | | x | | |
| 40. | IRWIN | x | | | | | x | x | | |
| 41. | JAMES | | | | | | | | x | |
| 42. | KEITH | x | | x | x | | x | | x | |
| 43. | LEROY | x | | | x | | x | | x | |

[a]Pandanus leaves are not eaten but serve as indicators for pandanus fruit.

[b]Rats are not eaten but serve as indicators for poultry and swine.

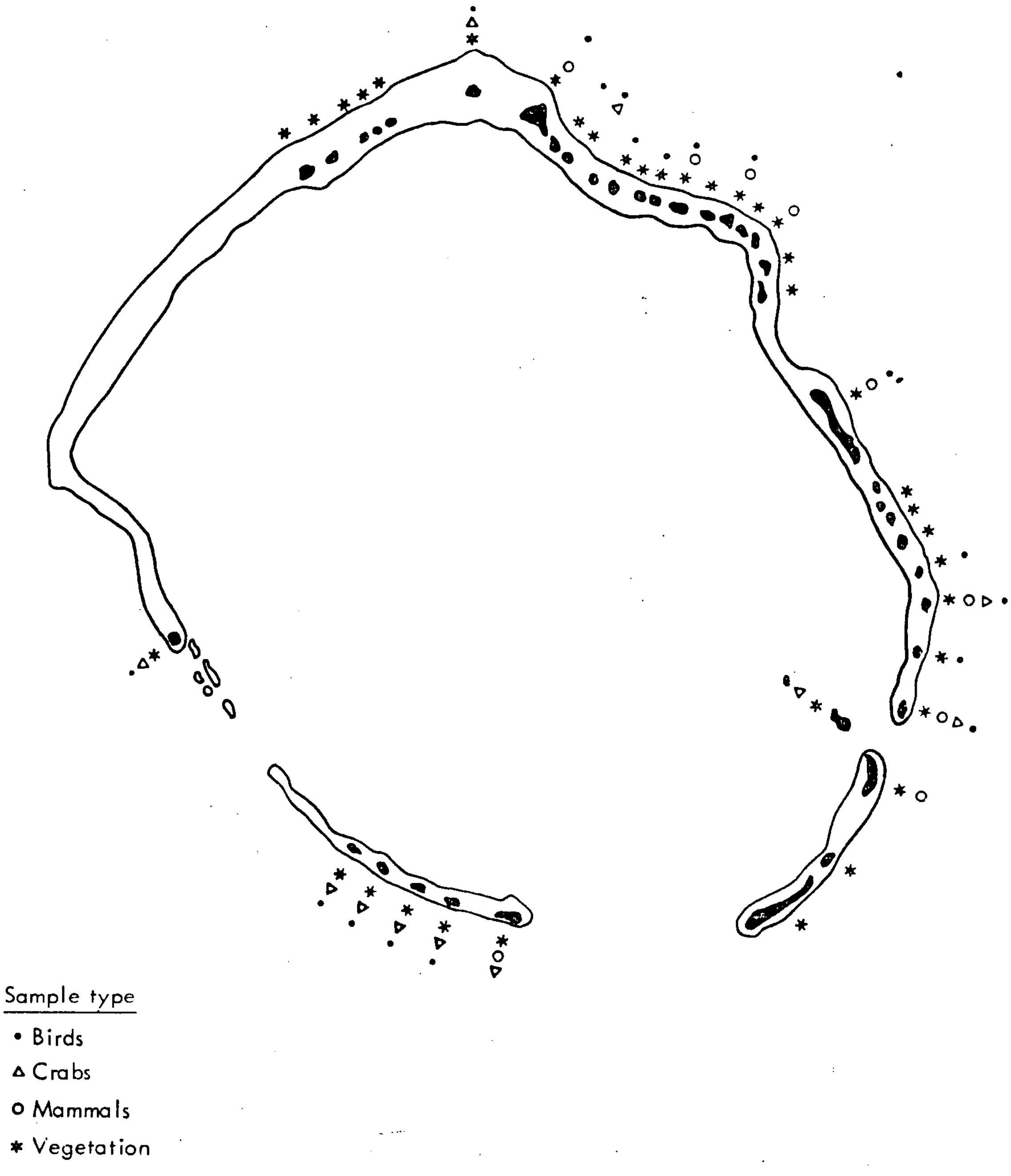



Fig. 166. Terrestrial biota program sampling locations.

For a given sample type, the radionuclide content generally corresponded with levels of soil contamination found on the Atoll. Data for $^{90}$Sr and $^{137}$Cs in coconut meat versus island sampling location, for example, are plotted in Fig. 167 and it is apparent that concentrations are significantly higher on the northern islands (islands 1-24) than on those on the southern part of the Atoll.

Since the main vegetation components in the human diet (coconut, pandanus,

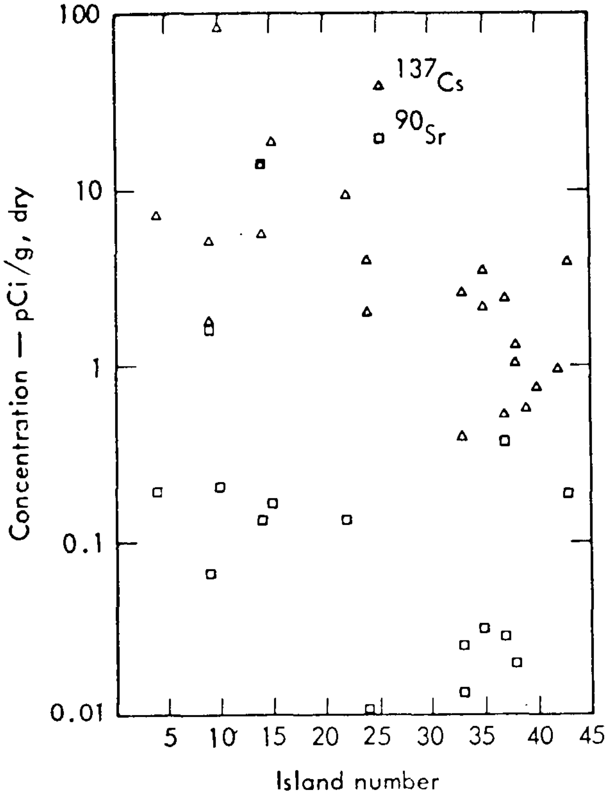



Fig. 167. Concentrations of $^{90}$Sr and $^{137}$Cs in coconut meat.

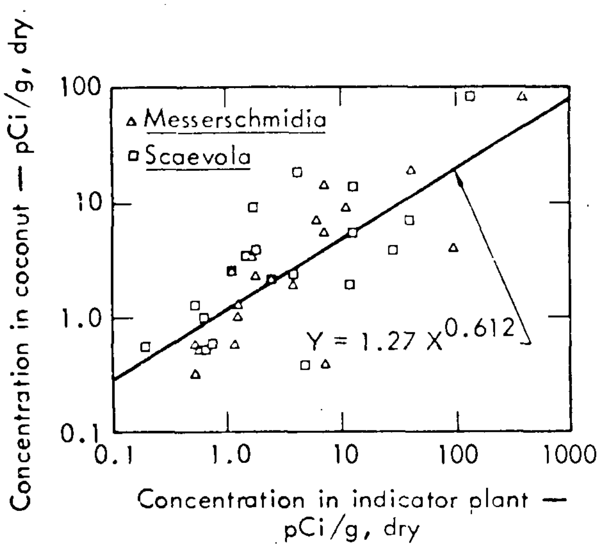



Fig. 168. Statistical correlation between $^{137}$Cs in coconut meat and $^{137}$Cs in Messerchmidia and Scaevola.

and breadfruit) are not growing now on all of the northern islands, the ubiquitous Messerschmidia and Scaevola were sampled and analyzed extensively with the intent that they be used as "indicator species" for estimating doses from the edible plants should they become available. The correspondence between $^{137}$Cs activity in coconut meat and Messerschmidia and/or Scaevola from the same location is shown in Fig. 168.

To increase accuracy, dose estimates to the human population through the terrestrial vegetation pathway should be based on the geographical distribution of radionuclides. In order to do this, however, a correlation between nuclide content of vegetation and nuclide content of soil must be established. As an example of the correlations that have been developed, data for $^{137}$Cs in Messerschmidia and Scaevola vs $^{137}$Cs in soil are shown in Fig. 169.

Similarly, data obtained from rats – the only mammals now found on the Atoll – were found to correlate with the vegetation radionuclide levels. For example, correlations for $^{137}$Cs in rat muscle vs Messerschmidia/Scaevola are shown in Fig. 170, and for $^{90}$Sr in rat bone vs Messerschmidia/Scaevola are shown in Fig. 171.

Three classes of data obtained from the terrestrial biota survey, therefore, have been used to estimate potential human doses through the terrestrial food pathway:

- Data obtained from the edible organisms where they were available.
- Data obtained from the correlation between edible plants – indicator

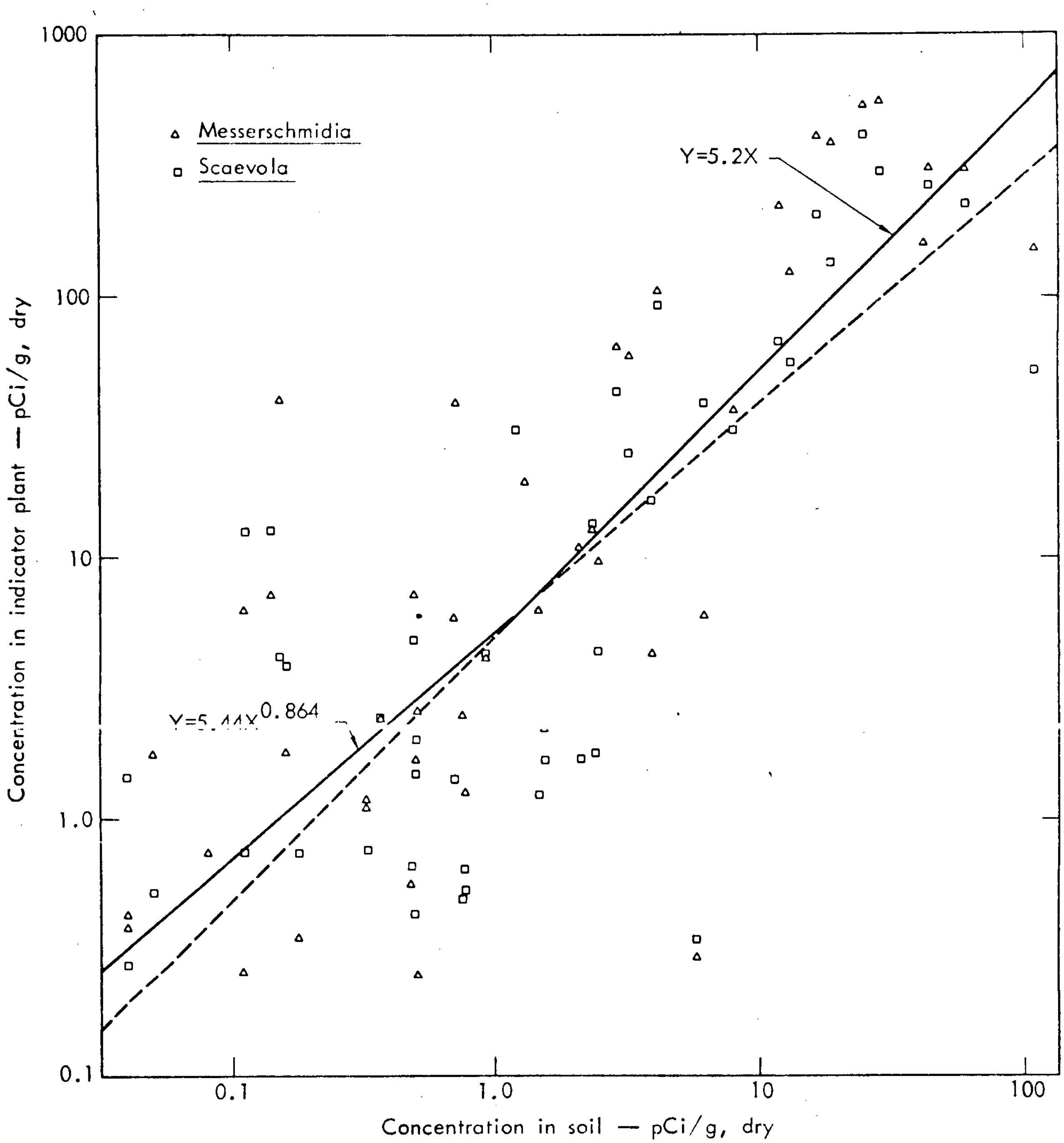



Fig. 169. Statistical correlation between $^{137}$Cs in Messerschmidia and Scaevola and $^{137}$Cs in soil.

plants – soil and applied to the plant component of the diet.

- Data obtained from the correlation between rats – indicator plants – soil and applied to the meat component of the diet.

Radioactivity Levels in Enewetak Air

A total of 32 samples of airborne Enewetak particulate debris have been analyzed to determine inhalation exposures likely to be encountered by residents of

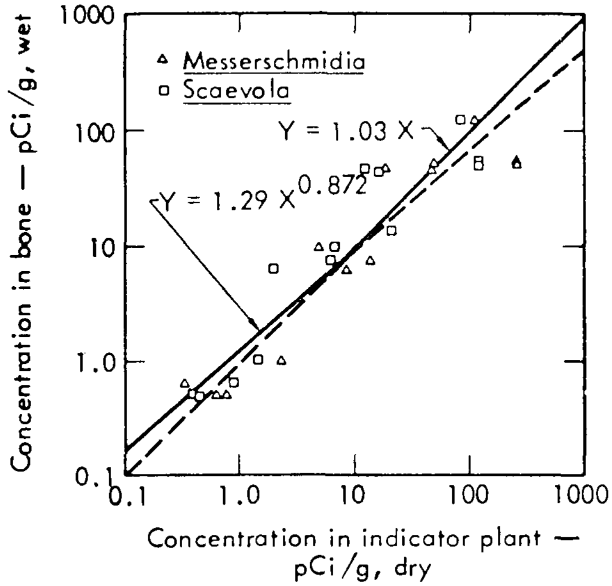



Fig. 170. Statistical correlation between $^{90}Sr$ in rat bone and $^{90}Sr$ in Messerschmidia and Scaevola.

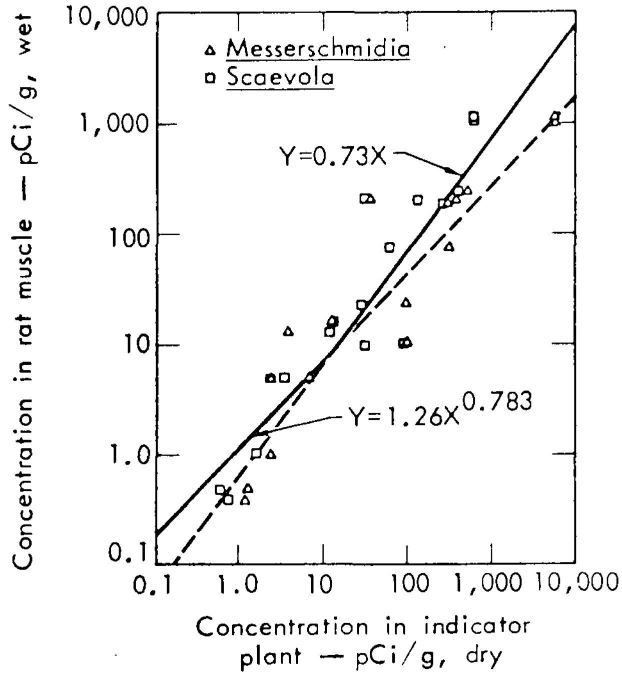



Fig. 171. Statistical correlation between $^{137}Cs$ in rat muscle and $^{137}Cs$ in Messerschmidia and Scaevola.

the Atoll. Samples were taken using the following three types of equipment:

- Ultra High-Volume Air Sampler (UHVS) – Used to sample large volumes of air in short time intervals. Typical samples were taken at a rate of 2000 $m^3$/hr for a continuous 24-hr period.
- Low-Volume Air Sampler (VCS) – Used to sample for extended periods. Typical samples were taken at a rate between 8 and 20 $m^3$/hr for a continuous 7-day period.
- Anderson Cascade Impactors (ACI) – Used to obtain data on the particle-size distribution of airborne radioactivity. These samplers operated at a throughput rate of 34 $m^3$/hr, sampled for 7- to 10-day periods, and separated each sample into the following particle-size ranges: 0.1-1.1, 1.1-2.0, 2.0-3.3, 3.3-7.0, and >7 μm.

Air samples were taken on FRED, DAVID, SALLY, JANET, and YVONNE, which are islands that include the full range of airborne activity levels likely to be found on the Atoll.

A number of radionuclides were detected in the surface air, including $^{7}Be$ (53 day), $^{40}K$ ($1.26 \times 10^9$ yr), $^{54}Mn$ (303 day), $^{95}Zr$ (65 day), $^{103}Ru$ (39.6 day), $^{106}Ru$ (1.0 yr), $^{125}Sb$ (2.7 yr), $^{137}Cs$ (30 yr), $^{144}Ce$ (285 day), $^{239}Pu$ ($2.4 \times 10^4$ yr), $^{238}Pu$ (86 yr), and $^{241}Am$ (458 yr). $^{7}Be$ and $^{40}K$ are naturally occurring activities. $^{54}Mn$, $^{95}Zr$, $^{103}Ru$, $^{106}Ru$, $^{125}Sb$, and $^{144}Ce$ are intermediate-life activation and fission products found in current worldwide fallout, but present in Enewetak soils in only very reduced quantities due to radioactive decay in the long interval since testing ended. Longer-life $^{137}Cs$,

Table 222. Comparison of radionuclides in surface air (fCi/m$^3$) on Enewetak, Livermore, California, and Balboa, Panama.

| Nuclide | YVONNE | Remainder of Enewetak Atoll | Livermore, Calif., 1972 | Balboa, Panama, 9°N 79°W, 1972-1973 |
|---|---|---|---|---|
| $^{7}Be$ | < 49-193 | < 6-116 | 90-250 | 43-143[c] |
| 54Mn | < 0.6-2.1 | < 0.14-4.0 | - | - |
| $^{95}Zr$ | < 0.4-0.4[a] | 0.03-0.3 | 0.005-0.4 | < 0.9-8.5 |
| $^{103}Ru$ | < 5.5-5.5[a] | NDET[b] | 0.29-3.4 | - |
| $^{125}Sb$ | < 0.27-0.27[a] | NDET | 0.04-0.23 | - |
| $^{106}Ru$ | < 0.9-2.6 | < 0.2-1.6 | 0.14-2.9 | - |
| $^{137}Cs$ | < 0.49-0.82 | < 0.04-2.5 | 0.63-3.2 | 0.09-1.7 |
| $^{144}Ce$ | < 2.5-3.7 | < 0.22-1.9 | 0.24-3.1 | 0.7-11.2 |
| $^{239,240}Pu$ | < 0.03-2.6 | < 0.001-0.025 | 0.01-0.05 | < 0.001-0.030 |
| $^{238}Pu$ | < 0.04-0.13 | < 0.0028-0.008 | 0.001-0.005 | < 0.001-0.003 |
| $^{241}Am$ | < 0.3-0.30[a] | NDET | NDET | NDET |

[a]Detected only one sample.
[b]Not detected.
[c]Oct.-Dec. 1972 range.

$^{238}Pu$, $^{239}Pu$, and $^{241}Am$ in air could be from either local resuspension or from worldwide fallout. A comparison of activity levels at Enewetak with those observed at Livermore, California, and Balboa, Panama is shown in Table 222. It appears that, with the exception of the single sample on which 5.5 fCi/m$^3$ of $^{103}Ru$ was observed, the only airborne radionuclides present at levels consistently higher than those at the other two locations were the Pu-Am species on YVONNE, a result not too surprising, considering the known soil contamination levels on that island.

Of the 32 air samples, four were taken in October 1972 before typhoon Olga struck, and the remainder were taken between November 28 and December 19, 1972. Wind speeds were almost always greater than 10 knots and often greater than 20 knots at all sampling locations. In addition, frequent light rain showers served to keep the ground surface damp. Table 223 presents climatological data which have been published for Enewetak and Kwajalein. It is apparent that December represents a fairly average month as far as total rainfall and rainfall frequency are concerned, while average windspeeds are higher than those observed most of the year.

## Radioactive Scrap and Buried Debris

Holmes and Narver, Inc., as part of the engineering survey they conducted

Table 223. Climatological data for Kwajalein and Enewetak.[a]

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Av | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percentage of total time at each wind-speed interval | | | | | | | | | | | | | |
| Wind speed, knots[b] | | | | | | | | | | | | | | |
| 0-3 | 1 | 1 | 1 | 0 | 1 | 1 | 6 | 10 | 16 | 9 | 3 | 1 | 4.2 | |
| 4-10 | 15 | 12 | 22 | 20 | 27 | 27 | 49 | 60 | 59 | 63 | 42 | 20 | 34.7 | |
| 11-21 | 68 | 80 | 70 | 75 | 69 | 70 | 44 | 29 | 24 | 28 | 53 | 70 | 56.7 | |
| 22-33 | 15 | 7 | 7 | 5 | 3 | 2 | 1 | 1 | 1 | 0 | 2 | 9 | 4.4 | |
| >33 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Prevailing wind direction and frequency[b] | NE 86% | NE 87% | NE 81% | NE 77% | NE 67% | NE 64% | E/NE 36% each | E 31% | NE 27% | NE 33% | NE 55% | NE 74% | -- -- | |
| Precipitation[c] | | | | | | | | | | | | | Yr | Yr. of record |
| Av. amount, in. | 1.02 | 1.84 | 1.86 | 1.28 | 4.57 | 3.37 | 6.45 | 6.81 | 6.24 | 9.09 | 6.30 | 2.63 | 51.46 | 30 |
| Greatest amount, in. | 1.95 | 10.21 | 7.33 | 3.86 | 8.38 | 7.03 | 15.35 | 14.41 | 13.17 | 18.07 | 17.38 | 9.18 | 69.86 | 13 |
| Least amount, in. | 0.12 | 0.40 | 0.37 | 0.49 | 0.37 | 1.33 | 1.36 | 4.22 | 1.53 | 2.60 | 1.94 | 0.86 | 24.42 | 13 |
| Mean number of days, 0.01 in. or more. | 11 | 10 | 13 | 13 | 16 | 16 | 21 | 21 | 20 | 21 | 21 | 16 | 198 | 10 |

[a] U. S. Hydrographic Office, Sailing Directions for the Pacific Islands, H. O. Pub. No. 82, Vol. 1, Second Edition (1964), updated to Dec. 5, 1970.

[b] Wind data for Kwajalein.

[c] Precipitation data for Enewetak.

for DNA,* estimated that there were approximately 7200 $yd^3$ of contaminated metal and concrete present on Enewetak Atoll in December 1972. AEC radiation monitors accompanied the H&N crews in order to identify the radioactive material. Table 224 shows the distribution of this debris on islands where this type of survey was conducted. The amounts of material listed should be taken only as an approximate lower limit, particularly on islands such as PEARL, where very heavy underbrush prevented the survey party from covering all parts of the island. In addition, it is conceivable that radioactive scrap material may be found on the other northern islands (KATE, LUCY, MARY, NANCY, OLIVE, URSULA, VERA, and WILMA), even though none of them contains ground-zero sites, and neither the aerial radiological survey nor the ground survey parties detected this type of debris.

On the southern islands, there were four locations where radioactive scrap material was found:

- On the north end of ELMER (in the "C" level area of Fig. B.37.1.b in Appendix II) there are several pieces of scrap iron with activity levels above local background.
- In the central part of ELMER (the large "E" level area of Fig. B.39.1.b) a partially shielded $^{60}Co$ source was found in a small storage building.

*Engineering Study for a Cleanup Plan, Enewetak Atoll-Marshall Islands, Holmes and Narver, Repts. HN-1348.1 and HN-1348.2 (1973).

Table 224. Contaminated metal and concrete scrap on Enewetak Atoll.

| Island | Approximate scrap quantities | Remarks |
|---|---|---|
| ALICE | 10 $yd^3$ | Background is up to 170 $\mu$R/hr. An M-boat wreck on beach reads 8 mR/hr. |
| BELLE | Small (< 10 $yd^3$) | Background up to 250 $\mu$R/hr. |
| CLARA | Small (< 10 $yd^3$) | Background up to 100 $\mu$R/hr. |
| DAISY | Small (< 10 $yd^3$) | Background up to 140 $\mu$R/hr. |
| EDNA | None | Sandbar |
| IRENE | Moderate[a] | Up to 1.2 mr/hr. |
| JANET | 568 $yd^3$ | Activated scrap metal in all sizes can be found in piles or individual pieces scattered over the island at levels up to 8 mr/hr. |
| PEARL | 317 $yd^3$ | Confined to SGZ area. Levels up to 5 mr/hr. |
| RUBY | 196 $yd^3$ | |
| SALLY | 2106 $yd^3$ | Scrap-metal activity levels up to 0.12 mr/hr. Alpha levels on concrete surfaces up to $10^3$ dpm/50 $cm^2$. |
| TILDA | 1 $yd^3$ | |
| YVONNE | 4064 $yd^3$ | Activity levels up to 60 mr/hr. |
| Total | 7262 $yd^3$ | |

[a]Reference does not identify volume.

- In the south-central part of ELMER (the small "E" level area of Fig. B.39.1.b) there appears to be scrap metal or other radioactive debris on, or just below, the ground surface in heavy underbrush.
- On the north-central shore of GLENN (the "C" area of Fig. B.48.1.b) there is a derelict barge which is contaminated with detectable amounts of $^{207}$Bi.

Because of the extremely low ambient radiation levels on the southern islands and the sensitivity of the aerial survey equipment, we can be reasonably confident that we have found all material above ground with activity levels greater than a few microroentgens per hour. On FRED, for example, the highest radiation level found (the "D" area in Fig. B.46.1.b) proved to be coming from barrels of fly ash stored in a warehouse intended to be

Table 225. Living patterns describing the geographical locations for activities involved in daily living.

| | Pattern I | Pattern II |
|---|---|---|
| Residence | FRED, ELMER, or DAVID | FRED, ELMER, or DAVID |
| Agriculture | ALVIN through KEITH | KATE through WILMA + LEROY |
| Fishing | Entire Atoll | Entire Atoll |
| | **Pattern III** | **Pattern IV** |
| Residence | JANET | BELLE |
| Agriculture | JANET | BELLE |
| Fishing | Entire Atoll | Entire Atoll |
| | **Pattern V** | **Pattern VI** |
| Residence | JANET | JANET |
| Agriculture | KATE through WILMA + LEROY | ALICE through IRENE |
| Fishing | Entire Atoll | Entire Atoll |

used for PACE drilling operations. Similarly, the nearby "C" level area proved to be a $^{60}Co$ source stored in a lead container in a locked building properly labeled, but of which we were unaware before the survey started.

## POPULATION DOSE ASSESSMENT

The total radiation dose to the Enewetak people returning to Enewetak Atoll is determined by the sum of the contributions of each of the exposure pathways; i. e.,

$$\text{Dose} = D_{\text{inhalation}} + D_{\text{external gamma}} + D_{\text{marine food chain}} + D_{\text{terrestrial food chain}}$$

The contribution of each pathway to the total dose for an individual depends on living patterns and diet. Six living patterns, shown in Tables 225 and 226, have been selected for the dose assessment on the basis of statements made by the Enewetak people as to how and where they would like to live after they return. Similarly, the diets shown in Table 227 have been selected on the basis of the best current information on the dietary habits of the Enewetak people, the current distribution of edible species on the Atoll, and growth periods before harvest for edible species which will have to be established after return. In addition, these assessments assume that the Enewetak people will continue their current practice of using catchment rainwater for drinking and that underground

Table 226a. Estimated time distribution (in percent) for men, women, children, and infants, with emphasis on residence island. Pattern A.

| | Village area | Beaches | Interior | Lagoon | Other islands |
|---|---|---|---|---|---|
| Men | 50 | 5 | 15 | 10 | 20 |
| Women | 60 | 10 | 10 | 0 | 20 |
| Children | 55 | 10 | 15 | 5 | 15 |
| Infants | 85 | 5 | 0 | 0 | 10 |

lens water, where available, will not be a significant part of the diet.

$D_{inhalation}$

$^{239,240}$Pu has been found to be the only significant contributor to inhalation doses on Enewetak Atoll. Airborne radioactive species observed during the survey, however, were identified as originating almost entirely from world-wide fallout or cosmic-ray activity. In order to make a conservative estimate of inhalation dosages, it has been assumed that the returning population will be exposed to air with an average dust loading of 100 $\mu g/m^3$, with the same $^{239,240}$Pu content as the local soil, all 0.4 $\mu$m in diameter and low in solubility.

Using these assumptions and $^{239,240}$Pu concentrations obtained from the soil samples, inhalation doses to bone, liver, and lung for each of the six living patterns have been estimated and are shown in Tables 228-230.

The "unmodified" cases represent calculations based on the $^{239,240}$Pu content of the top 2 cm of soil, while the "modified" cases represent calculations based on the average $^{239,240}$Pu content of the top 15 cm of soil. The latter condition would obtain if the soils were plowed or mixed during the replanting operations.

$D_{external\ gamma}$

Using gamma levels obtained from the aerial survey, estimates of the external gamma dose associated with each of the living patterns have been calculated (Table 231). In this table the "unmodified"

Table 226b. Estimated time distribution (in percent) for men, women, children, and infants with emphasis on additional time spent on nonresidence islands. Pattern B.

| | Village area | Beaches | Interior | Lagoon | Other islands |
|---|---|---|---|---|---|
| Men | 40 | 5 | 20 | 10 | 25 |
| Women | 50 | 5 | 15 | 5 | 25 |
| Children | 50 | 5 | 15 | 10 | 20 |
| Infants | 70 | 5 | 5 | 0 | 20 |

Table 227. Postulated diet for the returning adult Enewetak population for time of return and for 10 yr after initial return.

| Food item | Diet, g/day At time of return, | 10 yr after return |
|---|---|---|
| Fish | 600 | 600 |
| Domestic meat | 60 | 100 |
| Pandanus fruit | 0 | 200 |
| Breadfruit | 0 | 150 |
| Wild birds | 100 | 20 |
| Bird eggs | 20 | 10 |
| Arrowroot | 0 | 40 |
| Coconut | 100 | 100 |
| Coconut milk | 100 | 300 |
| Coconut crabs | 25 | 25 |
| Clams | 25 | 25 |
| Garden vegetables | 0 | 0 |
| Imports | 200-1000 | 200-1000 |
| | 1030 plus imports | 1570 plus imports |

Table 228. Cumulative rems to organs from $^{239,240}Pu$ via inhalation pathway, bone.

| LIVING PATTERN | PCI/G IN SOIL | 5 YRS | EXPOSED 10 YRS | 30 YRS | 50 YRS | 70 YRS |
|---|---|---|---|---|---|---|
| I. MODIFIED | 0.05 | 0.0000 | 0.0000 | 0.0003 | 0.0009 | 0.0018 |
| UNMODIFIED | 0.12 | 0.0000 | 0.0001 | 0.0007 | 0.0022 | 0.0043 |
| II. MODIFIED | 2.00 | 0.0001 | 0.0008 | 0.0122 | 0.0360 | 0.0720 |
| UNMODIFIED | 4.70 | 0.0003 | 0.0020 | 0.0287 | 0.0846 | 0.1692 |
| III. MODIFIED | 7.30 | 0.0004 | 0.0031 | 0.0445 | 0.1314 | 0.2628 |
| UNMODIFIED | 17.00 | 0.0010 | 0.0071 | 0.1037 | 0.3060 | 0.6120 |
| IV. MODIFIED | 15.00 | 0.0009 | 0.0063 | 0.0915 | 0.2700 | 0.5400 |
| UNMODIFIED | 77.00 | 0.0046 | 0.0323 | 0.4697 | 1.3860 | 2.7720 |
| V. MODIFIED | 7.30 | 0.0004 | 0.0031 | 0.0445 | 0.1314 | 0.2628 |
| UNMODIFIED | 17.60 | 0.0011 | 0.0074 | 0.1074 | 0.3168 | 0.6336 |
| VI. MODIFIED | 9.50 | 0.0006 | 0.0040 | 0.0579 | 0.1710 | 0.3420 |
| UNMODIFIED | 14.70 | 0.0009 | 0.0062 | 0.0897 | 0.2646 | 0.5292 |

Table 229. Cumulative rems to organs from $^{239,240}Pu$ via inhalation pathway, liver.

| LIVING PATTERN | PCI/G IN SOIL | 5 YRS | EXPOSED 10 YRS | 30 YRS | 50 YRS | 70 YRS |
|---|---|---|---|---|---|---|
| I. MODIFIED | 0.05 | 0.0000 | 0.0000 | 0.0002 | 0.0005 | 0.0008 |
| UNMODIFIED | 0.12 | 0.0000 | 0.0000 | 0.0004 | 0.0011 | 0.0020 |
| II. MODIFIED | 2.00 | 0.0001 | 0.0005 | 0.0066 | 0.0186 | 0.0340 |
| UNMODIFIED | 4.70 | 0.0002 | 0.0011 | 0.0155 | 0.0437 | 0.0799 |
| III. MODIFIED | 7.30 | 0.0003 | 0.0018 | 0.0241 | 0.0679 | 0.1241 |
| UNMODIFIED | 17.00 | 0.0007 | 0.0041 | 0.0561 | 0.1581 | 0.2890 |
| IV. MODIFIED | 15.00 | 0.0006 | 0.0036 | 0.0495 | 0.1395 | 0.2550 |
| UNMODIFIED | 77.00 | 0.0031 | 0.0185 | 0.2541 | 0.7161 | 1.3090 |
| V. MODIFIED | 7.30 | 0.0003 | 0.0018 | 0.0241 | 0.0679 | 0.1241 |
| UNMODIFIED | 17.60 | 0.0007 | 0.0042 | 0.0581 | 0.1637 | 0.2992 |
| VI. MODIFIED | 9.50 | 0.0004 | 0.0023 | 0.0313 | 0.0883 | 0.1615 |
| UNMODIFIED | 14.70 | 0.0006 | 0.0035 | 0.0485 | 0.1367 | 0.2499 |

case represents the current conditions; "village graveled" shows the effect of placing a 5-cm gravel layer in the village area; and "__________ plowed" indicates the effect of thoroughly mixing the top 30 cm of soil in the specified area.

$D_{marine\ food\ chain}$

Doses via the marine and terrestrial food chains were estimated using the following differential equation to describe the intake and retention by man:

$$\frac{dC_{man}}{dt} = \frac{I\, f_{man}\, C}{M} - \lambda_{man}\, C_{man} \qquad (3)$$

where

$C_{man}$ = concentration of nuclide in man, pCi/g

I = food intake, g/day,

$f_{man}$ = fraction of nuclide ingested reaching the organ of reference,

C = concentration of nuclide in food product, pCi/g, (i.e., fish, shellfish, coconut, land crab, etc.),

M = mass of the organ of reference, (g),

and

$\lambda_{man}$ = effective elimination rate of nuclide from man, $(day^{-1})$.

$(\lambda_{man} = \lambda_{biological} + \lambda_{radioactive})$

The concentration C in the food products is calculated assuming that the nuclide

Table 230. Cumulative rems to organs from $^{239,240}Pu$ via inhalation pathway, lung.

| LIVING PATTERN | PCI/G IN SOIL | 5 YRS | EXPOSED 10 YRS | 30 YRS | 50 YRS | 70 YRS |
|---|---|---|---|---|---|---|
| I. MODIFIED | 0.05 | 0.0000 | 0.0001 | 0.0004 | 0.0006 | 0.0009 |
| UNMODIFIED | 0.12 | 0.0001 | 0.0003 | 0.0009 | 0.0016 | 0.0022 |
| II. MODIFIED | 2.00 | 0.0017 | 0.0044 | 0.0152 | 0.0260 | 0.0360 |
| UNMODIFIED | 4.70 | 0.0040 | 0.0103 | 0.0357 | 0.0611 | 0.0846 |
| III. MODIFIED | 7.30 | 0.0063 | 0.0161 | 0.0555 | 0.0949 | 0.1314 |
| UNMODIFIED | 17.00 | 0.0146 | 0.0374 | 0.1292 | 0.2210 | 0.3060 |
| IV. MODIFIED | 15.00 | 0.0129 | 0.0330 | 0.1140 | 0.1950 | 0.2700 |
| UNMODIFIED | 77.00 | 0.0662 | 0.1694 | 0.5852 | 1.0010 | 1.3860 |
| V. MODIFIED | 7.30 | 0.0063 | 0.0161 | 0.0555 | 0.0949 | 0.1314 |
| UNMODIFIED | 17.60 | 0.0151 | 0.0387 | 0.1338 | 0.2288 | 0.3168 |
| VI. MODIFIED | 9.50 | 0.0082 | 0.0209 | 0.0722 | 0.1235 | 0.1710 |
| UNMODIFIED | 14.70 | 0.0126 | 0.0323 | 0.1117 | 0.1911 | 0.2646 |

disappears only by radioactive decay, i. e., that no other processes are in operation which reduce the nuclide availability in the food chain. Therefore $C = C_o e^{-\lambda_r t}$, where $C_o$ is the concentration observed at the time of the survey and $\lambda_r$ is the radioactive decay constant. The concentration in man at any time t after initial consumption of the food is:

$$C_{man} = \frac{I f_{man} C_o}{M(\lambda_{man} - \lambda_r)} \times \left(e^{-\lambda_r t} - e^{-\lambda_{man} t}\right), \text{ pCi/g.} \quad (4)$$

The dose at any time t after initial consumption is

$$\text{Dose (rem)} = KE\int_0^t C_{man}\, dt$$

$$= KE\int_0^t \frac{I f_{man} C_o}{M(\lambda_{man} \lambda_r)} \times \left(e^{-\lambda_r t} - e^{-\lambda_{man} t}\right) dt, \quad (5)$$

where K is a conversion constant from pCi/g to rem and equals $5.1 \times 10^{-5}$ $\frac{\text{disintegrations}\cdot \text{g}\cdot \text{rem}}{\text{pCi}\cdot \text{MeV}\cdot \text{day}}$ and E is the disintegration energy of the nuclide in MeV, including a factor for relative biological effectiveness (RBE). The final dose is then determined from the integration of the equation, i. e.,

$$\text{Dose} = \frac{K E I f_{man} C_o}{M(\lambda_{man} - \lambda_r)} \times \left[\frac{1 - e^{-\lambda_r t}}{\lambda_r} - \frac{1 - e^{-\lambda_{man} t}}{\lambda_{man}}\right], \text{ rem.} \quad (6)$$

Table 232 lists the $f_{man}$ (FMAN), $\lambda_{radioactive}$ (LR), $\lambda_{man}$ (LMAN), and disintegration energy (E) values for all of the isotopes in the dose calculations.

Fish and marine organism data from the survey have been found not to have any statistically significant differences for dose estimation purposes between samples taken in different parts of the lagoon. The radionuclide concentration, $C_o$, used in the marine food chain dose assessment, therefore, is the average value for all fish from the entire Atoll determined from the survey and is listed in Tables 233 and 234 for each nuclide. The average values for radionuclide concentrations listed in the tables are in pCi per gram dry weight, with data corrected to pCi per gram wet

Table 231. Estimated integral external free-air gamma doses.

| Case | Living pattern | Gamma dose, rad — Time interval, yr: 5 | 10 | 30 | 70 |
|---|---|---|---|---|---|
| I | Village: FRED/ELMER/DAVID<br>Visits to ALVIN-KEITH<br>Time distribution: Table 137 | | | | |
| Unmodified | | 0.14 | 0.28 | 0.83 | 1.92 |
| II | Village: FRED/ELMER/DAVID<br>Visits to ALICE-WILMA<br>Time distribution: Table 137 | | | | |
| Unmodified | | 0.38 | 0.68 | 1.59 | 2.97 |
| 3. Northern islands plowed | | (0.22) | (0.41) | (1.08) | (2.26) |
| III | Village: JANET<br>No visits to other islands<br>Time distribution: Table 137 with "other islands" time spent in interior of JANET | | | | |
| Unmodified | | 0.94 | 1.71 | 3.95 | 6.66 |
| 1. Village graveled | | (0.82) | (1.49) | (3.48) | (5.96) |
| 2. JANET plowed | | (0.36) | (0.68) | (1.70) | (3.24) |
| IV | Village: BELLE<br>Visits to ALICE-WILMA<br>Time distribution: Table 137 | | | | |
| Unmodified | | 2.72 | 4.78 | 10.06 | 15.50 |
| 1. Village graveled | | (1.78) | (3.14) | (6.69) | (10.53) |
| 2. Plus BELLE plowed | | (0.83) | (1.47) | (3.26) | (5.47) |
| 3. Plus Northern islands plowed | | (0.68) | (1.23) | (2.77) | (4.76) |

Table 231 (continued).

| Case | Living pattern | 5 | 10 | 30 | 70 |
|---|---|---|---|---|---|
| V | Village: JANET | | | | |
| | Visits to KATE-WILMA | | | | |
| | Time distribution: Table 137 | | | | |
| Unmodified | | 0.71 | 1.28 | 2.94 | 5.06 |
| 1. Village graveled | | (0.59) | (1.07) | (2.48) | (4.36) |
| 2. Plus JANET plowed | | (0.36) | (0.66) | (1.59) | (3.02) |
| 3. Plus KATE-WILMA plowed | | (0.29) | (0.54) | (1.36) | (2.71) |

| Case | Living pattern | Gamma dose, rad — Time interval, yr: 5 | 10 | 30 | 70 |
|---|---|---|---|---|---|
| VI | Village: JANET | | | | |
| | Visits to ALICE-IRENE | | | | |
| | Time distribution: Table 137 | | | | |
| Unmodified | | 1.15 | 2.03 | 4.39 | 7.13 |
| 1. Village graveled | | (1.02) | (1.81) | (3.93) | (6.43) |
| 2. Plus JANET plowed | | (0.80) | (1.41) | (3.05) | (5.09) |
| 3. Plus ALICE-IRENE plowed | | (0.43) | (0.78) | (1.85) | (3.39) |
| VIa | Village: JANET | | | | |
| | Visits to ALICE-WILMA | | | | |
| | Time distribution: Table 136 | | | | |
| Unmodified | | 0.76 | 1.37 | 3.12 | 5.33 |
| 1. Village graveled | | (0.62) | (1.12) | (2.58) | (4.51) |
| 2. Plus JANET plowed | | (0.41) | (0.75) | (1.77) | (3.27) |
| 3. Plus Northern islands plowed | | (0.30) | (0.56) | (1.40) | (2.76) |
| VIb | Village: JANET | | | | |
| | Visits to ALVIN-KEITH | | | | |
| | Time distribution: Table 136 | | | | |
| Unmodified | | 0.60 | 1.10 | 2.60 | 4.60 |
| 1. Village graveled | | (0.48) | (0.88) | (2.14) | (3.90) |
| 2. Plus JANET plowed | | (0.25) | (0.48) | (1.26) | (2.56) |
| Mean population dose (Average of Cases I, II, III, V, and VI) | | | | | |
| Unmodified | | 0.66 | 1.20 | 2.74 | 4.75 |
| 1. Village graveled | | (0.59) | (1.07) | (2.46) | (4.33) |
| 2. Plus JANET plowed | | (0.41) | (0.74) | (1.75) | (3.25) |
| 3. Plus All Northern islands plowed | | (0.29) | (0.54) | (1.36) | (2.70) |
| Sea level, U.S.A. (80 mrad/yr) Typical | | 0.40 | 0.80 | 2.40 | 5.60 |

Table 232. The disintegration energy E and the radioactive half-life LR are listed for each radionuclide. The effective biological half-time LMan and the fraction of ingested isotope reaching the organ of reference FMan are listed for three receptor organs, bone, liver, and whole body.

1

| NUCLIDE | E | LR | BONE MASS= 5.000E+03 -LMAN- | -FMAN- | LIVER MASS= 1.800E+03 -LMAN- | -FMAN- | WHOLEBODY MASS= 7.000E+04 -LMAN- | -FMAN- |
|---|---|---|---|---|---|---|---|---|
| 3 H | 6.287E-03 | 1.549E-04 | 5.790E-02 | 9.100E-02 | 5.790E-02 | 2.600E-02 | 5.790E-02 | 1.000E+00 |
| 14 C | 6.087E-02 | 3.314E-07 | 1.733E-02 | 2.500E-02 | 6.930E-02 | 2.600E-02 | 6.370E-02 | 1.000E+00 |
| 55FE | 6.540E-03 | 7.032E-04 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 60CO | 8.740E-01 | 3.609E-04 | [illegible] | [illegible] | 8.191E-03 | [illegible] | 8.191E-03 | [illegible] |
| 63NI | 1.780E-02 | 2.064E-05 | [illegible] | [illegible] | [illegible] | 2.000E-02 | [illegible] | [illegible] |
| 90SR | 5.500E+00 | 6.781E-05 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 106RU | 1.400E+00 | 1.800E-03 | 3.432E-03 | 3.300E-02 | 1.186E-02 | [illegible] | [illegible] | 3.000E-01 |
| 103RH | 1.000E+00 | 6.544E-04 | [illegible] | [illegible] | [illegible] | 8.000E-02 | [illegible] | 2.000E-01 |
| 113CD | 1.800E-01 | 1.356E-04 | 5.911E-03 | 9.000E-03 | 3.601E-03 | 1.900E-03 | 1.375E-04 | 5.900E-02 |
| 125SB | 3.600E-01 | 7.032E-04 | 7.633E-03 | 3.000E-03 | [illegible] | 6.000E-05 | 1.894E-02 | 3.000E-02 |
| 129 I | 7.586E-02 | [illegible] | 4.950E-02 | [illegible] | [illegible] | 1.207E-01 | 5.022E-03 | 1.000E+00 |
| 133BA | 3.940E-01 | 2.637E-04 | 1.033E-02 | [illegible] | 5.745E-04 | 3.000E-05 | 1.023E-02 | 5.000E-02 |
| 137CS | 5.900E-01 | 6.329E-03 | 6.733E-03 | 9.100E-02 | 6.363E-03 | 2.500E-02 | 7.143E-03 | 1.000E+00 |
| 144CE | 3.754E+00 | 2.432E-03 | 2.884E-03 | 3.000E-05 | 4.757E-03 | 2.300E-05 | 3.662E-03 | 1.000E-04 |
| 147PM | 2.297E+00 | 7.032E-04 | 1.165E-03 | 3.500E-05 | 1.760E-03 | 6.000E-06 | 1.163E-03 | 1.000E-04 |
| 151SM | 1.523E-02 | 2.110E-05 | 4.831E-04 | 3.500E-05 | 3.727E-03 | 3.500E-03 | 1.077E-03 | 1.000E-04 |
| 152EU | 6.600E-01 | 1.531E-04 | 3.379E-04 | 3.600E-05 | 5.610E-03 | 2.500E-05 | 3.379E-04 | 1.000E-04 |
| 155EU | 1.600E-01 | 1.055E-03 | 1.240E-03 | 3.600E-05 | 6.511E-03 | 2.500E-05 | 1.240E-03 | 1.000E-04 |
| 207BI | 1.000E+00 | 6.329E-05 | 5.217E-02 | 3.000E-04 | 4.626E-02 | 1.500E-03 | 1.387E-01 | 1.000E-02 |
| 235 U | 4.600E+00 | 2.660E-12 | [illegible] | 5.400E-05 | 1.899E-06 | [illegible] | [illegible] | 1.000E-04 |
| 238PU | 4.600E+01 | 2.134E-05 | 4.032E-05 | 1.350E-05 | 2.323E-05 | 1.200E-05 | 3.093E-05 | [illegible] |
| 239PU | 5.300E+01 | 7.794E-08 | [illegible] | 1.350E-05 | [illegible] | 1.200E-05 | [illegible] | [illegible] |
| 240PU | 5.300E+01 | 2.809E-07 | [illegible] | [illegible] | [illegible] | 1.200E-05 | [illegible] | [illegible] |
| 241AM | 5.700E+01 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

Table 233. Average concentration, number of samples in the average, standard deviation, and high and low of the range for all fish in the entire Enewetak Atoll.

| NUCLIDE | TISSUE | NO. OF SAMPLES | AVERAGE PCI/GRAM* | STANDARD DEVIATION | RANGE PCI/GRAM HIGH | RANGE PCI/GRAM LOW | AVERAGE PCI/GRAM** | LOGNORMAL MEDIAN PCI/GRAM |
|---|---|---|---|---|---|---|---|---|
| 01003 | MUSCLE | 9 | 3.955E-01 | 1.517E-01 | 7.189E-01 | 1.845E-01 | 3.955E-01 | 3.712E-01 |
| 19040 | MUSCLE | 116 | 1.189E+01 | 5.277E+00 | 2.697E+01 | 2.982E+00 | 1.189E+01 | 1.075E+01 |
| 26055 | MUSCLE | 123 | 1.574E+01 | 4.108E+01 | 3.833E+02 | 1.577E-01 | 1.566E+01 | 5.063E+00 |
| 27060 | MUSCLE | 128 | 2.005E+00 | 5.377E+00 | 3.827E+01 | 4.063E-02 | 1.958E+00 | 5.974E-01 |
| 38090 | MUSCLE | 125 | 1.562E-01 | 2.450E-01 | 1.541E+00 | 1.051E-03 | 1.177E-01 | 6.308E-02 |
| 44106 | MUSCLE | 88 | 8.095E-01 | 4.508E-01 | 2.237E+00 | 3.017E-01 | 0. | 7.058E-01 |
| 45102 | MUSCLE | 128 | 9.044E-02 | 6.601E-02 | 3.729E-01 | 1.805E-02 | 0. | 7.165E-02 |
| 48113 | MUSCLE | 1 | 2.635E-01 | 0. | 2.635E-01 | 2.635E-01 | 2.635E-01 | 2.635E-01 |
| 51125 | MUSCLE | 128 | 2.449E-01 | 2.581E-01 | 2.096E+00 | 7.734E-02 | 3.910E-02 | 1.970E-01 |
| 55137 | MUSCLE | 129 | 3.897E-01 | 7.940E-01 | 6.779E+00 | 2.636E-02 | 3.493E-01 | 1.955E-01 |
| 56133 | MUSCLE | 104 | 1.431E-01 | 1.205E-01 | 7.631E-01 | 2.445E-02 | 1.598E-02 | 1.004E-01 |
| 58144 | MUSCLE | 4 | 2.822E-01 | 1.269E-02 | 2.975E-01 | 2.699E-01 | 0. | 2.820E-01 |
| 63152 | MUSCLE | 129 | 7.826E-02 | 5.899E-02 | 3.415E-01 | 2.779E-02 | 0. | 6.329E-02 |
| 63155 | MUSCLE | 128 | 1.107E-01 | 7.631E-02 | 5.212E-01 | 3.097E-02 | 1.411E-02 | 9.242E-02 |
| 83207 | MUSCLE | 129 | 2.402E+00 | 2.233E+01 | 2.527E+02 | 1.965E-02 | 2.372E+00 | 1.350E-01 |
| 92235 | MUSCLE | 122 | 7.932E-02 | 4.703E-02 | 2.547E-01 | 2.271E-02 | 0. | 6.563E-02 |
| 94000 | MUSCLE | 123 | 2.477E-01 | 2.009E+00 | 2.203E+01 | 4.220E-04 | 2.444E-01 | 1.257E-02 |
| 94238 | MUSCLE | 64 | 1.390E-02 | 2.175E-02 | 1.140E-01 | 1.092E-03 | 5.241E-03 | 7.679E-03 |
| 95241 | MUSCLE | 128 | 1.144E-01 | 8.450E-02 | 8.020E-01 | 2.232E-02 | 2.771E-03 | 9.280E-02 |

*AVERAGE (IF NON-DETECTED, CONCENTRATION SET EQUAL TO DETECTION LIMIT) PCI/GRAM
**AVERAGE (IF NON-DETECTED, CONCENTRATION SET EQUAL TO ZERO) PCI/GRAM

Table 234. Radionuclide concentrations in fish (January 1972).

| Nuclide | Sample | No. of Samples | Concentration, pCi/g dry weight Average | High | Low |
|---|---|---|---|---|---|
| $^{137}Cs$ | All fish[a] | 128 | 0.39 | 6.8 | 0.026 |
| $^{60}Co$ | All fish[a] | 128 | 2.0 | 38 | 0.041 |
| $^{90}Sr$ | All fish[a] | 125 | 0.16 | 1.5 | 0.0010 |
| $^{90}Sr$ | Eviscerated whole fish | 74 | 0.21 | --- | --- |
| $^{90}Sr$ | Fish muscle only | 51 | 0.075 | --- | --- |

[a] All fish includes eviscerated whole fish and those fish where muscle was separated from bone and only the muscle was analyzed.

weight for use in the dose code by dividing by 3.5, the average wet-to-dry ratio for fish from the Atoll.

Integral doses calculated from the marine survey data are listed in Table 235 for the whole body and bone for 5. 10, 30 and 70 yr. The major contribution to the whole-body dose comes from $^{137}Cs$ and $^{60}Co$, while the bone dose comes from $^{90}Sr$, as well as from $^{137}Cs$ and $^{60}Co$. The third line of the table gives the summation of the dose to each organ from the three isotopes. The bottom entry in the table lists the dose from all radionuclides listed in the Table 235 footnote.

## D terrestrial food chain

Evaluation of the potential dose to the returning population via the terrestrial food chain has been structured on the basis of the living patterns in Table 225. The quantity of radionuclides ingested via terrestrial foods was computed from the measured and predicted concentration of activities according to the expected daily diets listed in Table 227. Except for coconut and arrowroot, the daily intake of the food items listed in this table refers to g/day of fresh food. The g/day intakes listed for coconut and arrowroot refer to the dry weight intake of coconut meat (copra) and processed arrowroot starch. Inferred initial ingestion rates assuming the diet at time of return are shown in Table 236. This diet contains only foods that are available on islands of the group at the time of return, i.e., domestic meat, birds, bird eggs, coconut crabs, and, in the case of the southern islands, coconut meat and coconut milk.

The 30- and 70-yr integral doses were calculated assuming the 10-yr post-return diet. In addition to the foods that are available at the time of return, the 10-yr post-return diet includes pandanus fruit, breadfruit, arrowroot, coconut meat, and coconut milk for all islands. The initial rates of ingestion for each island group assuming the 10-yr post-return diet are listed in Table 237. These values are presented in two parts; the rates of ingestion for the foods immediately available are presented on the left side of Table 237 under January 1, 1974, while the rates of ingestion for the foods that are to become available 8 yr after return

Table 235. Integral dose[a] for 5, 10, 30, and 70 yr from the marine food chain.

| | Integral dose, rem[b] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 yr | | 10 yr | | 30 yr | | 70 yr | |
| Nuclide | W. B. | Bone | W. B. | Bone | W. B. | Bone | W. B. | Bone |
| $^{137}Cs$ | 0.0061 | 0.0061 | 0.012 | 0.012 | 0.030 | 0.030 | 0.049 | 0.049 |
| $^{60}Co$ | 0.0078 | 0.0078 | 0.012 | 0.012 | 0.017 | 0.017 | 0.017 | 0.017 |
| $^{90}Sr$ | --- | 0.13 | --- | 0.31 | --- | 0.77 | -- | 1.3 |
| Sum | 0.014 | 0.14 | 0.024 | 0.33 | 0.047 | 0.82 | 0.066 | 1.4 |
| All nuclides[c] | 0.016 | 0.14 | 0.028 | 0.34 | 0.053 | 0.84 | 0.089 | 1.6 |

[a]The dose is based upon the average concentration for fish from the entire Atoll and upon a dietary fish intake of 600 g/day. These doses apply to all six living patterns.

[b]The concentration data were corrected to January 1974, the earliest possible return date to the Atoll; all integral doses are calculated for periods which begin on January 1974.

[c]Isotopes included in the "All nuclides" calculation:

| | | | | | |
|---|---|---|---|---|---|
| $^{3}H$ | $^{60}Co$ | $^{102}Rh$ | $^{137}Cs$ | $^{152}Eu$ | $^{235}U$ |
| $^{14}C$ | $^{90}Sr$ | $^{113}Cd$ | $^{133}Ba$ | $^{155}Eu$ | $^{238}Pu$ |
| $^{55}Fe$ | $^{106}Ru$ | $^{125}Sb$ | $^{144}Ce$ | $^{207}Bi$ | $^{239}Pu$ |
| | | | | | $^{241}Am$ |

are presented on the right side of Table 237 under the 8-yr post-return date, January 1, 1982. In essence, the foods immediately available are assumed to contribute to the diet beginning January 1, 1974, and the edible plants that are yet to be established are assumed to contribute to the diet beginning January 1, 1982.

Using these data, plus the integrated dose per unit rate of ingestion to whole body and bone shown in Table 238, the integral 5- and 10-yr doses shown in Table 239 have been calculated. The 5- and 10-yr dosages particularly relate to the situation during the initial few years following return.

In computing the bone dose, the whole-body dose from $^{137}Cs$ and the other non-bone seekers has been added to the bone dose from $^{90}Sr$ and $^{239,240}Pu$. The whole-body dose has been computed as the sum of the whole-body dosages from the non-bone seekers.

Similarly, integral 30- and 70-yr doses have been calculated assuming the 10-yr post-return diet (Table 240).

Total Dose

The total 30-yr integral dose predicted for whole body and for bone for the six living patterns are listed in Table 241. This table includes the contributions from each pathway and, for

Table 236. Rate of ingestion of radionuclides from terrestrial foods assuming diet at time of return (Jan. 1, 1974).

| Food item | Ingestion rate, pCi/day | | | | | |
|---|---|---|---|---|---|---|
| | $^{3}H$ | $^{55}Fe$ | $^{60}Co$ | $^{90}Sr$ | $^{137}Cs$ | $^{239,240}Pu$ |
| **A. Island group ALICE-IRENE** | | | | | | |
| Pork and chicken | | | | 185 | 3100 | |
| Wild birds | | 984 | 6.21 | 1.21 | <2.4 | 0.143 |
| Bird eggs | | 69 | <0.29 | 0.45 | <0.24 | 0.0074 |
| Total | | 1050 | 6.35 | 187 | 3100 | 0.150 |
| **B. Island group BELLE** | | | | | | |
| Pork and chicken | | | | 302 | 6960 | |
| Total | | | | 302 | 6960 | |
| **C. Island group JANET** | | | | | | |
| Pork and chicken | | | | 108 | 2320 | |
| Wild birds | | 1800 | 7.70 | 0.29 | 2.5 | 0.100 |
| Bird eggs | | 171 | <0.39 | 0.97 | 0.6 | 0.074 |
| Total | | 1970 | 7.89 | 109 | 2320 | 0.174 |
| **D. Island group KATE-WILMA, LEROY** | | | | | | |
| Pork and chicken | | | | 47.4 | 858 | |
| Wild birds | | 1800 | 7.70 | 0.29 | 2.50 | 0.100 |
| Bird eggs | | 113 | <0.28 | 0.02 | <0.25 | 0.077 |
| Coconut crabs | 0.480 | | 1.03 | 1.96 | 7.59 | 0.0035 |
| Total | 0.480 | 1900 | 8.87 | 49.7 | 868 | 0.180 |
| **E. Island group ALVIN-KEITH** | | | | | | |
| Pork and chicken | | | | 6.18 | 50.9 | |
| Wild birds | | 1700 | 6.41 | 0.37 | 2.55 | 0.704 |
| Bird eggs | | 131 | <0.35 | 0.02 | <0.35 | 0.003 |
| Coconut | 29.3 | <23 | <2.9 | 3.35 | 68.7 | <0.259 |
| Coconut milk | 14.9 | <11 | <1.42 | 0.17 | 3.44 | <0.129 |
| Coconut crabs | 2.91 | | 4.23 | 2.58 | 9.31 | 0.023 |
| Total | 47.1 | 1850 | 13.7 | 12.7 | 135 | 0.99 |

Table 237. Rate of ingestion of radionuclides from terrestrial foods assuming 10-yr post-return diet.

| Food item | Ingestion rate, pCi/day — January 1, 1974: $^{3}H$ | $^{55}Fe$ | $^{60}Co$ | $^{90}Sr$ | $^{137}Cs$ | $^{239,240}Pu$ | January 1, 1982: $^{3}H$ | $^{55}Fe$ | $^{60}Co$ | $^{90}Sr$ | $^{137}Cs$ | $^{239,240}Pu$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Island group ALICE-IRENE | | | | | | | | | | | | |
| Domestic meat | | | | 308 | 5170 | | | | | | | |
| Pandanus fruit | | | | | | | | | | 941 | 8840 | |
| Breadfruit | | | | | | | | | | 807 | 7570 | |
| Wild birds | | 197 | 1.24 | 0.242 | <0.5 | 0.0286 | | | | | | |
| Bird eggs | | 34.5 | <0.14 | 0.226 | <0.1 | 0.0037 | | | | | | |
| Arrowroot | | | | | | | | | | 47 | 71 | |
| Coconut meat | | | | | | | 23.7 | 664 | <16.3 | 135 | 2210 | 18.1 |
| Coconut milk | | | | | | | 35.6 | <37 | <8.5 | 20 | 331 | <1.7 |
| Total | | 231 | 1.31 | 308 | 5170 | 0.0323 | 59.3 | 683 | 12.4 | 1950 | 19000 | 19 |
| B. Island group BELLE | | | | | | | | | | | | |
| Domestic meat | | | | 504 | 11600 | | | | | | | |
| Pandanus fruit | | | | | | | | 1.34 | <1.46 | 1540 | 19800 | <9.5 |
| Breadfruit | | | | | | | | 1.15 | <1.25 | 1320 | 17000 | <8.1 |
| Arrowroot | | | | | | | | | | 77 | 159 | |
| Coconut meat | | | | | | | | | | 221 | 4960 | |
| Coconut milk | | | | | | | | | | 33 | 743 | |
| Total | | | | 504 | 11600 | | | 2.50 | 1.35 | 3180 | 42700 | 8.8 |
| C. Island group JANET | | | | | | | | | | | | |
| Domestic meat | | | | 180 | 3870 | | | | | | | |
| Pandanus fruit | | | | | | | | 7.12 | <1.25 | 550 | 6610 | 0.082 |
| Breadfruit | | | | | | | | 6.10 | <1.07 | 471 | 5560 | 0.071 |
| Wild birds | | 360 | 1.54 | 0.058 | 0.50 | 0.020 | | | | | | |
| Bird eggs | | 85.5 | <0.19 | 0.482 | 0.29 | 0.037 | | | | | | |
| Arrowroot | | | | | | | | | | 28 | 53 | |
| Coconut meat | | | | | | | | | <1.85 | 79 | 1650 | |
| Coconut milk | | | | | | | | <2.54 | <2.27 | 12 | 248 | <1.31 |
| Total | | 445 | 1.64 | 181 | 3870 | 0.057 | | 14.5 | 3.22 | 1140 | 14100 | 0.81 |

Table 237 (Continued).

| Food item | Ingestion rate, pCi/day | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | January 1, 1974 | | | | | | January 1, 1982 | | | | | |
| | $^{3}H$ | $^{55}Fe$ | $^{60}Co$ | $^{90}Sr$ | $^{137}Cs$ | $^{239,240}Pu$ | $^{3}H$ | $^{55}Fe$ | $^{60}Co$ | $^{90}Sr$ | $^{137}Cs$ | $^{239,240}Pu$ |
| D. Island group KATE-WILMA + LEROY | | | | | | | | | | | | |
| Domestic meat | | | | 79 | 1430 | | | | | | | |
| Pandanus fruit | | | | | | | | 3.94 | <13.8 | 241 | 2480 | 0.316 |
| Breadfruit | | | | | | | | 3.38 | <11.8 | 207 | 2120 | 0.271 |
| Wild birds | | 360 | 1.54 | 0.058 | 0.50 | 0.020 | | | | | | |
| Bird eggs | | 56 | <0.14 | 0.01 | <0.12 | 0.039 | | | | | | |
| Arrowroot | | | | | | | | | | 12 | 20 | |
| Coconut meat | | | | | | | 19.0 | 204 | <1.05 | 34.7 | 619 | <8.64 |
| Coconut milk | | | | | | | 28.5 | <6.44 | <2.27 | 5.2 | 93 | <0.38 |
| Coconut crabs | 0.480 | | 1.03 | 1.96 | 7.59 | 0.003 | | | | | | |
| Total | 0.480 | 416 | 2.59 | 81 | 1440 | 0.062 | 47.5 | 215 | 14.4 | 500 | 5330 | 5.0 |
| E. Island group ALVIN-KEITH | | | | | | | | | | | | |
| Domestic meat | | | | 10.3 | 84.9 | | | | | | | |
| Pandanus fruit | | | | | | | | 1.33 | <0.65 | 9.44 | 85.4 | 0.156 |
| Breadfruit | | | | | | | | 1.14 | <0.56 | 8.09 | 73.2 | 0.134 |
| Wild birds | | 340 | 1.28 | 0.073 | 0.51 | 0.141 | | | | | | |
| Bird eggs | | 65 | <0.17 | 0.009 | <0.17 | 0.002 | | | | | | |
| Arrowroot | | | Not available | | | | | | | 0.47 | 0.68 | |
| Coconut meat | 29.3 | <23 | <2.9 | 3.35 | 68.7 | <0.259 | | | | | | |
| Coconut milk | 44.6 | <33 | <4.2 | 0.50 | 10.3 | <0.386 | | | | | | |
| Coconut crabs | 2.91 | | 4.23 | 2.58 | 9.3 | 0.023 | | | | | | |
| Total | 76.8 | 433 | 9.17 | 16.8 | 174 | 0.488 | | 2.48 | 0.60 | 18.0 | 159 | 0.290 |

Table 238. Integrated dose per unit rate of ingestion to whole body and bone.

| Nuclide | Organ | $D_T$, rem/pCi/day — Period of integration: 2 yr | 5 yr | 10 yr | 22 yr | 30 yr | 62 yr | 70 yr |
|---|---|---|---|---|---|---|---|---|
| $^{3}H$ | Whole body | 4.51(-8)[a] | 1.05(-7) | 1.85(-7) | 3.05(-7) | 3.51(-7) | 4.17(-7) | 4.23(-7) |
| $^{55}Fe$ | Whole body | 7.50(-8) | 2.35(-7) | 3.73(-7) | 4.29(-7) | 4.32(-7) | 4.32(-7) | 4.32(-7) |
| $^{60}Co$ | Whole body | 1.27(-5) | 2.96(-5) | 4.65(-5) | 6.09(-5) | 6.33(-5) | 6.46(-5) | 6.46(-5) |
| $^{90}Sr$ | Bone | 2.87(-3) | 1.08(-2) | 2.39(-2) | 4.99(-2) | 6.33(-2) | 9.70(-2) | 1.02(-1) |
| $^{137}Cs$ | Whole body | 3.49(-5) | 9.62(-5) | 1.89(-4) | 3.74(-4) | 4.71(-4) | 7.22(-4) | 7.61(-4) |
| $^{239,240}Pu$ | Bone | 1.51(-6) | 9.39(-6) | 3.71(-5) | 1.75(-4) | 3.19(-4) | 1.27(-3) | 1.59(-3) |

[a]The number within parentheses denotes the power of 10. Thus, 4.51(-8) is a contraction of $4.51 \times 10^{-8}$ rem/pCi/day.

Table 239. Prediction of the dosage from ingestion of terrestrial foods assuming diet at the time of return.

| | Isotope | 5-yr dose, rem: Whole body | 5-yr dose, rem: Bone | 10-yr dose, rem: Whole body | 10-yr dose, rem: Bone |
|---|---|---|---|---|---|
| A. Island group ALICE-IRENE | | | | | |
| | $^{3}H$ | | | 2.7(-6) | |
| | $^{55}Fe$ | 2.5(-4)[a] | | 4.4(-4) | |
| | $^{60}Co$ | 1.9(-4) | | 4.5(-4) | |
| | $^{90}Sr$ | | 2.02 | | 10.1 |
| | $^{137}Cs$ | 0.298 | | 1.25 | |
| | $^{239,240}Pu$ | | 1.4(-6) | | 3.4(-5) |
| | Subtotal | 0.298 | 2.02 | 1.25 | 10.1 |
| | Total 5-yr whole-body dose | | 0.30 rem | Total 10-yr whole-body dose | 1.25 rem |
| | Total 5-yr bone dose | | 2.32 rem | Total 10-yr bone dose | 11.3 rem |
| B. Island group BELLE | | | | | |
| | $^{55}Fe$ | | | 1.9(-7) | |
| | $^{60}Co$ | | | 1.7(-5) | |
| | $^{90}Sr$ | | 3.26 | | 16.3 |
| | $^{137}Cs$ | 0.669 | | 2.81 | |
| | $^{239,240}Pu$ | | | | 1.3(-5) |
| | Subtotal | 0.67 | 3.26 | 2.81 | 16.3 |
| | Total 5-yr whole-body dose | | 0.67 rem | Total 10-yr whole-body dose | 2.81 rem |
| | Total 5-yr bone dose | | 3.93 rem | Total 10-yr bone dose | 19.2 rem |

Table 239 (Continued).

| | Isotope | 5-yr dose, rem Whole body | 5-yr dose, rem Bone | 10-yr dose, rem Whole body | 10-yr dose, rem Bone |
|---|---|---|---|---|---|
| C. Island group JANET | | | | | |
| | $^{55}Fe$ | 4.6(-4) | | 7.4(-4) | |
| | $^{60}Co$ | 2.3(-4) | | 4.1(-4) | |
| | $^{90}Sr$ | | 1.18 | | 5.88 |
| | $^{137}Cs$ | 0.223 | | 0.831 | |
| | $^{239,240}Pu$ | | 1.6(-6) | | 7.6(-6) |
| | Subtotal | 0.224 | 1.18 | 0.932 | 5.88 |
| | Total 5-yr whole-body dose | | 0.22 rem | Total 10-yr whole-body dose | 0.93 rem |
| | Total 5-yr bone dose | | 1.40 rem | Total 10-yr bone dose | 6.82 rem |
| D. Island group KATE-WILMA + LEROY | | | | | |
| | $^{3}H$ | 5.0(-8) | | 2.2(-6) | |
| | $^{55}Fe$ | 4.5(-4) | | 7.3(-4) | |
| | $^{60}Co$ | 2.6(-4) | | 6.0(-4) | |
| | $^{90}Sr$ | | 0.536 | | 2.62 |
| | $^{137}Cs$ | 0.0835 | | 0.350 | |
| | $^{239,240}Pu$ | | 1.7(-6) | | 1.4(-5) |
| | Subtotal | 0.0842 | 0.536 | 0.351 | 2.62 |
| | Total 5-yr whole-body dose | | 0.084 rem | Total 10-yr whole-body dose | 0.351 rem |
| | Total 5-yr bone dose | | 0.620 rem | Total 10-yr bone dose | 2.97 rem |

Table 239 (Continued)

| | Isotope | 5-yr dose, rem Whole body | Bone | 10-yr dose, rem Whole body | Bone |
|---|---|---|---|---|---|
| E. Island group ALVIN-KEITH | | | | | |
| | $^{3}H$ | 4.9(-6) | | 8.7(-6) | |
| | $^{55}Fe$ | 4.4(-4) | | 6.9(-4) | |
| | $^{60}Co$ | 4.1(-4) | | 6.5(-4) | |
| | $^{90}Sr$ | | 0.137 | | 0.355 |
| | $^{137}Cs$ | 0.0130 | | 0.0311 | |
| | $^{239,240}Pu$ | | 9.3(-6) | 0.0324 | 3.7(-5) |
| | Subtotal | 0.0138 | 0.137 | 0.0324 | 0.303 |
| | Total 5-yr whole-body dose | 0.014 rem | | Total 10-yr whole-body dose | 0.032 rem |
| | Total 5-yr bone dose | 0.151 rem | | Total 10-yr bone dose | 0.387 rem |

[a]The number within parentheses denotes the power of 10. Thus, 2.5(-4) is a contraction of $2.5 \times 10^{-4}$.

Table 240. Prediction of the dosage from ingestion of terrestrial foods assuming 10-yr post-return diet.

| Isotope | Ingestion rate, pCi/day January 1, 1974 | 30-yr dose, rem Whole body | 30-yr dose, rem Bone | 70-yr dose, rem Whole body | 70-yr dose, rem Bone | Ingestion rate, pCi/day January 1, 1984 | 22-yr dose, rem Whole body | 22-yr dose, rem Bone | 62-yr dose, rem Whole body | 62-yr dose, rem Bone |
|---|---|---|---|---|---|---|---|---|---|---|
| A. Island group | | | | | | | | | | |
| ALICE-IRENE | | | | | | | | | | |
| $^{3}H$ | | | | | | 59.3 | 1.8(-5) | | 2.5(-5) | |
| $^{55}Fe$ | 231 | 1.0(-4)[a] | | 1.0(-4) | | 683 | 0.0003 | | 0.0003 | |
| $^{60}Co$ | 1.31 | 8.3(-5) | | 8.5(-5) | | 12.4 | 0.0008 | | 0.0008 | |
| $^{90}Sr$ | 308 | | 19.5 | | 31.5 | 1950 | | 97.3 | | 190 |
| $^{137}Cs$ | 5170 | 2.44 | | 3.93 | | 19,000 | 7.11 | | 13.7 | |
| $^{239,240}Pu$ | 0.0323 | | 1.0(-5) | | 5.1(-5) | 19 | | 0.003 | | 0.024 |
| Subtotal | | 2.44 | 19.5 | 3.93 | 31.5 | | 7.11 | 97.3 | 13.7 | 190 |
| Total 30-yr whole-body dose | | 9.55 rem | | | | Total 70-yr whole-body dose | | 17.7 rem | | |
| Total 30-yr bone dose | | 126 rem | | | | Total 70-yr bone dose | | 239 rem | | |
| B. Island group | | | | | | | | | | |
| BELLE | | | | | | | | | | |
| $^{55}Fe$ | | | | | | 2.50 | 1.1(-6) | | 1.1(-6) | |
| $^{60}Co$ | | | | | | 1.35 | 8.2(-5) | | 8.7(-5) | |
| $^{90}Sr$ | 504 | | 31.9 | | 51.4 | 3180 | | 159 | | 309 |
| $^{137}Cs$ | 11,600 | 5.46 | | 8.83 | | 42,700 | 16.0 | | 30.8 | |
| $^{239,240}Pu$ | | | | | | 8.8 | | 1.5(-3) | | 1.1(-2) |
| Subtotal | | 5.46 | 31.9 | 8.83 | 51.4 | | 16.0 | 159 | 30.8 | 309 |
| Total 30-yr whole-body dose | | 21.4 rem | | | | Total 70-yr whole-body dose | | 39.6 rem | | |
| Total 30-yr bone dose | | 212 rem | | | | Total 70-yr bone dose | | 400 rem | | |

Table 240 (Continued).

| Isotope | Ingestion rate, pCi/day January 1, 1974 | 30-yr dose, rem Whole body | 30-yr dose, rem Bone | 70-yr dose, rem Whole body | 70-yr dose, rem Bone | Ingestion rate, pCi/day January 1, 1984 | 22-yr dose, rem Whole body | 22-yr dose, rem Bone | 62-yr dose, rem Whole body | 62-yr dose, rem Bone |
|---|---|---|---|---|---|---|---|---|---|---|
| C. Island group | | | | | | | | | | |
| JANET | | | | | | | | | | |
| $^{55}Fe$ | 445 | 1.9(-4) | | 1.9(-4) | | 14.5 | 6.2(-6) | | 6.2(-6) | |
| $^{60}Co$ | 1.64 | 1.0(-4) | | 1.1(-4) | | 3.22 | 2.0(-4) | | 2.1(-4) | |
| $^{90}Sr$ | 181 | | 11.4 | | 18.4 | 1140 | | 56.9 | | 111 |
| $^{137}Cs$ | 3870 | 1.82 | | 2.95 | | 14,100 | 5.28 | | 10.2 | |
| $^{239,240}Pu$ | 0.057 | | 1.8(-5) | | 9.1(-5) | 0.806 | | 1.4(-4) | | 1.0(-3) |
| Subtotal | | 1.82 | 11.4 | 2.95 | 18.4 | | 5.28 | 56.9 | 10.2 | 111 |
| Total 30-yr whole-body dose | 7.10 rem | | | | | Total 70-yr whole-body dose | 13.1 rem | | | |
| Total 30-yr bone dose | 75.4 rem | | | | | Total 70-yr bone dose | 142 rem | | | |
| D. Island group | | | | | | | | | | |
| KATE-WILMA + LEROY | | | | | | | | | | |
| $^{3}H$ | 0.480 | 2(-7) | | 2.0(-7) | | 47.5 | 1.5(-5) | | 2.0(-5) | |
| $^{55}Fe$ | 416 | 1.8(-4) | | 1.8(-4) | | 215 | 9.2(-5) | | 9.3(-5) | |
| $^{60}Co$ | 2.59 | 1.6(-4) | | 1.7(-4) | | 14.4 | 8.8(-4) | | 9.3(-4) | |
| $^{90}Sr$ | 81.0 | | 5.13 | | 8.26 | 500 | | 24.9 | | 48.5 |
| $^{137}Cs$ | 1440 | 0.677 | | 1.09 | | 5330 | 1.99 | | 3.85 | |
| $^{239,240}Pu$ | 0.062 | | 2.0(-5) | | 9.8(-5) | 4.96 | | 8.7(-4) | | 6.3(-3) |
| Subtotal | | 0.677 | 5.13 | 1.09 | 8.26 | | 1.99 | 24.9 | 3.85 | 48.5 |
| Total 30-yr whole-body dose | 2.67 rem | | | | | Total 70-yr whole-body dose | 4.94 rem | | | |
| Total 30-yr bone dose | 32.7 rem | | | | | Total 70-yr bone dose | 61.7 rem | | | |

Table 240 (Continued).

| Isotope | Ingestion rate, pCi/day January 1, 1974 | 30-yr dose, rem Whole body | 30-yr dose, rem Bone | 70-yr dose, rem Whole body | 70-yr dose, rem Bone | Ingestion rate, pCi/day January 1, 1984 | 22-yr dose, rem Whole body | 22-yr dose, rem Bone | 62-yr dose, rem Whole body | 62-yr dose, rem Bone |
|---|---|---|---|---|---|---|---|---|---|---|
| E. Island group | | | | | | | | | | |
| ALVIN-KEITH | | | | | | | | | | |
| $^{3}H$ | 76.8 | 1.3(-5) | | 3.3(-5) | | | | | | |
| $^{55}Fe$ | 433 | 1.9(-4) | | 1.9(-4) | | 2.48 | 1.1(-6) | | 1.1(-6) | |
| $^{60}Co$ | 9.17 | 5.8(-4) | | 5.9(-4) | | 0.60 | 3.7(-5) | | 3.9(-5) | |
| $^{90}Sr$ | 16.8 | | 1.07 | | 1.72 | 18.0 | | 0.898 | | 1.75 |
| $^{137}Cs$ | 174 | 0.0819 | | 0.132 | | 159 | 0.0596 | | 0.115 | |
| $^{239,240}Pu$ | 0.49 | | 1.6(-4) | | 7.8(-4) | 0.290 | | 1.8(-4) | | 1.3(-3) |
| Subtotal | | 0.0826 | 1.07 | 0.133 | 1.72 | | 0.0596 | 0.898 | 0.115 | 1.75 |
| Total 30-yr whole-body dose | | 0.142 rem | | | | Total 70-yr whole-body dose | | 0.248 rem | | |
| Total 30-yr bone dose | | 2.11 rem | | | | Total 70-yr bone dose | | 3.71 rem | | |

[a]The number within parentheses denotes the power of 10; thus, 1.0(-4) is a contraction of $1.0 \times 10^{-4}$.

Table 241. The 30-yr integral dose for the six living patterns assuming unmodified conditions.

| Living pattern | Inhalation | | | External | Terrestrial[b] | | Marine[b] | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30-yr integral dose, rem — Unmodified conditions | | | | | | | | | |
| | Bone | Lung | Liver | Bone,[a] W.B. | W.B. | Bone | W.B. | Bone | W.B. | Bone |
| I | 7(-4) | 9(-4) | 4(-4) | 0.83 | 0.14 | 2.1 | 0.053 | 0.84 | 1.0 | 3.8 |
| II | 0.029 | 0.036 | 0.016 | 1.6 | 2.7 | 33 | 0.053 | 0.84 | 4.4 | 35 |
| III | 0.10 | 0.13 | 0.056 | 4.0 | 7.1 | 75 | 0.053 | 0.84 | 11 | 80 |
| IV | 0.47 | 0.59 | 0.25 | 10 | 21 | 210 | 0.053 | 0.84 | 31 | 220 |
| V | 0.11 | 0.13 | 0.058 | 2.9 | 2.7 | 33 | 0.053 | 0.84 | 5.7 | 37 |
| VI | 0.090 | 0.11 | 0.049 | 4.4 | 9.6 | 130 | 0.053 | 0.84 | 14 | 135 |

| Living pattern | Village island | Agriculture | Visitation |
|---|---|---|---|
| I | Enewetak-Parry | ALVIN-KEITH | Southern Is. |
| II | Enewetak-Parry | KATE-WILMA + LEROY | Northern Is. |
| III | JANET | JANET | Northern Is. |
| IV | BELLE | BELLE | Northern Is. |
| V | JANET | KATE-WILMA + LEROY | Northern Is. |
| VI | JANET | ALICE-IRENE | Northern Is. |

[a]Taken from the chapter on external dose estimates, Table 22.
[b]Based upon diet 10 yr after return, as described in the dietary and living patterns chapter.

the external dose assessment, is based upon the unmodified conditions for the village island. The largest contribution to the whole-body and bone doses comes from the terrestrial food chain, the external dose pathway is the next highest contributor, and the marine food chain and inhalation pathway contribute the least.* The relative contributions of each diet component to the terrestrial pathway dose is shown in Tables 242 and 243.

In general, living on JANET, visiting northern islands, and maintaining agriculture on northern islands (living patterns III, V, and VI) lead to significantly higher doses than if the village and agriculture are located on islands in the southern half of the Atoll (living pattern I). Doses for these same patterns have been calculated for 5, 10, and 70 yr and are shown in Table 244.

The most significant contribution via the terrestrial food chain is the dose to bone resulting from $^{90}Sr$ uptake via pandanus fruit and breadfruit. For living pattern III, for example, the total terrestrial bone dose is 75 rem, of which 74% is derived from the intake of breadfruit and pandanus. It is important to note, however, that the large contribution to the bone dose via these fruits occurs only when they are grown on northern islands. Pandanus and breadfruit grown on the less contaminated southern islands lead to much lower dose commitments.

Table 245 shows the 30-yr integral dose for the six living patterns for the modified soil condition, i.e., where the village area has 5 cm of gravel and the village island is plowed. Table 246 shows the 5-, 10-, 30-, and 70-yr dose estimates for the same conditions.

Table 247 shows the additional effect on the 30-yr integral dose of limiting growth of pandanus, breadfruit, coconut, and tacca to the southern islands, while Table 248 shows the effect of limiting all terrestrial foods to the southern islands. The effect of the combination of these preventive measures reduces the dose for living pattern III from 11 rem to 1.9 rem for whole body and from 80 to 4.7 rem for bone.

A comparison of the 30-yr integral dose for living patterns I and III relative to the average United States external background dose over 30 yr is shown in Table 249.

Plutonium isotopes, because of their long half-lives, will still be present when the other major isotopes observed at the Atoll have decayed away; therefore, Tables 250 and 251 are included to show the predicted doses from plutonium to the three major receptor organs (lung, liver, and bone) via the three relevant exposure pathways.

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*As indicated earlier, these dose calculations assume that the Enewetak people will continue their current practice of using catchment rain water for drinking and that the underground lens water supply will not be a part of their diet. An indication of doses that are to be expected from lens water may be obtained from four water samples taken on JANET in July 1971. These samples, two each from each of two 2.5-m-deep holes about 100 m from the lagoon shore, gave average concentrations of 130 pCi/liter for $^{90}Sr$, and 400 pCi/liter for $^{137}Cs$. $^{239}Pu$ concentrations were scattered (<0.03, 21, <0.03, and 17 pCi/liter) but, for our current purpose, we will assume an average value of 20 pCi/liter.

Using these concentrations, and assuming an average daily intake of 100 ml of lens water, the resulting 30-yr doses would be 0.83 rem due to $^{90}Sr$, 0.019 rem due to $^{137}Cs$, and 0.00082 rem due to $^{239}Pu$.

The island of YVONNE presents a unique hazard on Enewetak Atoll. Pure plutonium particles are present on or close to the ground surface, randomly scattered in "hot spots" over most of the area from the tower to CACTUS crater. Examination of these "hot spots" has revealed the presence of occasional milligram-size pieces of plutonium metal, as well as smaller pieces which are physically indistinguishable in size from the surrounding coral matrix. Given these current conditions, it must be assumed that pure plutonium particles of respirable size are now also present on the surface or may be present in the future as weathering effects oxidize and break down the larger particles. Lung dose assessments for this area, therefore, must be based on inhalation of pure plutonium particles rather than those having the average plutonium content of the soil.

The potential health hazard via the inhalation pathway is sufficiently great to dictate two basic alternatives for remedial action for this island: (1) Make the entire island an exclusion area – off limits to all people, or (2) conduct a cleanup campaign which will eliminate the "hot-spot" plutonium problem and remove whatever amount of soil is necessary to reduce the soil plutonium concentration to a level comparable to other northern islands. As an indication of the volumes of soil involved, removal of a 10-cm-thick layer of topsoil in the area in which "hot spots" have been detected involves approximately 17,000 $m^3$ of material. Further removal of soil to reduce the maximum plutonium contamination levels to 50 pCi/g or less involves an additional 25,000 $m^3$ of material.

Table 242. Relative contributions of terrestrial foods to the integral dose assuming diet at time of return.

| Food item | Percentage of total 5-yr | | Percentage of total 10-yr | |
|---|---|---|---|---|
| | $^{90}$Sr dose to bone | $^{137}$Cs dose whole body | $^{90}$Sr dose to bone | $^{137}$Cs dose whole body |
| A. Island group ALICE-IRENE | | | | |
| Domestic meat | 98.9 | 100 | 43.9 | 46.9 |
| Pandanus fruit | | | 26.8 | 24.7 |
| Breadfruit | | | 23.1 | 21.1 |
| Wild birds | 0.65 | <0.08 | 0.29 | 0.04 |
| Bird eggs | 0.24 | <0.008 | 0.11 | 0.004 |
| Arrowroot | | | 1.3 | 0.20 |
| Coconut meat | | | 3.9 | 6.2 |
| Coconut milk | | | 0.57 | 0.93 |
| B. Island group BELLE | | | | |
| Domestic meat | 100 | 100 | 44.2 | 47.1 |
| Pandanus fruit | | | 27.0 | 24.6 |
| Breadfruit | | | 23.2 | 21.1 |
| Arrowroot | | | 1.4 | 0.20 |
| Coconut meat | | | 3.9 | 6.2 |
| Coconut milk | | | 0.58 | 0.92 |

Table 242 (continued)

| Food item | Percentage of total 5-yr | | Percentage of total 10-yr | |
|---|---|---|---|---|
| | $^{90}$Sr dose to bone | $^{137}$Cs dose whole body | $^{90}$Sr dose to bone | $^{137}$Cs dose whole body |
| C. Island group JANET | | | | |
| Domestic meat | 99. 1 | 100 | 43. 9 | 47. 0 |
| Pandanus fruit | | | 26. 9 | 24. 8 |
| Breadfruit | | | 22. 9 | 20. 8 |
| Wild birds | 0. 27 | 0. 11 | 0. 12 | 0. 05 |
| Bird eggs | 0. 89 | 0. 03 | 0. 39 | 0. 01 |
| Arrowroot | | | 1. 4 | 0. 20 |
| Coconut meat | | | 3. 9 | 6. 2 |
| Coconut milk | | | 0. 59 | 0. 93 |
| D. Island group KATE-WILMA + LEROY | | | | |
| Domestic meat | 95. 4 | 98. 8 | 43. 1 | 46. 3 |
| Pandanus fruit | | | 26. 4 | 24. 7 |
| Breadfruit | | | 22. 7 | 21. 1 |
| Wild birds | 0. 58 | 0. 29 | 0. 26 | 0. 14 |
| Bird eggs | 0. 04 | <0. 03 | 0. 02 | 0. 01 |
| Arrowroot | | | 1. 3 | 0. 20 |
| Coconut meat | | | 3. 8 | 6. 2 |
| Coconut milk | | | 0. 57 | 0. 93 |
| Coconut crabs | 3. 9 | 0. 87 | 2. 4 | 0. 41 |
| E. Island group ALVIN-KEITH | | | | |
| Domestic meat | 48.7 | 37. 7 | 41. 7 | 30. 9 |
| Pandanus fruit | | | 7. 6 | 9. 6 |
| Breadfruit | | | 6. 5 | 8. 2 |
| Wild birds | 2. 9 | 1. 9 | 2. 5 | 1. 5 |
| Bird eggs | 0. 2 | <0. 26 | 0. 13 | 0. 21 |
| Arrowroot | | | 0. 38 | 0. 08 |
| Coconut meat | 26. 4 | 50. 9 | 22. 6 | 41. 8 |
| Coconut milk | 1. 4 | 2. 5 | 1. 1 | 2. 1 |
| Coconut crabs | 20. 3 | 6. 9 | 17. 4 | 5. 6 |

Table 243. Relative contributions of terrestrial foods to the integral dose assuming 10-yr post-return diet.

| Food item | Percentage of total 30-yr dose | | | | Percentage of total 70-yr dose | | | |
|---|---|---|---|---|---|---|---|---|
| | $^{90}Sr$ dose to bone | | $^{137}Cs$ dose to whole body | | $^{90}Sr$ dose to bone | | $^{137}Cs$ dose to whole body | |
| | Commencement date | | Commencement date | | Commencement date | | Commencement date | |
| | 1/1/74 | 1/1/82 | 1/1/74 | 1/1/82 | 1/1/74 | 1/1/82 | 1/1/74 | 1/1/82 |
| **A. Island group ALICE-IRENE** | | | | | | | | |
| Domestic meat | 16.7 | | 25.5 | | 14.2 | | 22.3 | |
| Pandanus fruit | | 40.2 | | 34.7 | | 41.4 | | 36.2 |
| Breadfruit | | 34.5 | | 29.6 | | 35.5 | | 31.0 |
| Wild birds | 0.01 | | <0.002 | | 0.01 | | <0.002 | |
| Bird eggs | 0.01 | | <0.0005 | | 0.01 | | <0.004 | |
| Arrowroot | | 2.0 | | 0.28 | | 2.1 | | 0.29 |
| Coconut meat | | 5.8 | | 8.7 | | 5.9 | | 9.1 |
| Coconut milk | | 0.85 | | 1.3 | | 0.88 | | 1.4 |
| Subtotal | 17 | 83 | 26 | 74 | 14 | 86 | 22 | 78 |
| **B. Island group BELLE** | | | | | | | | |
| Domestic meat | 16.7 | | 25.4 | | 14.3 | | 22.3 | |
| Pandanus fruit | | 40.2 | | 34.5 | | 41.5 | | 36.1 |
| Breadfruit | | 34.5 | | 29.6 | | 35.6 | | 31.0 |
| Arrowroot | | 2.0 | | 0.27 | | 2.1 | | 0.29 |
| Coconut meat | | 5.8 | | 8.7 | | 6.0 | | 9.0 |
| Coconut milk | | 0.86 | | 1.3 | | 0.89 | | 1.4 |
| Subtotal | 17 | 83 | 25 | 75 | 14 | 86 | 22 | 78 |

Table 243 (Continued).

| Food item | Percentage of total 30-yr dose: $^{90}Sr$ dose to bone, Commencement date 1/1/74 | 1/1/82 | $^{137}Cs$ dose to whole body, Commencement date 1/1/74 | 1/1/82 | Percentage of total 70-yr dose: $^{90}Sr$ dose to bone, Commencement date 1/1/74 | 1/1/82 | $^{137}Cs$ dose to whole body, Commencement date 1/1/74 | 1/1/82 |
|---|---|---|---|---|---|---|---|---|
| C. Island group JANET | | | | | | | | |
| Domestic meat | 16.7 | | 25.7 | | 14.2 | | 22.6 | |
| Pandanus fruit | | 39.6 | | 34.8 | | 41.2 | | 36.6 |
| Breadfruit | | 34.4 | | 29.3 | | 35.3 | | 30.7 |
| Wild birds | 0.005 | | 0.003 | | 0.005 | | 0.003 | |
| Bird eggs | 0.05 | | 0.002 | | 0.04 | | 0.002 | |
| Arrowroot | | 2.0 | | 0.28 | | 2.1 | | 0.29 |
| Coconut meat | | 5.8 | | 8.7 | | 5.9 | | 9.1 |
| Coconut milk | | 0.88 | | 1.3 | | 0.90 | | 1.4 |
| Subtotal | 17 | 83 | 26 | 74 | 14 | 86 | 23 | 77 |
| D. Island group KATE-WILMA + LEROY | | | | | | | | |
| Domestic meat | 16.6 | | 25.2 | | 14.2 | | 22.0 | |
| Pandanus fruit | | 39.8 | | 34.8 | | 41.2 | | 36.2 |
| Breadfruit | | 34.2 | | 29.7 | | 35.4 | | 30.9 |
| Wild birds | 0.01 | | 0.009 | | 0.01 | | 0.008 | |
| Bird eggs | 0.002 | | 0.003 | | 0.002 | | 0.002 | |
| Arrowroot | | 2.0 | | 0.28 | | 2.0 | | 0.29 |
| Coconut meat | | 5.7 | | 8.7 | | 5.9 | | 9.0 |
| Coconut milk | | 0.86 | | 1.3 | | 0.89 | | 1.4 |
| Coconut crabs | 0.41 | | 0.13 | | 0.35 | | 0.12 | |
| Subtotal | 17 | 83 | 25 | 75 | 15 | 85 | 22 | 78 |

Table 243 (Continued).

| Food item | Percentage of total 30-yr dose | | | | Percentage of total 70-yr dose | | | |
|---|---|---|---|---|---|---|---|---|
| | $^{90}Sr$ dose to bone | | $^{137}Cs$ dose to whole body | | $^{90}Sr$ dose to bone | | $^{137}Cs$ dose to whole body | |
| | Commencement date | | Commencement date | | Commencement date | | Commencement date | |
| | 1/1/74 | 1/1/82 | 1/1/74 | 1/1/82 | 1/1/74 | 1/1/82 | 1/1/74 | 1/1/82 |
| E. Island group ALVIN-KEITH | | | | | | | | |
| Domestic meat | 33.3 | | 28.3 | | 30.3 | | 26.2 | |
| Pandanus fruit | | 24.1 | | 22.5 | | 26.5 | | 25.0 |
| Breadfruit | | 20.6 | | 19.4 | | 22.7 | | 21.4 |
| Wild birds | 0.24 | | 0.17 | | 0.22 | | 0.16 | |
| Bird eggs | 0.03 | | 0.06 | | 0.03 | | 0.05 | |
| Arrowroot | | 1.2 | | 0.18 | | 1.3 | | 0.20 |
| Coconut meat | 10.8 | | 22.9 | | 9.9 | | 21.2 | |
| Coconut milk | 1.6 | | 3.4 | | 1.5 | | 3.2 | |
| Coconut crabs | 8.3 | | 3.1 | | 7.6 | | 2.9 | |
| Subtotal | 54 | 46 | 58 | 42 | 50 | 50 | 54 | 46 |

Table 244. The 5-, 10-, 30-, and 70-yr doses for the six living patterns assuming unmodified conditions.

| Living pattern | Total integral dose, rem Unmodified conditions | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 yr | | 10 yr | | 30 yr | | 70 yr | |
| | W. B. | Bone | W. B. | Bone | W. B. | Bone | W. B. | Bone |
| I | 0.17 | 0.58 | 0.35 | 1.4 | 1.0 | 3.8 | 2.3 | 8.5 |
| II | 0.48 | 1.3 | 1.1 | 4.3 | 4.4 | 35 | 8.0 | 68 |
| III | 1.2 | 2.6 | 2.7 | 9.2 | 11 | 80 | 20 | 150 |
| IV | 3.4 | 6.9 | 7.6 | 25 | 31 | 220 | 56 | 420 |
| V | 0.81 | 1.6 | 1.7 | 4.9 | 5.7 | 37 | 10 | 71 |
| VI | 1.5 | 3.8 | 3.3 | 14 | 14 | 135 | 25 | 250 |

Table 245. The 30-yr integral dose for the six living patterns assuming modified conditions.

| Living pattern | 30-yr integral dose, rem Modified conditions[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inhalation | | | External | Terrestrial | | Marine | | Total | |
| | Bone | Lung | Liver | Bone, W. B. | W. B. | Bone | W. B. | Bone | W. B. | Bone |
| I | 3(-4) | 4(-4) | 2(-4) | 0.83 | 0.14 | 2.1 | 0.053 | 0.84 | 1.0 | 3.8 |
| II | 0.012 | 0.015 | 6.6(-3) | 1.1 | 2.7 | 33 | 0.053 | 0.84 | 3.9 | 35 |
| III | 0.045 | 0.056 | 0.024 | 1.7 | 7.1 | 75 | 0.053 | 0.84 | 8.9 | 78 |
| IV | 0.092 | 0.11 | 0.050 | 3.3 | 21 | 210 | 0.053 | 0.84 | 24 | 215 |
| V | 0.045 | 0.056 | 0.024 | 1.6 | 2.7 | 33 | 0.053 | 0.84 | 4.4 | 35 |
| VI | 0.058 | 0.072 | 0.031 | 3.1 | 9.6 | 130 | 0.053 | 0.84 | 13 | 135 |

[a] Modified by graveling the village area and by plowing the village island.

Table 246. The 5-, 10-, 30-, and 70-yr doses for the six living patterns assuming modified conditions.

| Living pattern | Total integral dose, rem Modified conditions[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 yr | | 10 yr | | 30 yr | | 70 yr | |
| | W. B. | Bone | W. B. | Bone | W. B. | Bone | W. B. | Bone |
| I | 0.17 | 0.58 | 0.35 | 1.4 | 1.0 | 3.8 | 2.3 | 8.5 |
| II | 0.48 | 1.3 | 1.1 | 4.3 | 3.9 | 35 | 8.0 | 68 |
| III | 0.60 | 2.1 | 1.7 | 8.2 | 8.9 | 78 | 16 | 150 |
| IV | 1.5 | 5.0 | 4.3 | 22 | 24 | 215 | 46 | 410 |
| V | 0.46 | 1.3 | 1.0 | 4.3 | 4.4 | 35 | 8.0 | 68 |
| VI | 1.1 | 3.4 | 2.7 | 13 | 13 | 135 | 23 | 250 |

[a]Modified by gravelling the village area and plowing the village island.

Table 247. The 30-yr integral dose for the six living patterns assuming modified conditions and agriculture on the southern islands.

| Living pattern | 30-yr integral dose, rem Modified conditions[a] and pandanus, breadfruit, coconut, and tacca grown on southern islands | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inhalation | | | External | Terrestrial[c] | | Marine | | Total | |
| | Bone | Lung | Liver | Bone, W. B. | W. B. | Bone | W. B. | Bone | W. B. | Bone |
| I | 3(-4) | 4(-4) | 2(-4) | 0.83 | 0.14 | 2.1 | 0.053 | 0.84 | 1.0 | 3.8 |
| II | 0.012 | 0.015 | 0.0066 | 1.1 | 0.77 | 7.1 | 0.053 | 0.84 | 1.9 | 9.1 |
| III | 0.045 | 0.056 | 0.024 | 1.7 | 1.9 | 15 | 0.053 | 0.84 | 3.7 | 18 |
| IV | 0.092 | 0.11 | 0.050 | 3.3 | 5.7 | 39 | 0.053 | 0.84 | 9.1 | 43 |
| V | 0.045 | 0.056 | 0.024 | 1.6 | 0.77 | 7.1 | 0.053 | 0.84 | 2.4 | 9.6 |
| VI | 0.058 | 0.072 | 0.031 | 3.1 | 2.5 | 23 | 0.053 | 0.84 | 5.7 | 27 |

[a]Modified by graveling the village area and by plowing the village island.

Table 248. The 30-yr integral dose for the six living patterns assuming modified conditions and agriculture on the southern islands.

| | 30-yr integral dose, rem Modified conditions[a] and agriculture on southern islands | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inhalation | | | External | Terrestrial | | Marine | | Total | |
| Living pattern | Bone | Lung | Liver | Bone, W.B. | W.B. | Bone | W.B. | Bone | W.B. | Bone |
| I | 3(-4) | 4(-4) | 2(-4) | 0.83 | 0.14 | 2.1 | 0.053 | 0.84 | 1.0 | 3.8 |
| II | 0.012 | 0.015 | 0.0066 | 1.1 | 0.14 | 2.1 | 0.053 | 0.84 | 1.3 | 4.1 |
| III | 0.045 | 0.056 | 0.024 | 1.7 | 0.14 | 2.1 | 0.053 | 0.84 | 1.9 | 4.7 |
| IV | 0.092 | 0.11 | 0.050 | 3.3 | 0.14 | 2.1 | 0.053 | 0.84 | 3.5 | 6.3 |
| V | 0.045 | 0.056 | 0.024 | 1.6 | 0.14 | 2.1 | 0.053 | 0.84 | 1.8 | 4.6 |
| VI | 0.058 | 0.072 | 0.031 | 3.1 | 0.14 | 2.1 | 0.053 | 0.84 | 3.3 | 6.1 |

[a]Modified by graveling the village area and by plowing the village island.

Table 249. The 30-yr integral dose from all pathways compared to U. S. external background dose.

| | 30-yr integral dose,[a] rem | | | |
|---|---|---|---|---|
| | Unmodified case | | Modified case | |
| Location | Whole body | Bone | Whole body | Bone |
| Enewetak Atoll Living pattern I | 1.0 | 3.8 | 1.0 | 3.8 |
| Enewetak Atoll Living pattern III | 11 | 80 | 8.9 | 78 |
| Enewetak Atoll Living pattern III, agriculture confined to southern islands | 4.2 | 7.0 | 1.9 | 4.7 |
| U. S. background only[b] | 3.0 | 3.0 | 3.0 | 3.0 |

[a]Sum of all pathways for the Enewetak living patterns (i.e., external, inhalation, marine, and terrestrial).
[b]Based upon background of 100 mrem/yr at sea level.

Table 250. The plutonium 30-yr integral dose to bone, liver, and lung via the three exposure pathways. This table assumes unmodified conditions on the village island.

| Living pattern | Plutonium 30-yr integral dose, rem Unmodified conditions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | | Terrestrial | | | Inhalation | | | Total | | |
| | Bone | Liver | Lung | Bone | Liver | Lung | Bone | Liver | Lung | Bone | Liver | Lung |
| I | 0.018 | 0.047 | - | 5.0(-5) | 1.8(-4) | - | 7(-4) | 4(-4) | 9(-4) | 0.018 | 0.048 | 9(-4) |
| II | 0.018 | 0.047 | - | 1.5(-3) | 5.0(-3) | - | 0.029 | 0.016 | 0.036 | 0.049 | 0.068 | 0.036 |
| III | 0.018 | 0.047 | - | 6.9(-3) | 5.3(-3) | - | 0.10 | 0.056 | 0.13 | 0.12 | 0.11 | 0.13 |
| IV | 0.018 | 0.047 | - | 3.0(-3) | 0.010 | - | 0.47 | 0.25 | 0.59 | 0.49 | 0.31 | 0.59 |
| V | 0.018 | 0.047 | - | 5.0(-5) | 1.8(-4) | - | 0.11 | 0.058 | 0.13 | 0.13 | 0.11 | 0.13 |
| VI | 0.018 | 0.047 | - | 3.0(-3) | 0.010 | - | 0.090 | 0.049 | 0.11 | 0.11 | 0.11 | 0.11 |

Table 251. The plutonium 30-yr integral dose to bone, liver, and lung via the three exposure pathways. This table assumes modified conditions.

| Living pattern | Plutonium 30-yr integral dose, rem Modified conditions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | | Terrestrial | | | Inhalation | | | Total | | |
| | Bone | Liver | Lung | Bone | Liver | Lung | Bone | Liver | Lung | Bone | Liver | Lung |
| I | 0.018 | 0.047 | - | 5.0(-5) | 1.8(-4) | - | 3(-4) | 2(-4) | 4(-4) | 0.018 | 0.047 | 4(-4) |
| II | 0.018 | 0.047 | - | 1.5(-3) | 5.0(-3) | - | 0.012 | 0.0066 | 0.015 | 0.032 | 0.057 | 0.015 |
| III | 0.018 | 0.047 | - | 6.9(-3) | 5.3(-3) | - | 0.045 | 0.024 | 0.056 | 0.070 | 0.076 | 0.056 |
| IV | 0.018 | 0.047 | - | 3.0(-3) | 0.010 | - | 0.092 | 0.050 | 0.11 | 0.11 | 0.11 | 0.11 |
| V | 0.018 | 0.047 | - | 5.0(-5) | 1.8(-4) | - | 0.045 | 0.024 | 0.056 | 0.063 | 0.071 | 0.056 |
| VI | 0.018 | 0.047 | - | 3.0(-3) | 0.010 | - | 0.058 | 0.031 | 0.072 | 0.079 | 0.088 | 0.072 |

## APPENDIX III

## REVIEW OF RADIATION PROTECTION STANDARDS

The Task Group has considered a number of concepts in devising an approach to guidance for cleanup and rehabilitation of Enewetak Atoll, accepting some and rejecting others. Notably, the concept that AEC recommendations should consist of a series of alternatives or fall back positions with the degree or level of radiation exposure reduction ultimately determined by some later deliberation based on factors such as availability of funds was rejected. The consensus of the Task Group opinion was that these recommendations should be specific and unequivocal, and should establish a clear position on what is needed. To do less would be unfair to the Federal agencies who have accepted responsibilities to perform the rehabilitations and to the Enewetak people who are looking to this agency for advice.

The judgement of the Task Group is that rehabilitation must conform with current radiation standards applicable for normal operations (not for accidents or for radiation workers) and with good health physics practice in implementing these standards. A summary of current radiation protection standards and material related to health risks that may be associated with the standards reviewed and radiation criteria recommended by the Task Group follows.

A. Federal Radiation Council (FRC)

Basic FRC numerical guidance and health protection philosophy are similar to those of the ICRP and NCRP. Radiation Protection Guides (RPG's) are provided which deal with exposures of individuals and of population groups. Actions are to be directed primarily toward control of the sources of radioactivity to restrict entry into the environment but also toward control of radioactive materials after entry into the environment in order to limit intake by humans. The RPG's express the dose that should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. The RPG's are intended for use with normal peacetime operations. There should be no man-made radiation exposure without expectation of benefits from such exposure. Considering such benefits, exposure at the level of the RPG is considered as an acceptable risk for a lifetime. The RPG's for the population are expressed in terms of annual exposure, except for the gonads, where the ICRP recommended value of five rems in 30 years is used. FRC states that the operational mechanism described for application of criteria to limit the whole body dose for individuals to 0.5 rem per year and to limit exposure of a suitable sample of the population to 0.17 rem per year is likely to assure that the gonadal exposure guide will not be exceeded.

The child, infant, and unborn infant are identified as being more sensitive to radiation than the adult. Exposures to be compared with the guidance are to be derived for the most sensitive members in the population. The guide for the individual applies when individual exposures are known; otherwise, the guide for a suitable sample (one-third the guide for the individual) is to be used. This operational technique may be modified to meet special situations.

The FRC primary numerical guides, expressed in rem, are provided in two reports, FRC Nos. 1 and 2, summarized in Table I. Secondary numerical guides developed by FRC are expressed in terms of daily intake of specific radionuclides corresponding to the annual RPG's. Consideration is given to all radionuclides through all pathways to derive a total annual exposure for comparison with FRC guides. However, for many practical situations, relatively few radionuclides yield the major contribution to total exposure; by comparison, exposures from others are very small.

TABLE I

FRC RADIATION PROTECTION GUIDES 1/

| | INDIVIDUAL | POPULATION GROUP |
|---|---|---|
| Whole body | 0.5 rem/yr | 0.17 rem/yr |
| Gonads | - | 5 rems/30 yrs |
| Thyroid 2/ | 1.5 rems/yr | 0.5 rem/yr |
| Bone marrow | 0.5 rem/yr | 0.17 rem/yr |
| Bone | 1.5 rems/yr | 0.5 rem/yr |
| Bone (alternate guide) 3/ | 0.003 µg of $^{226}Ra$ in adult skeleton | 0.001 µg of $^{226}Ra$ in adult skeleton |

1/ For conditions and qualifications see FRC Report Nos. 1 and 2.

2/ Based upon a child's thyroid, 2 gms in weight and other factors listed in paragraphs 2.10-2.14 of FRC Report No. 2.

3/ Or the biological equivalents of these amounts of $^{226}Ra$.

B. The International Commission on Radiological Protection (ICRP)

The ICRP originated in the Second International Congress of Radiology in 1928. It has been looked to as the appropriate body to give general guidance on widespread use of radiation sources caused by rapid developments in the field of nuclear energy. ICRP recommendations deal with the basic principles of radiation protection. To the various national protection bodies is left the responsibility for introducing the detailed technical regulations, recommendations, or codes of practice best suited to their countries. Recommendations are intended to guide the experts responsible for radiation protection practice.

ICRP states that the objectives of radiation protection are to prevent acute radiation effects and to limit the risks of late effects to an acceptable level. It holds that it is unknown whether a threshold exists, and it is assumed that even the smallest doses involve a proportionately small risk. No practical alternative was found to assuming a linear relationship between dose and effect. This implies that there is no wholly "safe" dose of radiation.

Exposure to natural background radiation carries a probability of causing some somatic or hereditary injury. However, the Commission believes that the risk resulting from exposures received from natural background should not affect the justification of an additional risk from man-made exposures. Accordingly, any dose limitations recommended by the Commission refer only to exposure resulting from technical practices that add to natural background radiation. These dose limitations exclude exposures received in the course of medical procedures. (These same qualifications with regard to natural background and medical procedures are applied to NCRP and FRC recommendations.)

ICRP developed the concept of "acceptable risk." Unless man wishes to dispense with activities involving exposures to ionizing radiation, he must recognize that there is a degree of risk and must limit the radiation dose to a level at which the assumed risk is deemed to be acceptable to the individual and to society in view of the benefits derived from such activities.

For planned or controlled exposures of individuals and populations, the ICRP has recommended the term "dose limit." Recommended dose limits are thought to be associated with a very low degree of risk. For unplanned exposures from uncontrolled sources the term "action level" is recommended. In general it will be appropriate to institute countermeasures only when their social cost and risk will be less than those resulting from the exposure. Setting of action levels is the responsibility of national authorities.

It is not desirable to expose members of the public to doses as high as those considered to be acceptable for radiation workers because children are involved, members of the public do not make the choice to be exposed, and members of the public are not subject to selection, supervision and monitoring, and are exposed to the risks of their own occupations. For planning purposes, dose limits for members of the public are set a factor of ten below those for radiation workers.

The ICRP dose limits for individual members of the public are presented in Table II. No maximum "somatically significant" dose for a population is given. The genetic dose to the population should be kept to the minimum amount consistent with necessity and should not exceed 5 rems in 30 years from all sources other than natural background and medical procedures. No single type of population exposure should take up a disproportionate share of the total of the recommended dose limit.

TABLE II

ICRP DOSE LIMITS 1/

| | Individuals | Population |
|---|---|---|
| Gonads, red bone-marrow | 0.5 rem/yr | - |
| Skin, bone, thyroid | 3.0 rems/yr 2/ | - |
| Hands and forearms; feet and ankles | 7.5 rems/yr | - |
| Other single organs | 1.5 rems/yr | - |
| Genetic dose 3/ | - | 5 rems/30 yrs |

1/ For conditions and qualifications see ICRP Publication 9.

2/ 1.5 rems/yr to thyroid of children up to 16 years of age.

3/ See paragraphs 84, 85, and 86, ICRP Publication 9.

C. National Council on Radiation Protection and Measurements* (NCRP)

The NCRP position is that the rational use of radiation should conform to levels of safety to users and the public which are at least as stringent as those achieved for other powerful agents. Continuing and chronic exposure attributable to peaceful uses of ionizing radiation are assumed.

The NCRP has adopted the assumption of no-threshold dose-effects relationship and uses the term "dose limits" in providing guidance on population exposures. All radiation exposures are to be kept as low as practicable. The numerical values of exposure as presented are to be interpreted as recommendations, not regulations. Use of the no-threshold concept involves the thesis that there is no exposure limit free from some degree of risk.

To establish criteria, NCRP uses the concept of "acceptable risk" (where the risk is compensated by a demonstrable benefit) broken down to fit classes of individuals or population groups exposed for various purposes to different quantities of radiation. Numerical recommendations for dose limits are necessarily arbitrary because of their mixed technical value-judgement foundation. The dose limits for individual members of the public and for the average population recommended by NCRP represent a level of risk considered to be so small compared with other hazards of life, and so well offset by perceptible benefits when used as intended, that public approbation will be achieved when the informed public review process is completed.

For peaceful uses of radiation, NCRP provides yearly numerical dose limits for individual members of the public, considering possible somatic effects, and strongly advocates maintenance of lowest practicable exposure levels, especially for infants and the unborn. NCRP also recommends yearly dose limits for the average population based upon somatic and genetic considerations and recommends the same value as ICRP of 5 rems in 30 years for gonadal exposure of the U. S. population. Table III contains a summary of recommended values. NCRP Report No. 39 entitled, "Basic Radiation Protection Criteria," dated January 15, 1971, contains the most recent updating of NCRP recommendations for protection of the public.

*Formerly known as the National Committee on Radiation Protection and Measurements.

TABLE III

NCRP DOSE LIMITS 1/

| | Individual | Population |
|---|---|---|
| Whole body | 0.5 rem/yr | 0.17 rem/yr |
| Gonads | - | 0.17 rem/yr 2/ |
| Gonads (alternative 3/ objective) | | 5.0 rems/30 yrs |

D. Criteria Against Which Survey Findings and Alternative Measures Will Be Evaluated

The Task Group approached the question of radiation dose criteria from two directions. First, FRC, ICRP, and NCRP recommendations reviewed above were judged as to applicability in this situation. Second, a risk approach was reviewed using information from ICRP, UNSCEAR, and the National Academy of Science BEIR Committee. The results of this latter effort are summarized in Part F which follows.

The radiological survey of Enewetak Atoll provides a comprehensive data base needed to derive recommendations relative to the radiologically safe return of the Enewetak people. These recommendations are to be based on an evaluation of the significance of all radioactivity on the Atoll in terms of the total exposure to be expected in the returning population, and on consideration of those reasonable actions and constraints which, where made, will result in minimum exposures.

The guidelines used in deriving these recommendations can be summarized as two interdependent considerations:

1. Expected exposures should be minimized and should fall in a range consistent with guidance put forward by the Federal Radiation Council (FRC).

1/ For conditions and qualifications on application, see NCRP Report No. 39, "Basic Radiation Protection Criteria."

2/ To be applied as the average yearly value for the population of the United States as a whole. See paragraph 247, NCRP Report No. 39.

3/ See paragraph 247, NCRP Report No. 39.

2. Actions taken to reduce exposures should be those which show promise of significant exposure reduction when weighed against total expected exposures and the "costs" of the actions. "Costs," in this context, are measured primarily in terms of costs to the Enewetak people as constraints on their activities or as dollar costs for cleanup or remedial action.

In these evaluations, it should be emphasized that dosages through various pathways are estimated on the basis of environmental data and considerations of expected living patterns and dietary habits. While "radiation standards" do not exist for environmental contamination levels in substances such as soil and foodstuffs, there is general agreement in terms of conservative models of these pathways and the relationships between a certain level in the environment and the likely dose to result from the pathway exposure.

The area of plutonium in soils, however, is one for which there is no general agreement as to the quantitative relationship between levels in soils and dosages to be expected through the inhalation pathway, the primary one through which man can receive a significant dose from plutonium. The ICRP recommends a maximum permissible average concentration (MPC) of 1 picocurie per cubic meter ($pCi/m^3$) of air for "insoluble" plutonium and 0.06 $pCi/m^3$ for "soluble" plutonium for unrestricted areas. While the plutonium in the soil at Enewetak is thought to be typical of world-wide fallout, and therefore insoluble, 0.06 $pCi/m^3$ will be used for the sake of conservatism.

Appendix A of Enewetak Radiological Survey, NVO-140, presents two possible methods for deriving the exposures that may occur through the inhalation pathway for plutonium in soil. (This is the pathway of interest for the present although it is recognized that for the very distant future, ingestion may become more important by comparison. Table 250 of Appendix II shows that exposure to bone, liver, and lung from $^{239}Pu$ is expected to be a few hundredths of a rem in 30 years for pathways other than inhalation.) This material is produced as Attachment I of this section. The two methods presented are the "resuspension-factor" approach and the "mass-loading" approach. Soil concentrations of $^{239}Pu$ that would be associated with the standard for $^{239}Pu$ in air (0.06 $pCi/m^3$) by the two methods are:

Resuspension-factor approach ............. 1,000 pCi/g

Mass-loading approach .................... 600 pCi/g

A recent report, A Proposed Interim Standard for Plutonium in Soils LA5483-MS, presents recommendations derived from estimates of exposure through inhalation considering the concentration of $^{239}$Pu in the very top surface soil.

The following values were recommended:

400 pCi/g - For all particle sizes provided no more than 200 pCi/g in < 100/mm size fraction.

A revised Maximum Permissible Concentration, MPC, of 0.3 pCi/m$^3$ for individuals was used in these determinations. The estimates apply to large area contamination. Levels several times larger could be permitted for localized deposition.

The Task Group recognizes that the islands of Enewetak Atoll are small and that the areas of highest $^{239}$Pu in soil on these islands are smaller still. On the other hand the people live close to the soil. It is also recognized that experts are not in agreement as to the critical organ for inhaled plutonium, whether to use an average dose for this organ, or the model to be used to predict dose. It is the view of the Task Group that available biological and environmental information is not adequate to establish general guidance for cleanup of plutonium contaminated soil. However, guidance for a particular set of circumstances or conditions can be developed on a case-by-case basis using conservative assumptions and safety factor. The following guidance is recommended only for use in making decisions concerning plutonium cleanup operations on islands of Enewetak Atoll:

1. Any areas or locations where soil concentrations of $^{239}$Pu are greater than 400 pCi/g should receive corrective action with contaminated soil removed for disposal.

2. Situations with soil levels in the 40 to 400 pCi/g range may receive corrective action with each area or location evaluated on a case-by-case basis.

The following guidance is provided for this evaluation:

a. Islands with soil levels in the above range may be divided into two categories, those of sufficient size for construction of permanent houses, and those that are not.

b. Removal of $^{239}Pu$ contaminated soil is better justified within the range above for the larger islands such as JANET or SALLY where permanent housing may someday be located and for near surface locations on the larger islands.

c. The smaller islands may be considered of less concern. Their long-term outlook is uncertain since they are sometimes increasing in size and sometimes erroding away. Small islands may be washed over by storm waves and are not a safe site for permanent housing. From that viewpoint, they are in the same category as unnamed sandbars along the reef where other islands may have disappeared or be forming.

d. The amount of effort that properly may be given to soil removal in this range increases as the soil concentration increases.

e. Once an action is taken, the objective is to achieve a substantial reduction in plutonium soil concentrations, and further, to reduce concentrations to the lowest practicable level, not to reduce them to some prescribed numerical value.

3. Areas or locations showing less than 40 pCi/g do not require corrective action because of the presence of plutonium alone.

E. Recommended Guides

The standards issued by FRC are recommend as the basic guidance for evaluation of exposures to individuals to Enewetak.

This is recommended with provisos that:

1. The full amount of the numerical values should not be used for evaluating exposures from a single man-made source, in this case radioactivity from weapons tests. This is applied so that the Enewetak people will not be denied benefits of future nuclear technology because they are receiving exposures from man-made radiation at the maximum level of acceptable standards.

2. Environmental followup surveys and studies of radioactivity levels in people are performed such that the full range of radiation exposures of individual members of the Enewetak population will be known.

3. Exposures of the Enewetak people are kept to the minimum practicable level.

Survey, Cleanup, and Rehabilitation Evaluation

It is recommended in this context that:

1. The FRC Radiation Protection Guide (RPG's) for individuals should be used as the basic standard. The requirement is to assure that exposures for continuous residence in Enewetak Atoll will be well within the annual and 30-year criterion. While these are conservative standards from a health view point, there is no built-in conservatism to account for uncertainty in prediction of annual exposures to individuals. Because of the complex circumstances of exposure and the many pathways, each with its uncertainty, the Task Group recommends use of 50 percent of the FRC annual standards for evaluation of the many cleanup and rehabilitation alternatives at Enewetak Atoll. This is not to be viewed as an attempt to establish new standards but is considered to be a necessary precaution in the application of current standards. The following values apply for evaluation of alternatives:

| | |
|---|---|
| Whole body | 0.25 Rem/yr |
| Bone marrow | 0.25 Rem/yr |
| Bone | 0.75 Rem/yr |
| Thyroid | 0.75 Rem/yr |

2. The Task Group recommends use of 100 percent of the FRC RPG's to evaluate post-cleanup and rehabilitation and post-return conditions wherein direct measurement of levels of radiation and radioactivity in foods and in people are made. Under such conditions, dose estimates should be subject to much less uncertainty. The requirement is to assure that exposures are well within the FRC standards. See Section A. of this Appendix for the FRC RPG's.

3. The criteria for evaluating gonadal exposures at Enewetak Atoll should be 4 rems in 30 years. The requirement is to assure that long-term exposures will be well within this criteria. The Task Group feels justified in using 80 percent rather than 50 percent of the FRC standard since there will be ample time to verify exposure estimates using actual sampling of the diet and time to follow the changing pattern of exposures of people.

4. The recommended guidance for cleanup of $^{239}Pu$ in soil at Enewetak Atoll is:

   a. < 40 pCi/g - corrective action not required.

   b. 40 to 400 pCi/g - corrective action may be needed. Action to be taken should be determined on a case-by-case basis.

   c. > 400 pCi/g - corrective action required.

   In applying the criteria for bone and bone marrow in part 1 above, it is assumed that if annual exposures do not exceed the applicable criteria in the year of highest dose, there will not be a requirement for limiting longer term cumulative exposures. On the other hand, implementation of the "lowest practicable" concept will require considerations of effectiveness of remedial measures to reduce both annual and longer term exposures to the extent practicable.

## F. Risk Considerations

The Task Group and its technical advisors have reviewed the available information from ICRP, UNSCEAR, and the National Academy of Science BEIR Committee that could be used to estimate the health risk that may be associated with long-term exposures at the level of the radiation dose and soil removal criteria being recommended. It is clear from this review that knowledge of the relationship between radiation dose and effects of that dose on man as characterized in dose-effect curves is incomplete even for external radiation exposures. For internal emitters and particularly for plutonium, the situation is even less satisfactory. UNSCEAR has summarized their findings by stating that one should not extrapolate in a linear fashion from effects seen at high doses and dose rates to effects at low doses and dose rates since there is strong likelihood of recovery and repair. The BEIR Committee, using only human data, concluded that since the low dose data were incomplete, one should conservatively assume a linear no-threshold dose-effect curve drawn through data obtained at high doses and dose rates. The committee further suggested that if this linear no-threshold curve is assumed to be correct, it follows that 6,000 cases of cancer would be produced each year in a population of 200,000,000 people exposed at a rate of 0.17 Rem/yr. (This is the FRC RPG for population groups - see Table I.) For the Enewetak population of less than 500 exposed at the same level, one can make the following estimate:

$$\frac{6 \times 10^{3} \text{ cases/yr} \times 500 \text{ people}}{2 \times 10^{8} \text{ people}} = 1.5 \times 10^{-2} \text{ cases of cancer/yr}$$

Using a linear dose-effect curve, exposure at the level of the recommended criterion of 0.25 Rem/yr would give $2.2 \times 10^{-2}$ cases per year. The Task Group views this as a pessimistic upper limit of risk. It could be inferred that there may be between zero and three cases of cancer in 100 years if the entire Enewetak population were continuously exposed to 0.25 Rem/yr over that time period.

Most of the exposure to whole body, at Enewetak, and in fact, to all organs will come from internal emitters. The shape of the dose-effect curve for exposures from internal emitters is most uncertain because of lack of experience and lack of confidence in extrapolation of high dose and dose rate effects into the very low dose and low dose rate situation. A lack of confidence in the statistics and risk estimate drawn therefrom has therefore led the Task Group to have serious reservations about their validity. The Task Group holds the opinion that such estimates cannot be used in any definitive way to draw conclusions on whether current radiation standards are too high or too low or as a basis for decision-making relative to resettlement of Enewetak Atoll. While the risk associated with doses at the level of current standards is possibly not zero, it is viewed as being very low as described by FRC, ICRP, and NCRP. The basic FRC standards, conservatively applied, are viewed as suitable for Enewetak rehabilitation provided there is also a serious and concerted effort to keep exposures as low as practicable.

# A T T A C H M E N T I

## RELATIONSHIP BETWEEN RESUSPENDED PLUTONIUM IN AIR AND PLUTONIUM IN SOILS

## Relationship Between Resuspended Plutonium in Air and Plutonium in Soil

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There are no general models that may be used with confidence to predict the resuspended air activity in the vicinity of an area contaminated with plutonium.

However, two approximate methods may be used — the resuspension factor approach and an argument based upon ambient air particulate concentrations, with the assumption that the particulates are derived from the contaminated surface. The former method has been frequently used, but almost always in the context of a fresh surface deposit. The latter method is inappropriate to the fresh deposit situation, but should be reasonably valid after enough time has elapsed for the surface-deposited material to become fairly well mixed with a few centimeters of the soil surface.

Resuspension Factor Approach

The resuspension factor, K, is defined as

$$K = \frac{\text{Air concentration } (Ci/m^3)}{\text{Surface deposition } (Ci/m^2)},$$

and thus has units of $m^{-1}$. It is almost always implied that both measurements are made at the same location. The difficulties with this approach are fairly obvious — no allowance is made for the geometrical configuration of the source, the particle-size distributions of the contaminant and the soil surface, vegetation cover, etc. Stewart[1] and Mishima[2] have tabulated values of K from many experiments including those involving laboratory floors as well as native soils. As would be expected, the tabulated values cover an enormous range and vary from $10^{-2}$ to $10^{-13}$/m. Most of the high values, however, are derived from experiments with laboratory floor surfaces and/or with artificial disturbance.

For outdoor situations, Stewart[1] suggests as a guide for planning purposes that a value for K of $10^{-6}$/m be used "under quiescent conditions, or after administrative control has been established in the case of an accident." A value of $10^{-5}$/m is suggested under conditions of moderate activity. Stewart states, however, that exceptionally higher values (mean of $10^{-5}$/m) were observed during the Hurricane Trial (Monte Bello Islands) and credited this to the nature of the small islands exposed to sea breezes. Values approaching $10^{-3}$/m when dust is raised by pedestrians and vehicles are also reported by Stewart.

Kathren[3] has also considered the resuspension factor approach and has recommended the use of $10^{-4}$/m as a conservative but appropriate value for setting standards for $PuO_2$ surface contamination.

Langham[4, 5] has suggested that a value of $10^{-6}$/m is a reasonable average value to use in estimating the potential hazard of occupancy of a plutonium-contaminated area. At the same time, however, Langham notes that many measured values lie in the range of $10^{-5}$ to $10^{-7}$/m and reports that his own measurements in 1956 produced a value of $7 \times 10^{-5}$/m.

These recommended values, however, are all intended for application during the time period immediately following deposition. Numerous studies[1, 5-8] have shown that air concentrations of resuspended materials decrease with time. With the assumption that this decrease can be represented by a single exponential function, half-times of 35 to 70 days have been reported[5, 7, 8]. This decrease in air activity is not explainable by the relatively minor loss of material from the initial site of deposition[1, 6], but is presumably caused by the migration of the initial surface-deposited material into the soil.

Attempts to use the resuspension factor approach to derive acceptable levels of soil surface contamination have included this "attenuation factor" as a simple exponential function with half-times of 35 or 45 days[3, 4]. There are major uncertainties in such a formulation, however. The longest study of this decrease with time extended to only 11 mo following the initial deposition[8], which is extremely short compared to the half-life of a radionuclide such as $^{239}Pu$. There are also published reports which indicate on experimental and theoretical bases that the decrease with time will not be adequately represented by a single exponential function, but that the rate of decrease itself will also decrease with time[1, 6]. Fortunately, the exact nature of this time dependence is not critical in determining the integrated exposure from the time of initial deposition due to the fairly well-documented rapid decrease at early times. However, it is obviously the controlling factor for questions concerning the reoccupation of areas many years after the contaminating event.

As an illustration, the most conservative published model (Kathren[3]) may be used to calculate a resuspension rate for material 15 yr after deposition:

$$K = \frac{10^{-4}}{m} \exp\left(\frac{-0.693 \times 15y \times 365d}{45d \qquad y}\right) \simeq 10^{-41}/m.$$

If, however, the resuspension rate asymptotically approached some finite value $10^{-6}$ of the original, then the resuspension rate 15 yr later would obviously be $10^{-10}$/m. However, the total integrated air activity (from t = 0 to ∞) for $^{239}Pu$ would be changed only by

$$A \times 10^{-4} \int_0^\infty \exp\,(-\,0.693t/45d)\,dt + A \times 10^{-10} \int_0^\infty \exp\,(-\,0.693t/24,400y)\,dt = 6.5A \times 10^{-3} + 1.3A \times 10^{-3},$$

which is an increase of 20%, and more importantly, cannot be accumulated during an individual's life span.

Because the functional nature of the decrease in resuspension rate with time cannot be confidently extrapolated, previously published models should not be applied to the reoccupation of areas many years after the contaminating event.

The resuspension-factor approach can be applied in an approximate way, however, if resuspension factors are used which were derived from measurements over aged sources. Perhaps the most relevant data are unpublished results from current resuspension experiments at the GMX site in Area 5 of the Nevada Test Site. The $^{239}Pu$ at this location was deposited following 22 high-explosive detonations during the period from December 1954 to February 1956. Measurements of resuspended air activity levels at this site during 1971-1973 appear to be the only available data concerning resuspension of $^{239}Pu$ from a source of this age.

Data from two types of measurements are available and can be used to derive average resuspension factors. The first type of measurement[9] was accomplished by placing five high-volume cascade impactors[10] within the most highly contaminated area, and running them for

36 days, from July 7 to August 12, 1972. The collected $^{239,240}Pu$ activity was distributed lognormally with particle size with an activity median aerodynamic diameter (AMAD) of 3.0 $\mu m$ and a geometric standard deviation of 8.2. The $^{239,240}Pu$ concentration varied from $1.0 \times 10^{-14}$ to $3.9 \times 10^{-14}$ $\mu Ci/cm^3$, with an average of $2.3 \times 10^{-14}$ $\mu Ci/cm^3$ for the five samplers. At the present time only limited data are available regarding the soil activity in the area. Four soil samples of depth 0-3 cm from approximately the same location have been analyzed with results[11] of 2060 to 3550 dpm/g, with a mean of 2700 dpm/g. Profile data from other locations at the same general site indicate that about 90% of the total deposition is contained within the top 2.5 cm of the soil[12]. Measurements of soil density in the area average 1.8 $g/cm^3$ [9]. The resuspension factor is therefore

$$\frac{2.3 \times 10^{-14}\ \mu Ci}{cm^3} \times \frac{g}{2700\ dpm} \times \frac{cm^3}{1.8\ g} \times \frac{0.9}{3\ cm} \times \frac{10^2\ cm}{m} \times \frac{2.22 \times 10^6\ dpm}{\mu Ci} = 3 \times 10^{-10}/m .$$

Additional air samples were taken by the Reynolds Electrical and Engineering Co. (REECo) on the edge of the contaminated area during the period of February 1971 to July 1972, with a sampling time of approximately 48 hr[13]. Measurements were made at four locations, but the most pertinent is the one which was most frequently in the direction of strong winds from the strongly contaminated area and where the highest air activities were recorded. Here, 254 individual air-filter samples were collected and detectable results reported for 236. $^{239,240}Pu$ concentrations ranged from $3.5 \times 10^{-17}$ to $6.3 \times 10^{-13}$ $\mu Ci/cm^3$, with arithmetic and geometric means of $6.6 \times 10^{-15}$ and $7.9 \times 10^{-16}$ $\mu Ci/cm^3$, respectively. Results for four soil samples taken from approximately the same location range from 128 to 202 dpm/g, with a mean of 160 dpm/g[11]. Because the arithmetic mean is a better representation of average lung exposure, it is used to derive a resuspension factor at this site:

$$\frac{6.6 \times 10^{-15}\ \mu Ci}{cm^3} \times \frac{g}{160\ dpm} \times \frac{cm^3}{1.8\ g} \times \frac{0.9}{3\ cm} \times \frac{10^2\ cm}{m} \times \frac{2.22 \times 10^6\ dpm}{\mu Ci} = 2 \times 10^{-9}/m .$$

This value is nearly an order of magnitude higher than the one previously calculated, and reflects some of the inherent difficulties in the resuspension-factor approach, i.e., that no allowance is made for the geometrical configuration of the source and that higher ground activities may be present upwind.

It is obvious that this approach is subject to major uncertainties, but does serve as an order-of-magnitude indication of the resuspended air activities that may arise from a $^{239,240}Pu$ contaminated area which has weathered for 15 to 20 yr. The data discussed above also demonstrate unequivocally that resuspension of $^{239,240}Pu$ does in fact occur from such aged deposits and at levels many orders of magnitude higher than would be expected if the often noted decrease with time were represented by a single exponential function with a half-time of 35 to 70 days.

### Mass-Loading Approach

The other approximate prediction method is based upon measured or assumed levels of particulate matter in ambient air with the assumption that this material is derived from the contaminated soil. For fresh deposits this approach is not valid because the freshly deposited debris is much more likely to be resuspended than the remainder of the weathered soil surface. After many years of weathering since the initial deposition, however, the contaminating material should be reasonably well mixed with a centimeter or two of soil, such that the contaminant activity per gram of airborne particulate should approximate that in the upper soil. However, a major difficulty could arise if, for example, $^{239,240}Pu$ were preferentially associated with the smaller particle sizes more likely to become airborne. For the Nevada Test Site, such is not the case as determined by soil analyses[14] and by the high-volume cascade impactor study. The latter study found an AMAD of 3.0 $\mu m$ for $^{239,240}Pu$, whereas the total mass median aerodynamic diameter was 1.7 $\mu m$. The specific activity of the material collected on each stage can also be examined for a preferential association of plutonium with particle size. Average data from all five samplers are:

| Size, $\mu m$ | $^{239,240}Pu$, dpm/g |
|---|---|
| >7 | 950 |
| 3.3 to 7 | 700 |
| 2.0 to 3.3 | 1030 |
| 1.1 to 2.0 | 1300 |
| 0.01 to 1.1 | 480 |
| All stages | 890 |
| (Soil) | (2700) |

Although there is considerable spread in these data, there is no indication of a preferential association of $^{239,240}Pu$ with a particular particle size; as would be expected as a result of dilution by inert aerosol, the specific activity is lower than that of the soil.

If we assume that this is generally true, a general and conservative method of predicting resuspended air concentrations of contaminants would be to simply multiply the ambient air mass loading by the contaminant concentration in soil. A factor of some uncertainty for a specific calculation is what value to use for the ambient air mass loading in the absence of specific data. This becomes even more uncertain because of the possibility that the people involved may be highly correlated with the source in the sense that children playing in sand, adults cultivating crops, etc., may generate their own "ambient air" which contains much more mass than would be recorded by a remote stationary sampler.

The lower and upper bounds of ambient air mass loading can be fixed rather easily for any site. There has been considerable interest in establishing a "background level" of mass loading, and this is generally believed to be about 10 $\mu g/m^3$ [15]. The upper bound can be established in a reasonable way by the levels found in mine atmospheres which have led to a considerable prevalence of pneumoconiosis in the affected workers[16]. Examination of these data indicate that current standards for occupational dust exposure ($\sim$1-10 $mg/m^3$) have a very small, or perhaps no margin of safety, such that a reasonable upper bound can be taken as 1 $mg/m^3$. British data[17] indicate that if the general public were exposed to dust levels in excess of 1 $mg/m^3$, the public health problem from the dust alone might be enormous. The reasonableness of the upper limit value of 1 $mg/m^3$ is also demonstrated by data which indicate that nonurban ambient air mass concentrations this high are usually associated with conditions described as dust storms[18,19].

Measurements of ambient air mass loading can be used to further define a reasonable estimate for predictive purposes. The National Air Surveillance Network (NASN) has reported such results for several years. Data[20] for 1966 show that there were 217 urban and 30 nonurban stations reporting. The annual arithmetic average for the urban stations ranged from 33 (St. Petersburg, Florida) to 254 $\mu g/m^3$ (Steubenville, Ohio), with a mean arithmetic average for all 217 stations of 102 $\mu g/m^3$. For the nonurban stations, the range was from 9 (White Pine County, Nevada) to 79 $\mu g/m^3$ (Curry County, Oregon), with a mean arithmetic average for all 30 stations of 38 $\mu g/m^3$. No data in this report are available for nonurban locations on small islands similar to the Enewetak group; perhaps the closest analog is the urban station at Honolulu, Hawaii, which had an annual arithmetic average of 35 $\mu g/m^3$.

More pertinent, but limited, data have recently been published for the island of Hawaii[21, 22]. Data are given for three locations: Mauna Loa Observatory located at a height of 3400 m, Cape Kumukahi, and the city of Hilo. NASN data for Hilo (for an unspecified period) are given as 18 $\mu g/m^3$, and nephelometer measurements varied from 18 $\mu g/m^3$ during the day to 26 $\mu g/m^3$ at night. At Cape Kumukahi the nephelometer measurement was 9.2 $\mu g/m^3$. The greatest amount of data is available for Mauna Loa Observatory. Here, the NASN measurement was 3 $\mu g/m^3$, and the nephelometer measurements varied from 1.7 $\mu g/m^3$ at night to 6.5 $\mu g/m^3$ during the day. Additional measurements made by the USAEC Health and Safety Laboratory (HASL) were 3 $\mu g/m^3$. It is of interest in the present context that Simpson[22] made the following comment concerning the HASL measurements: "The HASL filter samples contain substantial dust (3-5 $\mu g/m^3$ of air sampled) because of the fact that the filter was located less than one meter above the ground surface near areas with substantial personnel activity at the observatory site." Thus, while this method of measurement may not have coincided with Simpson's interest, it does indicate that ambient air mass loadings may be very low on such remote islands even when considerable human activity is occurring nearby.

On the basis of the above data, it would appear reasonable to use a value of 100 $\mu g/m^3$ as an average ambient air mass loading for predictive purposes. Indications are that this value should be quite conservative for the Enewetak Islands, and therefore allows room for the uncertainty involved because the people themselves may generate a significant fraction of the total aerosol. Therefore, they may be exposed to higher particulate concentrations than would be measured by a stationary sampler.

Supporting evidence that 100 $\mu g/m^3$ is a reasonable value to use for predictive purposes is provided by the National Ambient Air Quality Standards[23]. Here ambient air is defined as "...that portion of the atmosphere, external to buildings, to which the general public has access." The primary ambient air standards define "levels which... are necessary, with an adequate margin of safety, to protect the public health." The secondary standards define "levels which...(are)...necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant." These standards for particulate matter are given below:

National ambient air quality standards for particulate matter, $\mu g/m^3$.

| Annual geometric mean | Max. 24-hr concentration not to be exceeded more than once a year |
|---|---|
| Primary: | |
| 75 | 260 |
| Secondary: | |
| 60 | 150 |

Data to support these standards in terms of health effects, visibility restrictions, etc. have been provided[24].

An arithmetic mean would be more desirable for predictive purposes. Data from 1966[20] for nonurban locations indicate that the annual arithmetic mean is (on the average) 120% of the annual geometric mean.

Representative Calculations

Because one of the primary objects is to derive an acceptable soil level for the Enewetak Islands, the approaches developed above were used to derive such levels for both soluble and insoluble $^{239}Pu$. The derived values are given in Table 151. The two methods agree within a factor of two, at least for soil distributions like those found at the Nevada Test Site. The ambient air mass loading at

Table 151. Acceptable soil levels of $^{239}Pu$ for a source which has weathered for several years. Values are approximate and are subject to uncertainty. Permissible Concentration in Air for 168-hr occupational exposure ($MPC_a$)25.

| | Insoluble | Soluble |
|---|---|---|
| Acceptable air concentration, $\mu Ci/cm^3$ | $10^{-12}$ | $6 \times 10^{-14}$ |
| *Resuspension-factor approach* | | |
| Assumed resuspension factor, $m^{-1}$ | $10^{-9}$ | $10^{-9}$ |
| Acceptable soil deposition[a], $\mu Ci/m^2$ | $10^3$ | 60 |
| Acceptable soil concentration[b], nCi/g | 20 | 1 |
| *Mass-loading approach* | | |
| Assumed mass loading, $\mu g/m^3$ | $10^2$ | $10^2$ |
| Acceptable soil concentration, nCi/g | 10 | 0.6 |

[a]Equivalent to approximately $10^4$ $\mu g$ of insoluble $^{239}Pu/m^2$.

[b]Assumes same distribution of $^{239}Pu$ with depth and soil density as measured at the Nevada Test Site.

NTS during the cascade impactor run was measured to be 70 $\mu g/m^3$.

Such derived values must, of course, be used with a great deal of discretion. They are based on simple model systems which are believed to be generally conservative, but individual situations can be imagined which could exceed the predictions.

### Other Considerations

The above calculations relate only to the resuspended air activity in ambient air, and do not consider the additional problems of resuspension of material from contaminated clothing or the resuspension of material which has been transferred to homes.

Healy[26] has considered these and other problems, and has provided tables of "decision levels" for surface contamination levels and home transfer levels. A decision level is based upon National Council on Radiation Protection and Measurements (NCRP) recommended dose limitations. Because the derivations

Table 152. Decision levels[26] for soluble $^{239}Pu$, and their equivalent in soil mass based upon the "acceptable soil concentration" from Table 151.

| Pathway | Decision level | Mass equivalent |
|---|---|---|
| A. Direct personal contamination | | |
| Direct inhalation[a] | $2 \times 10^{-5}$ nCi/cm$^2$ | $1 \times 10^{-5}$ g/cm$^2$ |
| Direct ingestion[b] | 0.2 nCi/cm$^2$ | 0.2 g/cm$^2$ |
| Skin absorption[c] | $8 \times 10^{-4}$ $\mu$Ci | 0.8 g |
| B. Transfer (to homes) levels | | |
| Resuspension[d] | 0.01 $\mu$Ci/day | 10 g/day |
| Direct inhalation | 0.01 $\mu$Ci/day | 10 g/day |
| Direct ingestion | 100 $\mu$Ci/day | $10^5$ g/day |
| Skin absorption | 0.03 $\mu$Ci/day | 30 g/day |

[a] "The contamination level on clothing and skin that could result in inhalation of air at the $MPC_a$ for the public."[26]

[b] "The contamination level on skin or clothing that could result in ingestion of a quantity of radioactive material equivalent to the ingestion of water at the $MPC_w$ for an individual in the public."[26]

[c] "The total quantity of radioactive material maintained on the skin for 24 h/day that could result in absorption of a quantity equal to that which would be absorbed from the GI tract if water at the $MPC_w$ for "soluble" isotopes for an individual in the public were ingested."[26]

[d] "The amount transferred per day that could result in air concentrations due to resuspension in a medium-sized home averaging at the $MPC_a$ for an individual in the public."[26]

are rather tenuous, Healy has used the phrase decision level and states that its use is to serve as a signal that further careful investigation is warranted.

Healy's decision levels for soluble $^{239}Pu$ are given in column 1 of Table 152. The values in column 2 are derived from these and an acceptable soil concentration of 1 nCi/g from Table 151 to give equivalent dirt (soil) contamination and transfer levels. The results are interpreted as indicating that the potential exists for greater dose contributions from these infrequently considered pathways than from the usually considered pathway of resuspension as calculated for ambient air. This conclusion would be the same for insoluble $^{239}Pu$. Therefore, if dose calculations based on the usual resuspension pathway should appear limiting compared to other pathways such as food-chain transfer, these pathways considered by Healy need to be carefully evaluated for the specific Enewetak situation.

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# APPENDIX IV

## Annual Bone and Whole-Body Doses

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1. Introduction

The purpose of this appendix is to evaluate the potential annual bone doses for adults and children for the six living patterns considered in the Enewetak Radiological Survey Report (NVO-140). The bone doses presented in NVO-140 were calculated for mineral bone for adults as integrated doses for 5-, 10-, 30-, and 70-yr periods. Bone and whole-body doses to children were not considered separately because in most cases the doses predicted for adults are usually a good estimate of the dose to children. For example, the external gamma contributes similarly to both adults and children. Strontium-90 and $^{137}Cs$ contribute over 95% of the food-chain dose and there is evidence to show that doses to children from ingestion of $^{137}Cs$ are usually less than those to adults. Strontium-90 differs from $^{137}Cs$. Doses to children can exceed adult doses; however, the additional dose increment to children over the first 1 to 5 yr is not large and increases the integral 30- and 70-yr doses by only a few percent. With the uncertainties involved in other parts of the dose assessment, for example the actual diet at time of return, the differentiation between child and adult integrated doses was not included in the tables.

Because of the magnitude of some of the 30-yr integral bone doses, it was decided that annual bone doses should be evaluated to indicate the living patterns and agricultural situations which are within FRC guides for annual bone doses. The more detailed assessment of bone doses is directed at estimating the dose to the critical cell population at risk in bone - the bone marrow - rather than to the entire bone mass, as was calculated in the original report (NVO-140). In adopting this approach, we are following the recommendations of the ICRP (ICRP-11) and the approach of Spiers used by UNSCEAR (22).

The following text considers the information available for estimating the doses to the fetus, the newborn, and children relative to adults, and also the dietary changes which are assumed for children.

2. Dose to Fetus and Newborn Relative to Adults

The Sr/Ca ratio in the fetus and in mothers' milk is determined by the Sr/Ca ratio in the maternal blood. Sr/Ca discrimination across the placental barrier and across the mammary gland is nearly the same.[1,2] In fact, the observed ratio OR $\frac{\text{fetus or mothers' milk}}{\text{maternal blood}}$ $\left(OR = \frac{(\text{pCi } ^{90}\text{Sr/g Ca}) \text{ milk or fetus}}{(\text{pCi } ^{90}\text{Sr/g Ca}) \text{ maternal blood}}\right)$ is $\sim 0.5$.[1-3] Therefore, the Sr/Ca ratio of the fetus or newborn is very similar to that of the mothers' milk.

There is considerable evidence to show that the OR milk/diet for human breast milk is in the range of 0.1 to 0.16.[3,5] The same observed ratio exists for the fetus and newborn relative to the adult diet.[1,2] This ratio has been observed directly and can also be calculated from data which indicate that the average OR body/diet for adults is 0.25;[1,6] when this is combined with a further discrimination of approximately a factor of 2 across the placental or mammary membrane, the range of values of 0.1 to 0.16 for milk or fetus is obtained.

As a result, the Sr/Ca ratio in the fetus and newborn is approximately 1/8 to 1/10 that of the adult, and the resulting dose to the fetus is less than that to adults.

The dose to a young infant being breast fed will of course also be less than that calculated for adults. The OR body/diet for young infants is 0.9;[1,4] that is, the young infant nearly equilibrates with his diet. However, the mothers' milk, as discussed previously, has a Sr/Ca ratio ~ 0.1 that of the adult diet. The OR body/diet then decreases to 0.5 for a 1-year-old and by approximately 3 or 4 years of age has reached the adult value of 0.25.[2,4,6]

Similar data are available for $^{137}Cs$. Cesium-137 is metabolized and turned over more rapidly in pregnant women than in nonpregnant women.[7,8] As a result, $^{137}Cs$ incorporation in the fetus and the resulting exposure are less than would be expected from normal retention times observed for adults. Experimental data further indicate that for the fetus and for breast-fed infants the concentration of $^{137}Cs$ and the resulting dose never exceeds that of the mother or of other adults.[9,10] Therefore, as indicated in reports by Rundo,[9] Iinuma et al.,[10] and Cook and Snyder,[11] the dose calculated for an adult for $^{137}Cs$ is a conservative estimate for the fetus and the newborn.

3. Dose to Children Relative to Adults

$^{137}Cs$ — A considerable body of evidence is available which indicates that the half-time for $^{137}Cs$ in the body is a function of age, with a more rapid turnover for younger ages.[11-14] The biological half-time appears to be the order of 10-15 days for 1- to 2-year-old children and increases to ~ 100 days by age 20. It then remains reasonably constant throughout adult life. The body mass is less for the younger age groups, and these two factors tend to offset each other in dose calculations. Doses to children are generally less than for adults as a result of the combination of these two offsetting factors. When the relative dietary intake is included, children receive a lesser dose than adults. Therefore, dose estimates for adults are usually a conservative estimate for children.

$^{90}Sr$ – Reports by Loutit,[15] Bennett,[16] and Rivera[17] indicate that the pCi $^{90}Sr$/g Ca in human bone is greater for ages 1-5 than for ages greater than 6 yr, including adults. However, the turnover rate is much more rapid and the retention time much shorter for $^{90}Sr$ in ages 1-5. The combination of these two factors determines the bone burden, the annual dose, and the dose commitment resulting from a specified ingestion of $^{90}Sr$. For children, these two factors tend to offset each other; the resulting dose to children, therefore, is not straightforward and is dependent upon the relative interaction of these two factors.[1] Any comparison with adults must therefore take into account the age dependence of these factors, as well as the difference in dietary intake. The model reported by Bennett[16] is therefore used for estimating the doses to children.

4. Dose Models and Diet

$^{90}Sr$ – Models developed by ICRP for estimating the bone dose from ingested $^{90}Sr$ are considered to be age invariant.[18-20] A recent model from Bennett[16] does model the child separately from the adult, and this model is applied for estimating the bone doses to children.

The bone-marrow dose-rates to children are calculated by combining Bennett's model for children with the approach developed by Spiers[21] and used in the UNSCEAR report[22] for estimating bone-marrow dose from the mineral or matrix bone dose. The values used for converting $D_o$ doses, to bone-marrow and endosteal cell doses, are 0.314 and 0.434 respectively. Bennett's model also extrapolates to the adult case and is combined with the Spiers approach for predicting the bone-marrow doses to adults.

The bone mass is assumed to correlate directly with body mass, and these data as a function of age are taken from Spiers.[21] These body masses are based upon average data from the U.S. population and a factor of 0.85 was incorporated to account for the smaller size of the Enewetakese. The calcium concentration in bone (gCa/g bone) as a function of age is taken from Bennett.[16]

In calculating the mineral bone dose ($D_o$ dose) in NVO-140, the approach of ICRP[18] was followed, using a QF = 1 and n = 5. The doses calculated from this model are compared to the 3-rem/yr guide (ICRP 9)[23] for bone for general public. However, in assessing the annual dose to both children and adults, the bone marrow is taken as the critical organ, and the recommendations in ICRP 11[24] are used.

In this model the quality factor is still one (QF = 1), and the "n" factor is no longer applicable. The bone marrow is considered in the category of sensitive blood-forming organs, and the corresponding dose guide for such organs is 0.5 rem/yr rather than the 3 rem/yr for mineral bone.

$^{137}$Cs – In the dose model for $^{137}$Cs, it is assumed that the loss of $^{137}$Cs from the body can be described as an exponential loss with a turnover time that varies as a function of age.[10-14] The annual dose is calculated, always taking into account the residual body burden from the previous year. Body mass as a function of age is taken from Spiers.[21] Initial dietary intakes are calculated and doses are predicted, based upon the initial intake and the exponential loss of $^{137}$Cs in the diet at a rate equal to the physical half-time of $^{137}$Cs.

Diet – The diet for adults is that listed in the original report NVO-140. For children from ages 1 through 10, the intake of coconut milk and coconut meat is doubled to 600 and 200 g/day, respectively. These two products are the most likely to be consumed in greater quantity by children than by adults. The rest of the diet for children is assumed to be one-half of the adult diet.

At age 10, it is assumed that the child is on the full adult diet. From information available, this is a conservative assumption in that children are not usually considered to reach the average adult intake until age 14 or 15. However, because of the diet changes which occur at 10 yr (i.e., pandanus, breadfruit, coconut, etc., which become available) it is convenient to use this point for adjusting the child to the adult diet, and if anything, this adjustment produces a slightly conservative dose estimate for the children due to the high $^{90}$Sr content in the adult diet.

5. Results

The results of the calculations based upon the models described above and upon the diets listed in NVO-140 and altered for children as previously discussed, are listed in Tables 1-8. The data are presented as maximum annual bone-marrow and whole-body doses. The living patterns are listed after Tables 1 and 6 for convenience of reference; they are the same as those listed in NVO-140.

The annual doses for external exposure and for food chain exposure from $^{137}$Cs and $^{90}$Sr are calculated for 70 yr, beginning at either age 1 or age 20. The three different components contributing to the dose produce a maximum dose at different times. The external component, for instance, is maximum at 1 yr and decreases thereafter with the physical half-life of $^{137}$Cs and $^{60}$Co; the effective decay depends on the particular percentage of each isotope in the soil. Strontium-90 delivers its maximum dose several years after intake of the nuclide begins. The year of maximum dosage depends upon whether an adult or child is considered and upon whether or not a diet change is involved at some point in time. The dosage from $^{137}$Cs incorporated in man via food chains tends to peak early and decreases exponentially thereafter. The annual dose is then selected for the years at which the sum of these three components was maximum.

The maximum annual bone-marrow doses are listed in Table 1 for the case where no restrictions are placed upon the location of agriculture and source of the diet and no modifications are made for external gamma on the village island. Table 2 lists the results for the case where no restrictions are placed upon the diet but where the village island has been modified by plowing and graveling. Living Pattern 1, where the home island and agriculture are on southern islands, is the only living pattern for these two situations where the total bone-marrow doses do not exceed 50% of the FRC guide; in this instance, it is less by a factor of 5. All other living patterns lead to an annual dose which for at least 1 yr, and in most cases several years, exceeds the FRC guide.

The results also indicate that there is not a great deal of difference between the predicted child and adult maximum annual doses. This is due in part to the assumed diets of adults and children and the large $^{90}Sr$ and $^{137}Cs$ intake via the food chains for such products as pandanus, breadfruit, coconut, and meat. For coconut milk and coconut meat, the children are assumed to have an intake twice that of the adults, but until age 10 the rest of the dietary intake is assumed to be one-half that of the adults.

Table 3 lists the results for the six living patterns when pandanus and breadfruit are grown on southern islands only. As a result of this action, three living patterns fall within 50% of the FRC guide — Patterns 1, 2, and 5. When pandanus, breadfruit, coconut, and tacca are all confined to southern islands, then Living Pattern 3 also falls within the guide (Table 4). If the total diet is confined to the southern islands, then all living patterns are within FRC guide, and the only variation among living patterns is the result of the difference in external exposure for each of the situations (Table 5). For all the cases where there is a restriction on the agriculture and diet, it is assumed the village island will be plowed and graveled.

Similar results for whole-body exposure for the four different agricultural situations are presented in Tables 6-10. With no restrictions on the diet, Living Patterns 1, 2, and 5 are under FRC guides. Therefore, the bone-marrow is the more limiting feature. When the other agricultural conditions are used, the living patterns which fall below the FRC guide are the same as those for the bone-marrow dose.

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Table 1. Maximum annual bonemarrow dose (rem).

No restrictions on diet

Village island unmodified for external gamma

| Living Pattern | Start January 1974 Child [a] | Start January 1974 Adult [a] | Start January 1984 Child [b] | Start January 1984 Adult |
|---|---|---|---|---|
| 1 | 0.047 | 0.045 | 0.047 | 0.043 |
| 2 | 0.314 | 0.294 | 0.282 | 0.290 |
| 3 | 0.790 | 0.760 | 0.759 | 0.754 |
| 4 | 2.27 | 2.15 | 2.17 | 2.13 |
| 5 | 0.361 | 0.348 | 0.333 | 0.344 |
| 6 | 1.10 | 1.04 | 1.03 | 1.02 |

| Living Pattern | | Village island | Agriculture | Visitation |
|---|---|---|---|---|
| 1 | (A) | Enewetak-Parry | ALVIN-KEITH | Southern Is. |
| 2 | (B) | Enewetak-Parry | KATE-WILMA + LEROY | Northern Is. |
| 3 | (D) | JANET | JANET | Northern Is. |
| 4 | (F) | BELLE | BELLE | Northern Is. |
| 5 | (C) | JANET | KATE-WILMA + LEROY | Northern Is. |
| 6 | (E) | JANET | ALICE-IRENE | Northern Is. |

[a] Diet change at 10 yr., i.e., 1984.

[b] Diet change at 10 yr., i.e., 1994.

Table 2. Maximum annual bonemarrow dose (rem).

No restrictions on diet

Village island graveled and plowed

| Living Pattern | Start January 1974 Child [a] | Start January 1974 Adult [a] | Start January 1984 Child [b] | Start January 1984 Adult |
|---|---|---|---|---|
| 1 | 0.047 | 0.045 | 0.047 | 0.043 |
| 2 | 0.314 | 0.294 | 0.282 | 0.290 |
| 3 | 0.718 | 0.677 | 0.680 | 0.672 |
| 4 | 2.08 | 1.92 | 1.93 | 1.90 |
| 5 | 0.317 | 0.300 | 0.285 | 0.296 |
| 6 | 1.06 | 0.989 | 0.988 | 0.977 |

Table 3. Maximum annual bonemarrow dose (rem).

Pandanus and breadfruit from southern islands

Village island graveled and plowed

| Living Pattern | Start January 1974 Child [a] | Start January 1974 Adult [a] | Start January 1984 Child [b] | Start January 1984 Adult |
|---|---|---|---|---|
| 1 | 0.047 | 0.045 | 0.047 | 0.043 |
| 2 | 0.148 | 0.149 | 0.200 | 0.142 |
| 3 | 0.293 | 0.294 | 0.418 | 0.284 |
| 4 | 0.786 | 0.774 | 1.16 | 0.749 |
| 5 | 0.151 | 0.178 | 0.201 | 0.148 |
| 6 | 0.428 | 0.437 | 0.574 | 0.419 |

[a] Diet change at 10 yr., i.e., 1984.

[b] Diet change at 10 yr., i.e., 1994.

Table 4. Maximum annual bonemarrow dose (rem).
Pandanus, breadfruit, coconut, tacca from southern islands
Village island graveled and plowed

| | Start January 1974 | | Start January 1984 | |
|---|---|---|---|---|
| Living Pattern | Child [a] | Adult [a] | Child [b] | Adult |
| 1 | 0.047 | 0.045 | 0.047 | 0.043 |
| 2 | 0.122 | 0.130 | 0.092 | 0.101 |
| 3 | 0.168 | 0.204 | 0.138 | 0.166 |
| 4 | 0.415 | 0.516 | 0.325 | 0.392 |
| 5 | 0.121 | 0.135 | 0.094 | 0.106 |
| 6 | 0.253 | 0.354 | 0.202 | 0.254 |

Table 5. Maximum annual bonemarrow dose (rem).
Total diet from southern islands
Village island graveled and plowed

| | Start January 1974 | | Start January 1984 | |
|---|---|---|---|---|
| Living Pattern | Child [a] | Adult [a] | Child [b] | Adult |
| 1 | 0.047 | 0.045 | 0.047 | 0.043 |
| 2 | 0.097 | 0.091 | 0.071 | 0.069 |
| 3 | 0.094 | 0.094 | 0.077 | 0.079 |
| 4 | 0.199 | 0.193 | 0.133 | 0.129 |
| 5 | 0.096 | 0.096 | 0.074 | 0.074 |
| 6 | 0.189 | 0.213 | 0.123 | 0.134 |

[a] Diet change at 10 yr., i.e., 1984.

[b] Diet change at 10 yr., i.e., 1994.

Table 6. Maximum annual whole-body dose (rem).

No restrictions on diet

Village island unmodified for external gamma

| Living Pattern | Start January 1974 Child[a] | Adult[a] | Start January 1984 Child[b] | Adult |
|---|---|---|---|---|
| 1 | 0.039 | 0.039 | 0.038 | 0.039 |
| 2 | 0.234 | 0.236 | 0.200 | 0.233 |
| 3 | 0.619 | 0.630 | 0.531 | 0.628 |
| 4 | 1.81 | 1.80 | 1.54 | 1.79 |
| 5 | 0.285 | 0.291 | 0.252 | 0.291 |
| 6 | 0.798 | 0.812 | 0.674 | 0.802 |

| Living Pattern | | Village island | Agriculture | Visitation |
|---|---|---|---|---|
| 1 | (A) | Enewetak-Parry | ALVIN-KEITH | Southern Is. |
| 2 | (B) | Enewetak-Parry | KATE-WILMA + LEROY | Northern Is. |
| 3 | (D) | JANET | JANET | Northern Is. |
| 4 | (F) | BELLE | BELLE | Northern Is. |
| 5 | (C) | JANET | KATE-WILMA + LEROY | Northern Is. |
| 6 | (E) | JANET | ALICE-IRENE | Northern Is. |

[a]Diet change at 10 yr., i.e., 1984.

[b]Diet change at 10 yr., i.e., 1994.

Table 7. Maximum annual whole-body dose (rem).

No restrictions on diet

Village island graveled and plowed

| Living Pattern | Start January 1974 Child[a] | Adult[a] | Start January 1984 Child[b] | Adult |
|---|---|---|---|---|
| 1 | 0.039 | 0.039 | 0.039 | 0.038 |
| 2 | 0.234 | 0.236 | 0.200 | 0.233 |
| 3 | 0.540 | 0.542 | 0.452 | 0.540 |
| 4 | 1.56 | 1.55 | 1.30 | 1.55 |
| 5 | 0.237 | 0.241 | 0.204 | 0.240 |
| 6 | 0.749 | 0.761 | 0.631 | 0.757 |

Table 8. Maximum annual whole-body dose (rem).

Pandanus and breadfruit from southern islands

Village island graveled and plowed

| Living Pattern | Start January 1974 Child[a] | Adult[a] | Start January 1984 Child[b] | Adult |
|---|---|---|---|---|
| 1 | 0.039 | 0.039 | 0.039 | 0.038 |
| 2 | 0.125 | 0.128 | 0.146 | 0.127 |
| 3 | 0.245 | 0.252 | 0.304 | 0.249 |
| 4 | 0.662 | 0.663 | 0.846 | 0.656 |
| 5 | 0.128 | 0.133 | 0.149 | 0.132 |
| 6 | 0.350 | 0.367 | 0.430 | 0.363 |

[a] Diet change at 10 yr., i.e., 1984.

[b] Diet change at 10 yr., i.e., 1994.

Table 9. Maximum annual whole-body dose (rem).

Pandanus, breadfruit, coconut, and tacca from southern islands

Village island graveled and plowed

| | Start January 1974 | | Start January 1984 | |
|---|---|---|---|---|
| Living Pattern | Child[a] | Adult[a] | Child[b] | Adult |
| 1 | 0.040 | 0.039 | 0.039 | 0.039 |
| 2 | 0.091 | 0.122 | 0.078 | 0.093 |
| 3 | 0.146 | 0.187 | 0.119 | 0.151 |
| 4 | 0.357 | 0.475 | 0.280 | 0.355 |
| 5 | 0.093 | 0.127 | 0.080 | 0.098 |
| 6 | 0.246 | 0.328 | 0.160 | 0.241 |

Table 10. Maximum annual whole-body dose (rem).

Total diet from southern islands

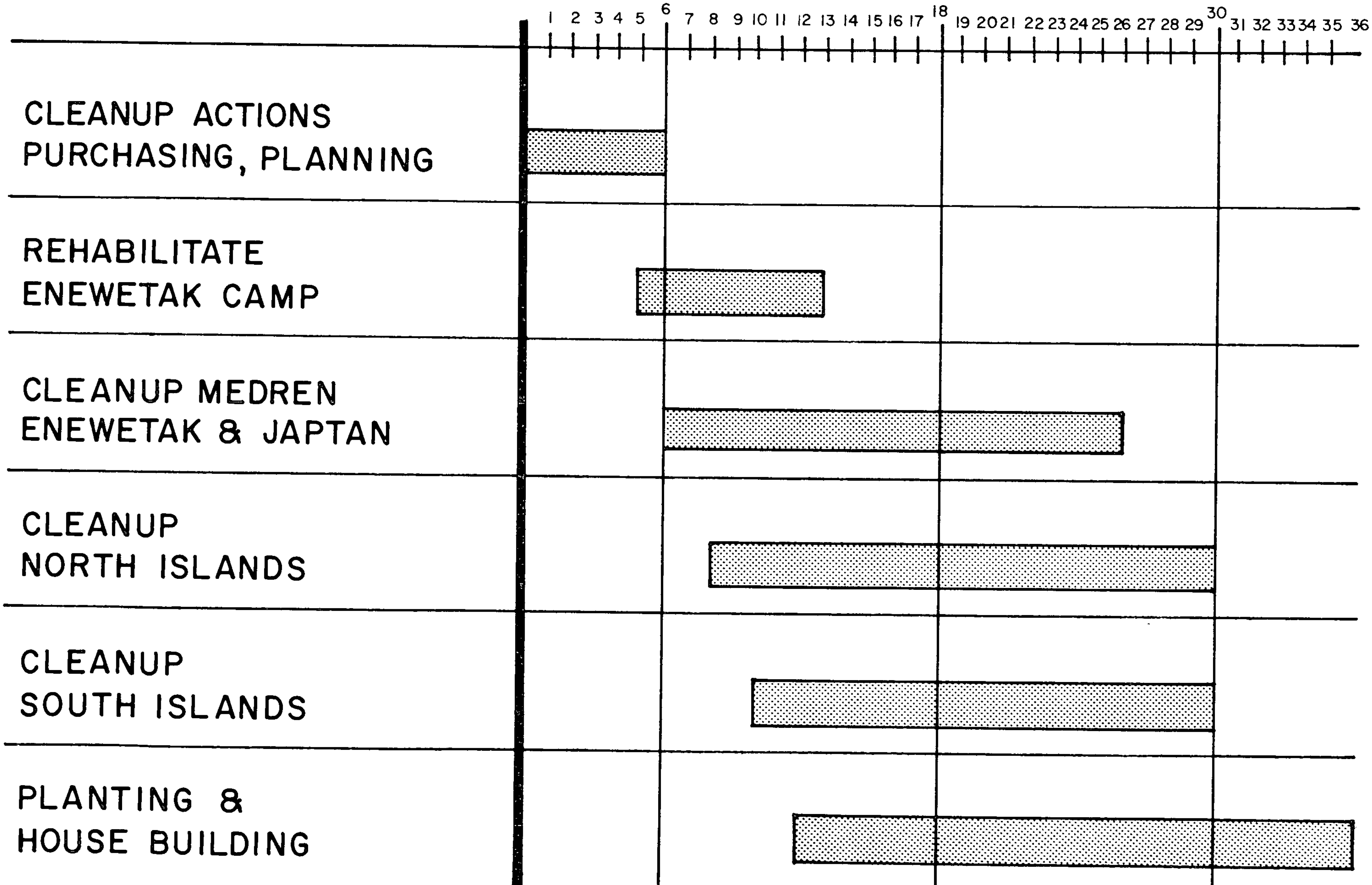
Village island graveled and plowed

| | Start January 1974 | | Start January 1984 | |
|---|---|---|---|---|
| Living Pattern | Child[a] | Adult[a] | Child[b] | Adult |
| 1 | 0.040 | 0.039 | 0.039 | 0.039 |
| 2 | 0.090 | 0.083 | 0.065 | 0.066 |
| 3 | 0.087 | 0.097 | 0.070 | 0.076 |
| 4 | 0.192 | 0.191 | 0.126 | 0.126 |
| 5 | 0.089 | 0.094 | 0.066 | 0.071 |
| 6 | 0.182 | 0.211 | 0.116 | 0.131 |

[a]Diet change at 10 yr., i.e., 1984.

[b]Diet change at 10 yr., i.e., 1994.

# SCHEDULE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CLEANUP ACTIONS
PURCHASING, PLANNING
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ENEWETAK CAMP
CLEANUP MEDREN
ENEWETAK & JAPTAN
CLEANUP
NORTH ISLANDS
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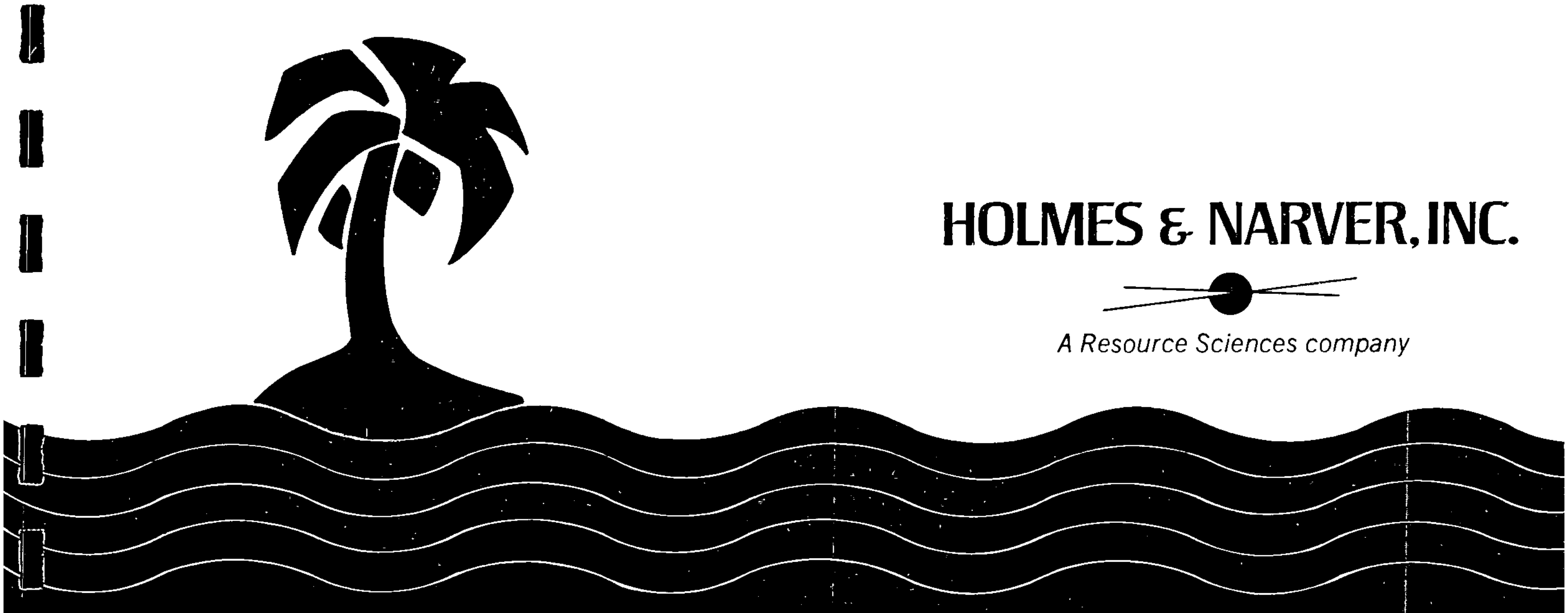
# ENEWETAK ATOLL MASTER PLAN

## for island rehabilitation and resettlement

## VOLUME 1

NOVEMBER 1973



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# 1. INTRODUCTION

# 1. INTRODUCTION

## 1.1 AUTHORITY AND PURPOSE

Authority for preparation of the Enewetak Atoll Master Plan for Island Rehabilitation and Resettlement of the Enewetak people was granted by the Government of the Trust Territory of the Pacific Islands to Holmes & Narver, Inc., through an agreement dated June 13, 1973.

The purpose of this master plan is to provide an in-depth study to be used as a basis for developing both immediate and long range programs for the rehabilitation and resettlement of Enewetak Atoll. It has involved the Enewetak people, through their planning council, in the various decision-making processes to the maximum extent possible. It will provide cost estimates to be used by the Department of Interior and the Trust Territory of the Pacific Islands in budgeting for the programs. The plan also contains a preliminary study of long range market areas that can be developed to broaden the economic base of the Enewetak people. It also develops information for the Environmental Impact Statement for the cleanup and rehabilitation of Enewetak Atoll.

## 1.2 SCOPE

The scope of work in preparation of the master plan includes the following items of work:

- Master Land Use Plans
- Conceptual Plans and Models for Residences and Community Buildings

- Agricultural Plans
- Utilities Plan
- Industrial Facilities Plan
- Preliminary Study of Potential Market Areas for Commercial Development
- In-Depth Review of Existing Facilities and Assets
- Budget Estimates

## 1.3 SUMMARY

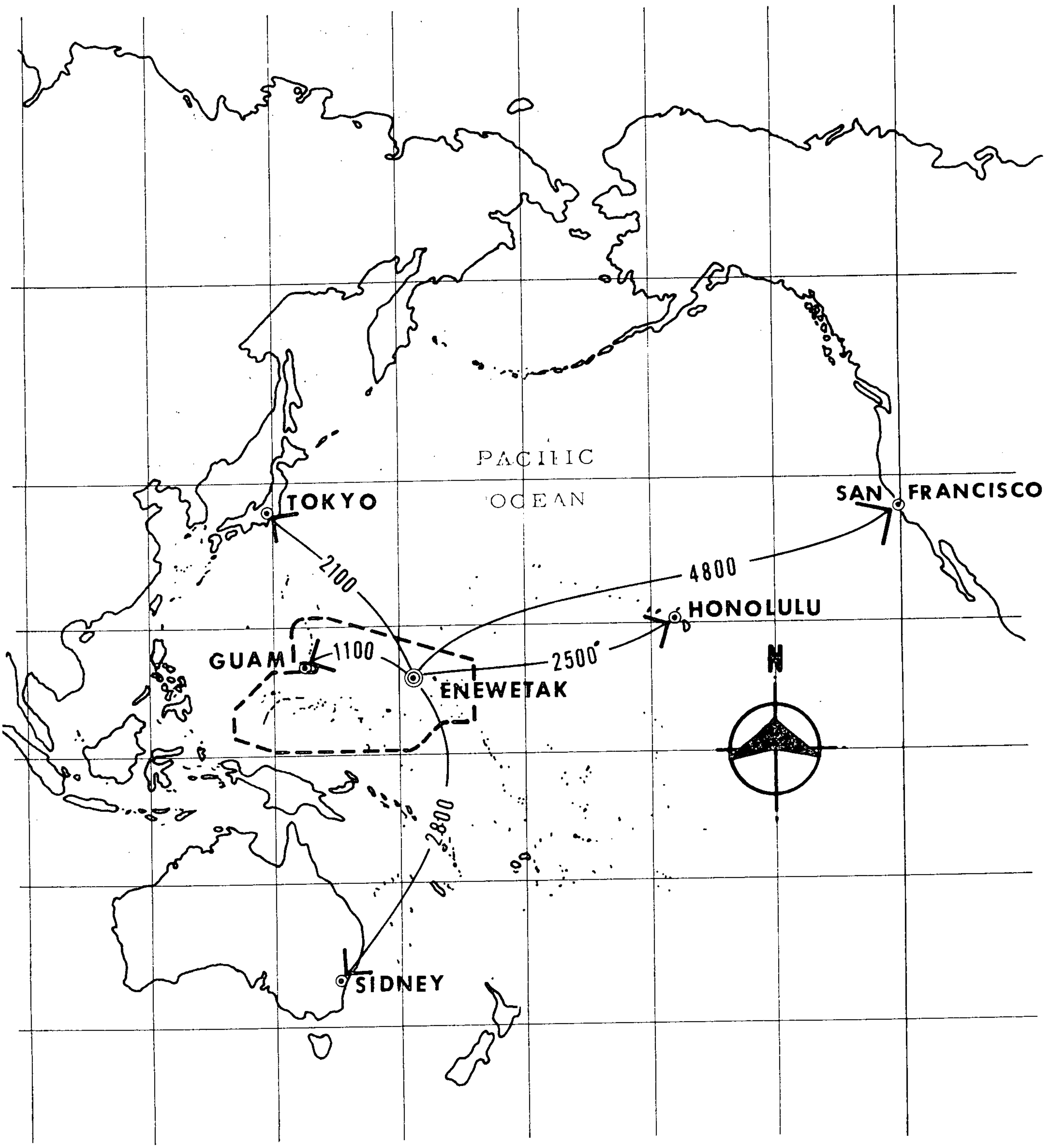
This report has been prepared in accordance with the Scope of Work contained in the Trust Territory of the Pacific Islands Contract agreement dated June 13, 1973. In the course of preparing the report, it was necessary to make certain assumptions due to the absence of the United States Atomic Energy Commission's radiological survey report which is not due for completion until approximately December, 1973. The assumptions made are as follows:

- Enewetak Atoll can be sufficiently cleaned up of all radiological hazards.
- Enjebi Island can be made radiologically safe for habitation.
- The normal food chain is safe for human consumption.
- The fresh or brackish water lenses on islands to be inhabited can be utilized for human use as required.
- The fresh or brackish water lenses can be used for irrigation of both subsistence and cash crops when required on both the inhabited and agricultural islands.

Other assumptions upon which this plan is based are:

- Prior to atoll rehabilitation the condition of the islands will reflect the degree of cleanup depicted by Case IV A of the Preliminary Draft Environmental Impact Statement.
- Enewetak Island will be utilized for commercial development and as such will not be inhabited by the driEnewetak who will reside on Medren.
- Development of Enewetak Island for use as an inhabited island is an alternate to the basic plan.

The plan presents all necessary elements required for the orderly development of Enewetak Atoll and encompasses the desires of the Ujelang people as discussed with them during a field trip in July 1973. It covers all aspects of residential, island community, and agricultural requirements and presents a review of potentials for economic development of Enewetak Atoll. Recommendations for implementation of the plan along with a preliminary construction schedule for rehabilitation and a budget estimate are included.




# REGIONAL MAP-PACIFIC AREA

TRUST TERRITORY OF THE PACIFIC ISLANDS
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# 2. HISTORICAL AND CULTURAL BACKGROUND

# 2. HISTORICAL AND CULTURAL BACKGROUND

## 2.1 ANTHROPOLOGY

Most anthropologists are of the opinion that the Marshalls and other islands of Micronesia were settled by peoples who migrated from the area of Indonesia and into the insular Pacific centuries ago. Reflecting the ancient migration patterns in Oceania, the Marshallese language belongs to the large Malayo-Polynesian language family which is spread from Madagascar, through the Indonesian area, and across Micronesia, Polynesia, and most regions of Melanesia. With regard to physical type, Marshallese are relatively short in stature and of slender build. They have brown skin, brown eyes, broad flat noses, straight to curly black hair, and sparse body hair.

According to their own oral traditions, the people of Enewetak had always lived on Enewetak Atoll prior to their relocation to Ujelang; in their own words: "We were there from the beginning." Because of Enewetak Atoll's isolated location in the northwestern region of the Marshallese archipelago, the people had relatively little contact with others prior to the European era. As a consequence, the language and culture of the Enewetakese became differentiated from those of other Marshall Islanders, and the people did not identify themselves with the others. Rather, they thought of themselves as a people who were separate and unique, "the people of Enewetak" as opposed to the islanders to the east and south.

The past and current accomplishments of the Enewetakese reflect intelligence and qualities of ingenuity, self-reliance, and hardiness of the Marshallese which have allowed them to meet the challenge of the atoll environment which is quite restrictive in comparison to the high volcanic islands of Oceania. Long before the advent of Europeans, the Marshallese had developed a culture which represented a sophisticated adaptation to their ecological setting. They were skilled navigators (an art which has been lost with the availability of travel on the vessels of foreigners); they remain expert builders of sailing canoes and are among the world's best fishermen. In response to traders, missionaries, and the successive colonial governments which have dominated the islands over the past century, they have been quick to learn and adjust to the different categories of outsiders. Today, they have achieved a good understanding of the behavior and values of Americans, and several have distinguished themselves in government and mission schools.

## 2.2 CULTURE AND ECONOMY

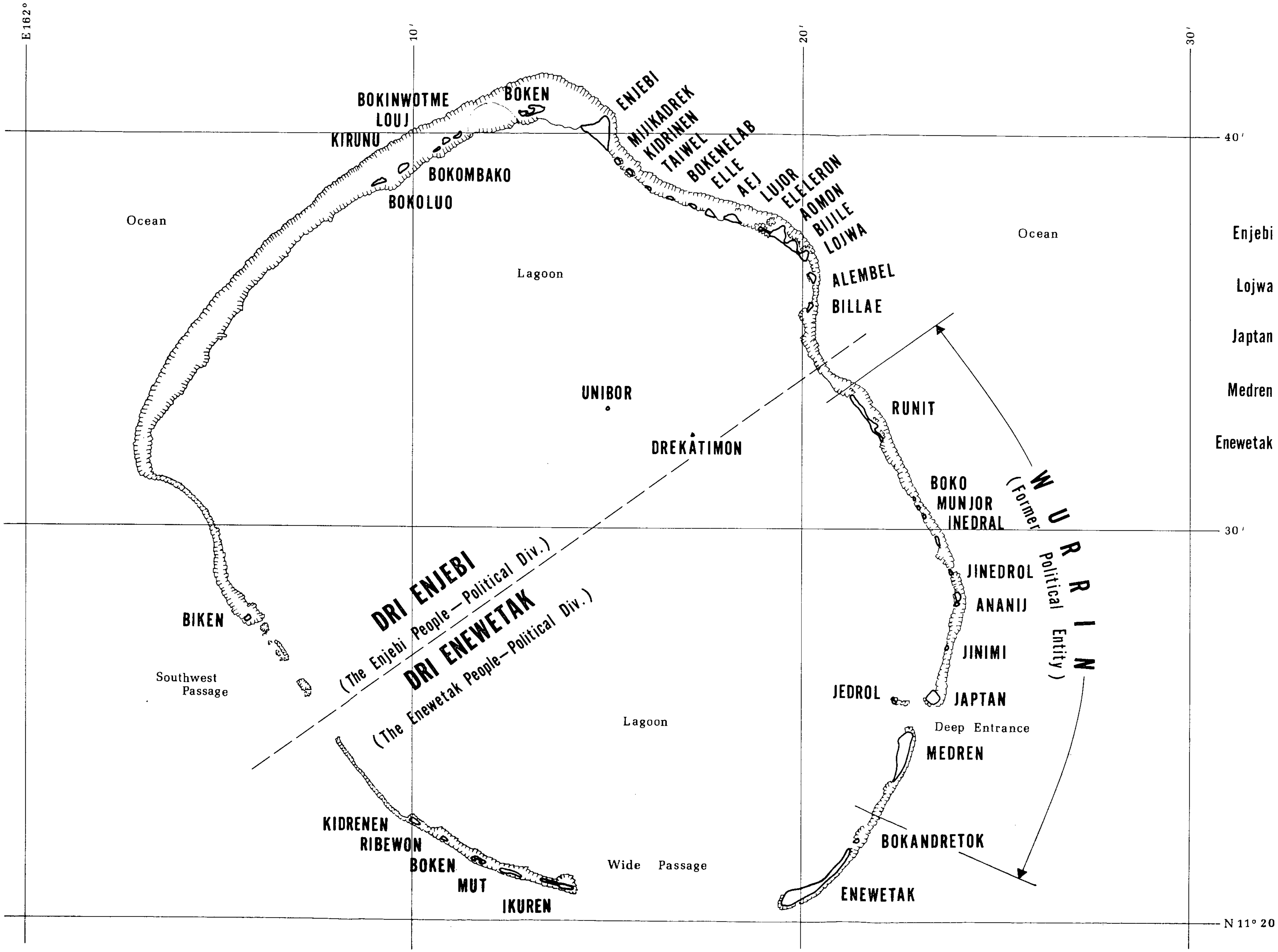
Throughout the Marshall Islands, the traditional forms of settlement patterns and exploitation of the natural resources are characterized by several general features. First, the people of an atoll reside on one or more of its largest islands. Secondly, the people are quite mobile as a nonintensive type of agriculture, and various fishing and collecting activities are extended to embrace every niche of the environment. Regular expeditions are made to all islands in an atoll to make copra and collect coconuts, breadfruit, pandanus, arrowroot, and other vegetable foods in season. Clearing of brush and planting are done during these visits. The marine resources are also exploited, and a wide variety of marine animals are utilized. Special expeditions are made to catch fish, collect shellfish, capture turtles, and gather their eggs. Several species of birds are also captured as a food source. The Enewetak people may be expected to continue this way of life to some degree when they return to their home atoll, as influenced by their contacts with Western culture.

### 2.2.1 Sociopolitical Pattern

Before their relocation to Ujelang, the Enewetakese were divided into two separate and distinct communities (community is defined as "the maximal group of persons who normally reside together in face-to-face association") which were located on the two largest islands of the atoll. One was situated on Enjebi Island on the northern rim, and the other was located on Enewetak Island across the lagoon in the southeast quadrant of the atoll. The traditional settlement pattern of both communities was dispersed; residences were located on separate land parcels and were scattered along the length of the lagoon beach.

Members of the two communities intermarried and cooperated in certain economic activities. Each functioned, however, as a separate sociopolitical unit, and its members had their own identity. In contrast to the identity of "the people of Enewetak" by which they defined themselves in reference to all other populations, the people of the Enjebi community were identified as driEnjebi, "the people of Enjebi Island," and those of the Enewetak community were driEnewetak, "the people of Enewetak Island." (See Plate #2.) (J. A. Tobin, 1973)

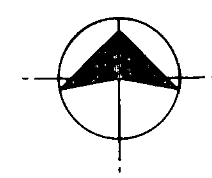
The sociopolitical structure of the two communities was identical. Each was headed by a hereditary iroij or chief, and succession to the office was patrilineal. Chiefs directed the affairs of their respective communities, arbitrated disputes, and consulted one another with regard to concerns of the entire atoll and the total population's relations with outsiders. Each of the chiefs had authority over one of the two domains into which the atoll was divided. The domain of the Enewetak chief began with the Islands of Kidrenen, Ribewon, Boken, Mut, and Ikuren in the atoll's southwest quadrant; extended counterclockwise around the atoll's south and western rims up to and including Runit Island; and also included Aomon on the northeast rim. With the exception of Aomon, the Enjebi chief's domain began north of Runit with Billae Island and extended counterclockwise around the atoll's northern and western rims up to and including Biken Island.

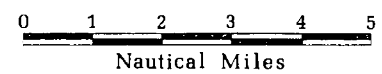



| | Enjebi | Lojwa | Japtan | Medren | Enewetak |
|---|---|---|---|---|---|
| Enjebi | | 6 | 17 | 17 | 20 |
| Lojwa | 6 | | 12 | 13 | 16 |
| Japtan | 17 | 12 | | 2 | 6 |
| Medren | 17 | 13 | 2 | | 5 |
| Enewetak | 20 | 16 | 6 | 5 | |

**MILEAGE TABLE**

(Nautical Miles From Dock To Dock)






# ENEWETAK ATOLL—POLITICAL DIVISION

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

Plate No.

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NOV. 1973

Relations between the two communities and the traditional dispersed pattern of residence were altered with the invasion of Enewetak Atoll. Because Enewetak and Enjebi Islands were devastated by the warfare, the U. S. Navy resettled all of the people in a compact village on small Aomon Island which, as indicated above, fell within the domain of the Enewetak Island chief. After several months, the Enjebi people moved to the nearby and adjacent Bijile Island which was within the domain of their own chief. With these relocations within Enewetak Atoll, the Enjebi and Enewetak peoples were no longer separated by the atoll's large lagoon; and while retaining their dual political structure, they in fact became a single community.

The consolidation of the population into one community and the new compact settlement pattern were perpetuated with the islanders resettlement on Ujelang Atoll. It has only one sizeable island, Ujelang Island; and the entire population was resettled there. Navy officials established a dividing line at the midpoint of the island and allotted the western half to the Enjebi people and the eastern half to the Enewetak people. A compact village was constructed in the middle of the island with the Enjebi and Enewetak peoples occupying houses on their respective sides of the dividing line. Later, each group divided the land on its portion of the island. At a still later date, other islands in the atoll were divided among members of the two groups.

During the initial years on Ujelang, and traditional political structure remained intact. The chiefs functioned in their accustomed roles, and they resisted American efforts to introduce democratic institutions. (According to American designs, each atoll population was to be governed by an elected council of elders headed by an elected magistrate.) By the early 1960s, however, some change was observable. Both chiefs were by then aged men; and being men who matured in a former era, some contemporary problems required that the decision-making process be opened to include younger men who had attended schools and/or had some other experiences with the American administration. Meetings of all males were occasionally held, and some decisions about community affairs were decided by a majority vote. The authority and status of the chiefs further declined in the latter 1960s when the old Enjebi chief died and was succeeded in office by his younger brother who was also an aged man and suffered the disadvantage of frequent poor health.

The combination of the above events precipitated a major transformation of the political structure. The chiefs yielded to younger men who desired and had been gaining a greater voice in community affairs. Then, in 1968, a magistrate and a council of 12 men were elected; reflecting the traditional division of the population, the Enjebi people elected six councilmen from among their ranks, and the Enewetak people elected six. The magistrate became the head of the entire community, and the council became the legislative body governing the people's affairs. In a very recent election, however, the 12 councilmen were elected from the population at large and not from the two groups. Thus, the current council reflects a demise of the traditional system and indicates that the old division between Enjebi and Enewetak peoples has lost much of its meaning. The council is now a representative body drawn from the entire population and reflects a unified community with acknowledged common goals. The chiefs, however, remain important figures as advisors and men of influence.

### 2.2.2 Church and Religion

The church is the focal point for many community social activities of the Enewetak people. The prevailing religious system is a conservative type of Protestantism in which church services, Bible classes, church group meetings, and hymn singing have replaced traditional intertribal wars, sports, games, and dancing.

The minister is the spiritual leader of the community and is supported and assisted by the chiefs of the clans. The church functions are time consuming and require a considerable effort from the membership. Sundays in particular are devoted almost entirely to church services and related activities. From this it is apparent that the church influences the life of the Enewetakese to a great degree (J. A. Tobin, 1967).

### 2.2.3 Land

The atoll soil is poor, thus agriculture is limited. For centuries subsistence has been marginal and precarious for the island inhabitants despite hard work. Nevertheless, the residents have always maintained a deep emotional attachment to their home islands and ancestral land.

The land parcels, or wātos, on Enewetak Atoll were like those found elsewhere in the Marshalls. Most commonly, each was a strip of land stretching across an island from lagoon beach to ocean reef and varying in size from about 1 to 5 acres in extent. The resources of all ecological zones were thus available to the individuals who held right to the land. Less commonly, a parcel was divided into two or more portions with transverse boundaries. This usually occurred when an island, Enjebi for example, was very wide. Boundaries were usually marked by slashes on the trunks of coconut trees, or less commonly, ornamental plants. Also, other features of the natural topography, e.g., large boulders on the ocean reef and the very configuration on an island, were used to fix the position of landholdings. The latter type of markers have been employed by the Bikini people after all other markings had been obliterated.

One facet of Enewetak Atoll culture that differed from that of the rest of the Marshalls was the system of land tenure and inheritance. In contrast to the rest of the Marshalls where matrilineal descent groups known as bwij or lineage constitute landholding corporations, the land tenure system at Enewetak was in ideal and in practice a bilateral one.

In most cases, a married couple divided the land they had each inherited among their children, and a child usually received some land from both his father and mother. As younger islanders matured, they worked the land with their parents. As the parental generation died and as members of the next generation married and produced children, the process was repeated with parents allocating land among their offspring.

The islanders resided upon their landholdings on Enjebi and Enewetak Islands. Households were either extended or nuclear family groupings. In most cases, households were headed by males and were situated upon land held by them. Ideally, residence was patrilocal, i.e., upon marriage, females moved to their husband's households, although exceptions to the rule did occur.

Every individual possessed rights to some land on islands away from the settlements on Enewetak and Enjebi. All land in the atoll was held by someone with the exception of one parcel on Enewetak Island which was donated to the mission.

## 2.3 RELOCATION OF THE ENEWETAK PEOPLE

After the capture of Enewetak Atoll in 1944, the U. S. Forces removed the Enewetak people from their homes on Enjebi and Enewetak Islands and placed them on Aomon. Later the Enjebi community moved (at their own request) to Bijile Island because the latter was under the authority of the Chief of the Enjebi community. Thus, the Enjebi people were moved twice (Enjebi to Aomon to Bijile) whereas the Enewetak people were moved once (Enewetak to Aomon) prior to relocation to Ujelang. In 1946, when nuclear testing was first considered for Enewetak, the Enewetakese were moved to Meik Island in Kwajalein Atoll. Their stay there was short, and they were again moved back to Aomon where they remained almost a year. Late in 1947, they were again moved, this time to Ujelang Atoll where they are at the present time.

## 2.4 COMPARISON OF UJELANG AND ENEWETAK

Ujelang lies 124 miles southwest of Enewetak. In preEuropean times, Ujelang was inhabited by a Marshallese population. In the late 1800s a typhoon decimated the atoll and killed all but a handful of people who moved to the southern Marshalls. The atoll was then developed as a commercial copra plantation during the German and Japanese colonial eras. During the plantation period, a small group of islanders from the Eastern Carolines served as wage laborers on the atoll. It was abandoned, however, during World War II and was thus uninhabited. As U. S. Government property, inherited from the Japanese, it was available for the relocation of the Enewetakese.

Ujelang also is much smaller than Enewetak, both in size of the lagoon and in the total dry land area. (See Plate #3.) A comparison of both atolls in square miles of area shows:

| | Lagoon | Dry Land |
|---|---|---|
| Ujelang Atoll | 25.47 | 0.67* |
| Enewetak Atoll | 387.99 | 2.75** |

From this comparison, it is apparent that the potential for production of food from the reefs and lagoon is considerably less on Ujelang than it is on Enewetak. The limited food potential on Ujelang has made it necessary to import more commodities than would normally be required on Enewetak.

## 2.5 LIVING CONDITIONS ON UJELANG

The U. S. Navy had constructed a village on the main island of Ujelang for the displaced Enewetakese and a brush clearing program was in progress when they arrived on the atoll. Coconut trees planted during German and Japanese administrations were still standing and

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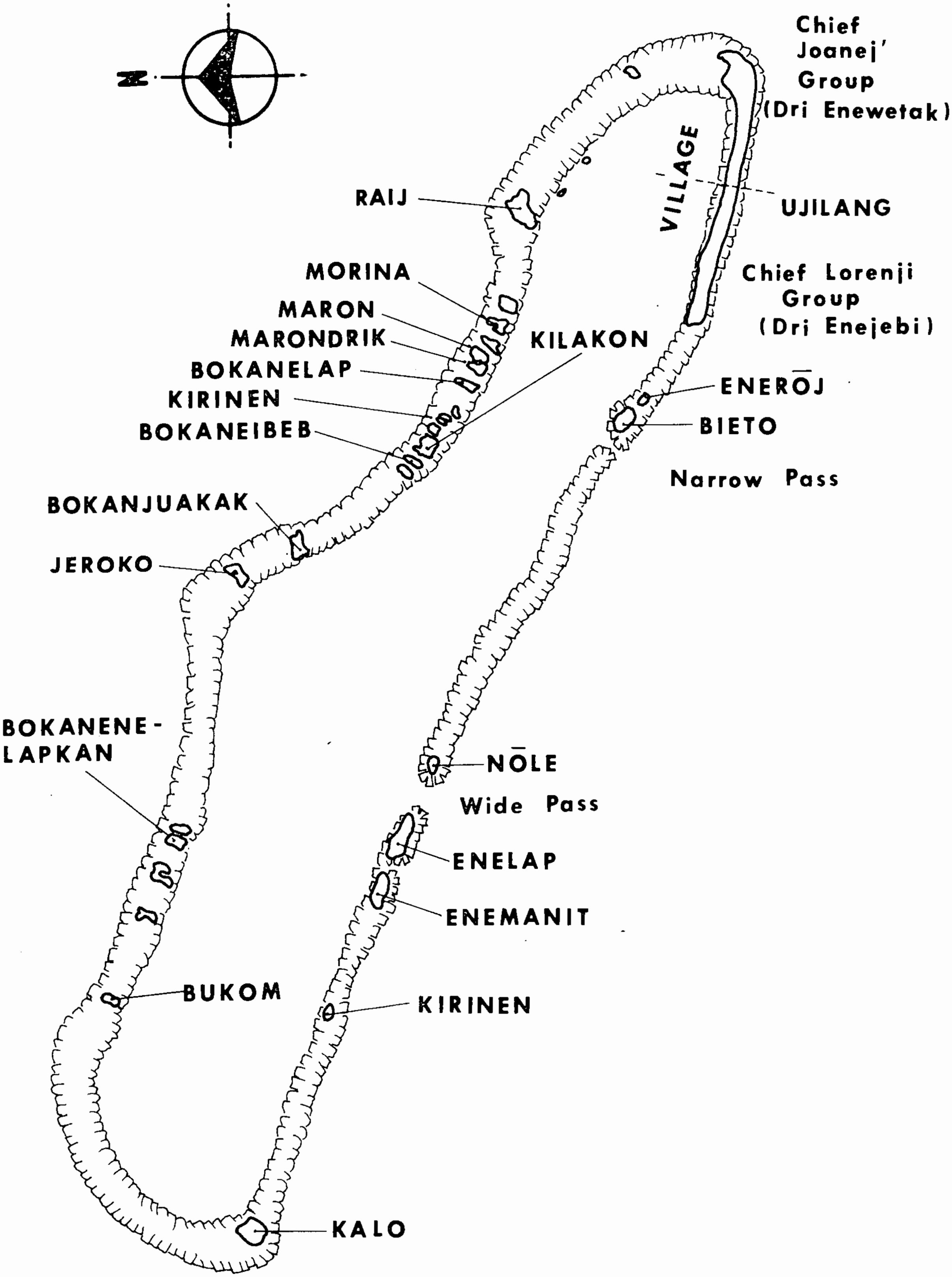
* J. A. Tobin, 1967.
**Holmes & Narver, Inc., 1973.




# UJELANG ATOLL-POLITICAL DIVISIONS

TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
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bearing. Seedlings of breadfruit and pandanus were brought ashore and planted. After the Enewetak people had settled in, the Navy departed. There was no U. S. official remaining on the atoll, nor was there any radio communication with the outside world.

While on Ujelang, the people have been housed, supplied with a water system (including numerous rain catchments), a church, a council hall, a school, and a dispensary. Supply ships have brought in tools, clothing, and food to supplement the meager natural resources (Tobin, 1967).

The people practice a nonintensive type of agriculture but utilize the environment to the maximum, using the plants that can survive and produce in the atoll environment. Coconut is converted to copra for cash sale to the visiting Trust Territory supply ship. Consumer goods are purchased from the ship with the proceeds of the copra sales. The interest payments from the trust funds provided by the TTPI administration also help buy needed commodities. Rice, flour, sugar, canned meats, and other canned goods are staple items of the diet and have been for many years. Fish, clams, lobster, turtles (flesh and eggs), seabirds (flesh and eggs), chickens, and pigs provide protein in the diet. The marine resources are extremely important in the diet of these people.

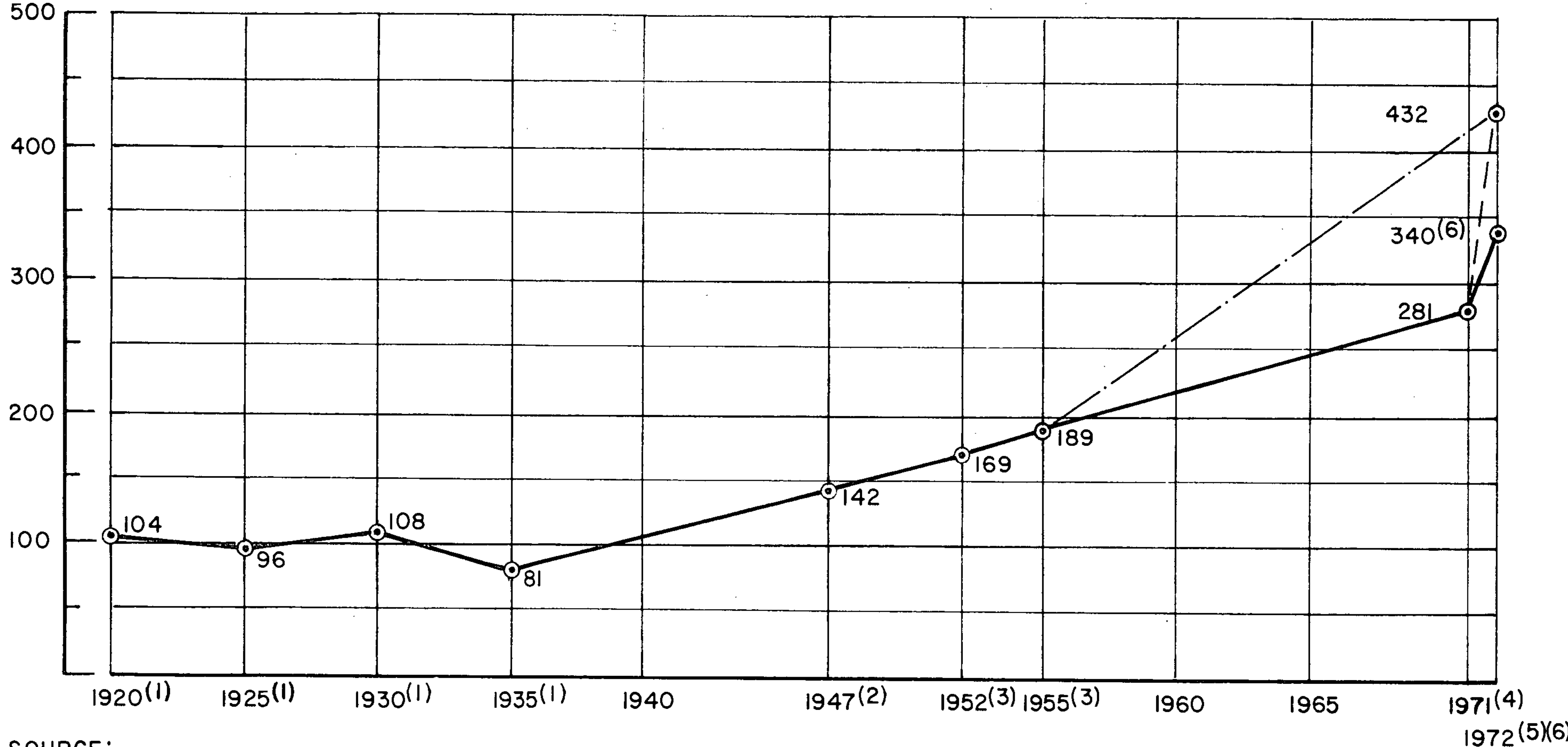
Coconuts, pandanus, breadfruit, and arrowroot are the main vegetable products used. Bananas, papayas, and squash are used to a lesser extent, probably due to the relative scarcity of the banana and papaya which do not seem to grow well on Ujelang.

The former Enewetak inhabitants attempted to adjust to their new location. They had, and still have, several formidable problems with which to cope. The most obvious problem, and one which they have uppermost in their minds, is the great disparity in the size of Ujelang and that of Enewetak. The traditional Marshallese pattern of habitation is for family units to live on their land parcels, not in a village cluster. While it is common for community buildings, church, school, dispensary, and warehouse to be centralized for convenience and access to all, dwellings are usually dispersed over the length of the lagoon beach of an island. This pattern is obviously desirable from the point of view of environmental sanitation and public health. As described, the traditional settlement pattern of the Enewetakese was disrupted because of their relocation.

## 2.6 DEMOGRAPHY

It is estimated that nearly all of the Enewetak people want to return to the atoll as their leaders have stated on several occasions. The few who have jobs and interests elsewhere may leave the atoll after a visit, but it is expected that they will want to reestablish old land claims and see how the atoll has changed in twenty-five years. These people will visit the atoll at intervals, just as they visit Ujelang today, and will eventually retire on Enewetak. Present planning anticipates the return of all the Enewetak people.

Plate #4 follows the growth trend of the Enewetakese from 1920 to 1972. The fluctuation in population between 1930 and 1947 can be explained partially by the fact that members of the community left the atoll for extended periods at different times to work on the copra plantations on Ujelang and to visit the administrative headquarters on Ponape. Subsequent increases in population also can be attributed to the return of the Ujelang workers accompanied by Ujelang spouses. It should be noted that the TTPI official census of 281 taken in 1971 and the 1972 census of 340 taken by J. A. Tobin include only those Enewetakese in residence on Ujelang at the time. The 1972 figure of 432 includes these people as well as those residing elsewhere (from Tobin, 1973).




SOURCE:

(1) Japanese Consul-General, Honolulu (1966).

(2) U.S. NAVY (at the time of relocation to Ujelang).

(3) J.A.Tobin (on Ujelang).

(4) TTPI Official Census (on Ujelang only).

(5) J.A.Tobin (Total - Ujelang & elsewhere).

(6) J.A.Tobin (on Ujelang only).

Data from J.A.Tobin - 1973.

# POPULATION-1920 to 1972 - ENEWETAK ATOLL

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

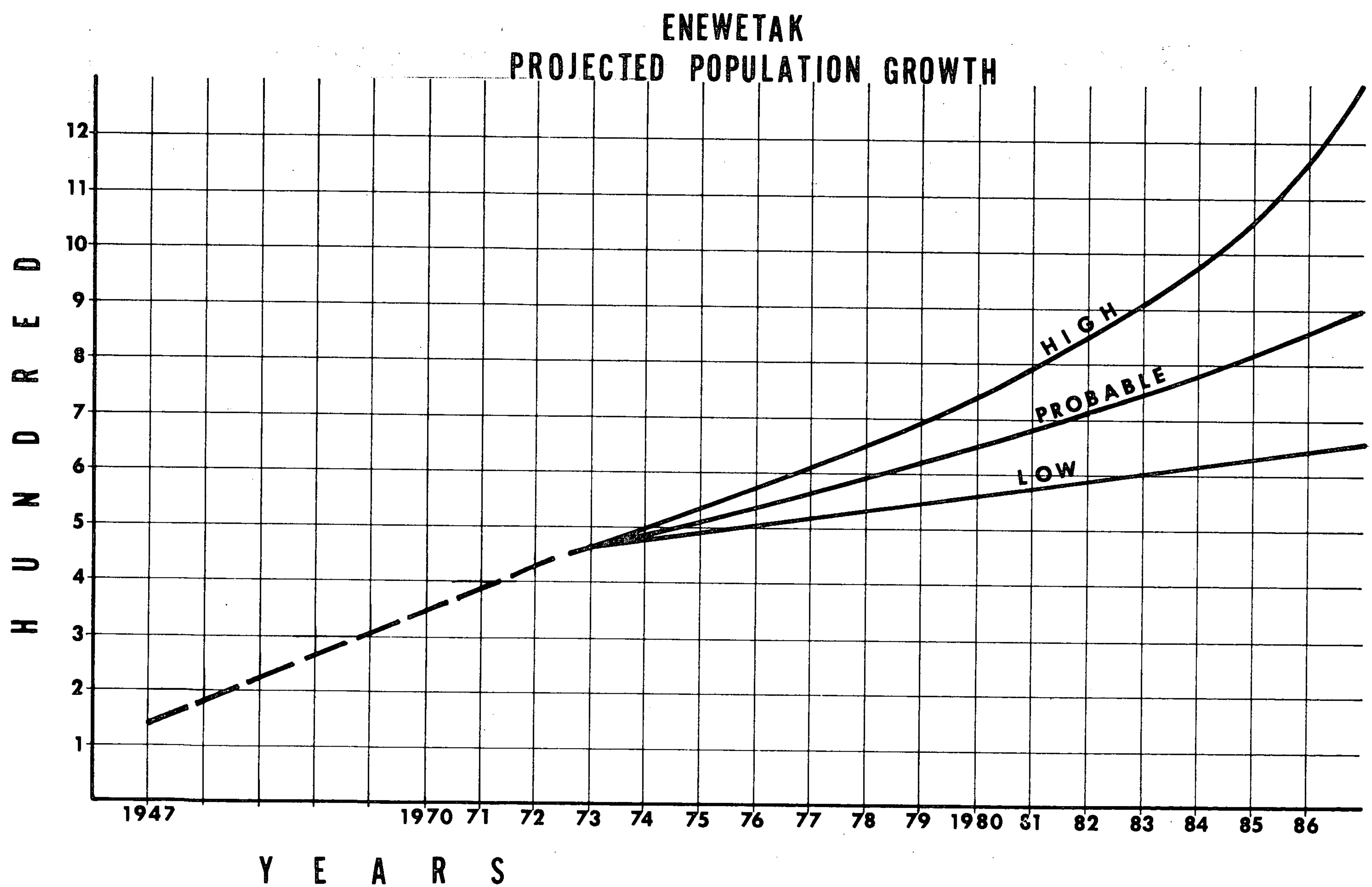
HOLMES & NARVER, INC.

Plate No. 4

NOV. 1973

Estimates based on available census data indicate a growth rate of the Enewetakese people from 1948 to 1973 of approximately 6 percent per year. It is anticipated that population growth on the long term will not exceed that rate, and in all probability will slow to a more moderate rate. Plate #5 establishes projected population growth curves based on rates of growth of 3 percent, 5 percent, and 7 percent as being the most probable range and indicates that in 1978 the population of Enewetak Atoll may be between 530 to 650 persons, and in 1983 may be between 600 and 900 persons. Limitations on food supply or other resources may, of course, reduce population growth below the maximum limits of the graph, particularly in the latter half of the time period. However, the graph does indicate some parameters of population growth that may be useful in planning future food requirements on a gross basis. At some future time, the growth curve will tend to stabilize; but at this time, there is insufficient data for an accurate projection.

The population pyramids in Plate #6 were prepared from a census taken on Ujelang in July, 1973. The pyramids separate the driEnjebi from the driEnewetak and provide classification by sex and age group. One factor that points up a growth trend in the population is the high percentage of people under 30 years of age. Approximately 80 percent of the total population falls within the 0 to 29 age group. This also is apparent in the case of each of the two communities. One other indicator is the number of children under ten years of age representing both the driEnjebi and the driEnewetak. Plate #6 shows 157 in that age group, or about 35 percent of the total population. This also indicates a probable rapid increase in the population over the next five to ten years.




TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
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Plate No.
5
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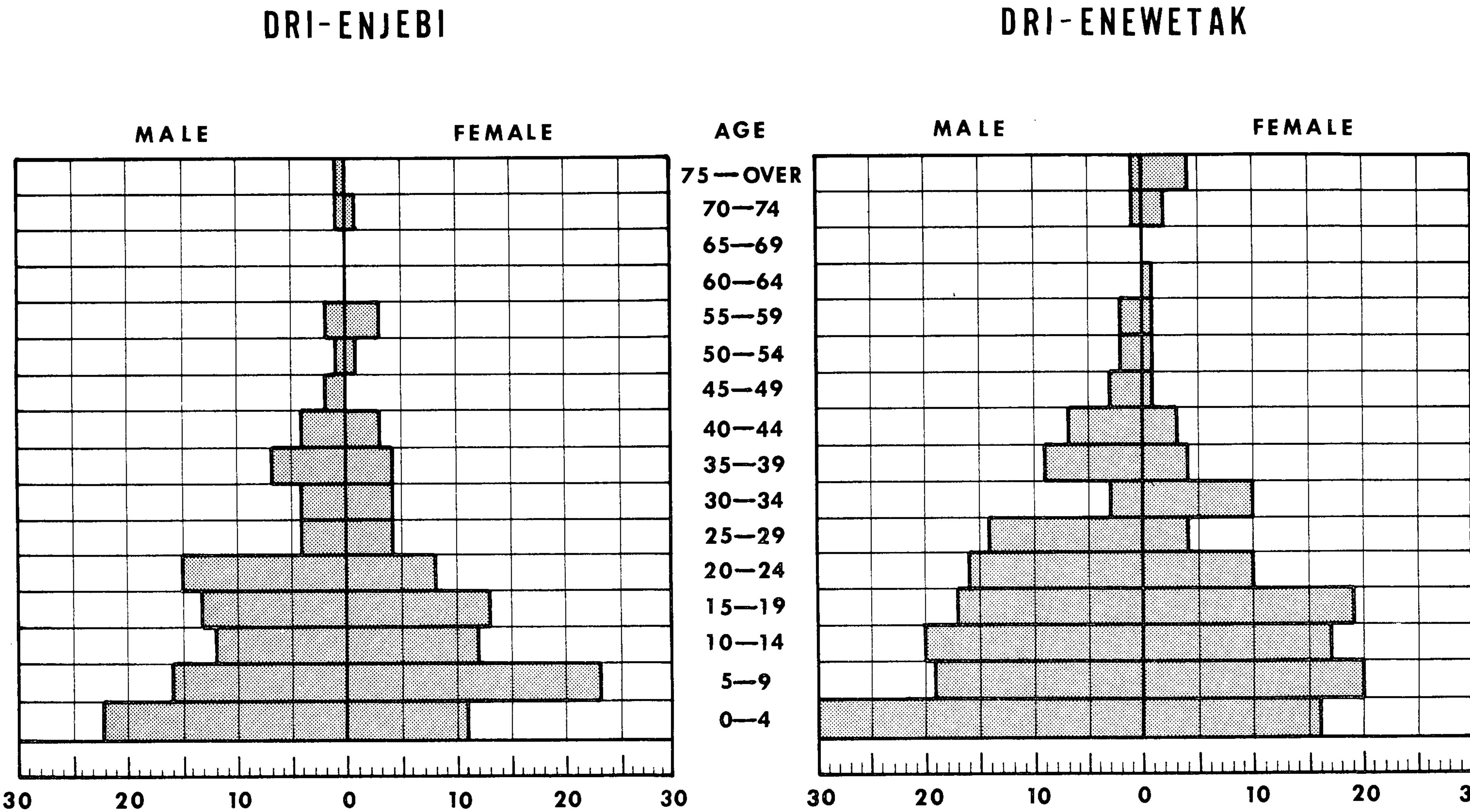



# COMPARISON POPULATION PYRAMID

Ujelang Atoll - 1973

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No.
6

NOV. 1973

# 3. PHYSICAL DESCRIPTION OF ENEWETAK ATOLL

# 3. PHYSICAL DESCRIPTION OF ENEWETAK ATOLL

## 3.1 LOCATION AND PHYSIOGRAPHY

Enewetak Atoll is located at approximately 11°21'N and 162°21'E in the northwestern portion of the Marshall Islands, 600 miles from the District Headquarters at Majuro. (See Plate #7.)

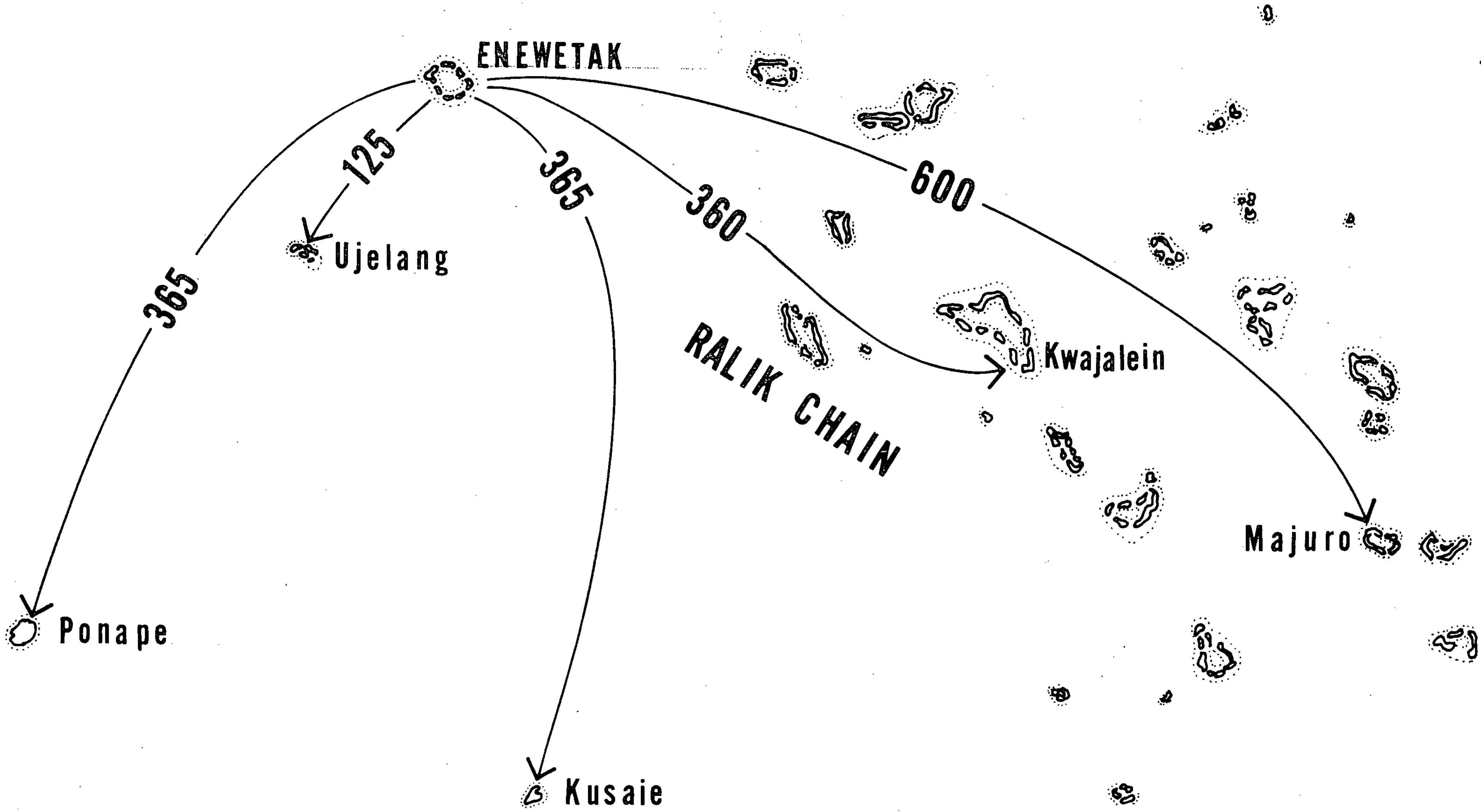
The atoll encompasses about 388 square miles of lagoon area surrounded by 39 small islets with a total dry land area of about 2.75 square miles (see Table 3-1). The nearest neighboring atoll is Ujelang, where the Enewetakese people were evacuated prior to the atomic testing program and where most of them now reside. The relative isolation of Enewetak and Ujelang from the rest of the Marshall Island group, which limits normal transportation links, and the marginal soils, marginal rainfall, and limited land area of Enewetak Atoll place severe constraints on the ability of the atoll to provide both subsistence crops to directly support the people and cash crops to provide for import of supplies and materials necessary to the health and economy of the people.

The soils at Enewetak are basically coral rock and coraline sands with minimal organic content and little or no fertility reserve. Almost the entire life cycle of the atoll is tied into a narrow pattern of the living plant, the debris of leaves and other fallen material, and the extremely limited humic content of the top few inches of the coral sands. Rainfall is limited and is the only source of fresh water. The soils have limited water holding capacity, and there is virtually no economic justification for large-scale irrigation even if water supplies were available.

TABLE 3-1

LAND AREAS - ENEWETAK ATOLL

| Site | Square Feet | Acres |
|---|---|---|
| ENEWETAK | 14,019,200 | 321.84 |
| ENJEBI | 12,657,600 | 290.58 |
| MEDREN | 9,574,200 | 219.79 |
| AOMON | 4,323,600 | 99.26 |
| RUNIT | 3,975,390 | 91.26 |
| JAPTAN | 3,430,400 | 78.75 |
| LUJOR | 2,358,000 | 54.13 |
| BIJILE | 2,263,500 | 51.96 |
| IKUREN | 1,803,900 | 41.41 |
| LOJWA | 1,762,200 | 40.45 |
| AEJ | 1,758,600 | 40.37 |
| MUT | 1,758,600 | 40.37 |
| BOKEN | 1,733,700 | 39.80 |
| ALEMBEL | 1,645,200 | 37.77 |
| BOKOMBAKO | 1,328,400 | 30.50 |
| BOKEN | 1,247,740 | 28.60 |
| ANANIJ | 1,108,000 | 25.44 |
| KIDRENEN | 1,059,300 | 24.32 |
| BOKOLUO | 974,700 | 22.38 |
| LOUJ | 924,300 | 21.22 |
| KIDRINEN | 884,725 | 19.39 |
| RIBEWON | 818,875 | 18.80 |
| MIJIKADREK | 692,475 | 15.90 |
| BILLAE | 630,000 | 15.83 |
| BIKEN | 590,475 | 13.56 |
| BOKENELAB | 505,625 | 11.61 |
| ELLE | 480,600 | 11.03 |
| BOKINWOTME | 429,300 | 9.86 |
| KIRUNU | 298,800 | 6.86 |
| VAN | 285,825 | 6.56 |
| JEDROL | 231,775 | 5.32 |
| BOKAIDRIK | 220,000 | 5.05 |
| TAIWEL | 209,400 | 4.81 |
| ELELERON | 167,300 | 3.84 |
| INEDRAL | 167,150 | 3.84 |
| JINIMI | 134,100 | 3.08 |
| JINEDROL | 95,025 | 2.18 |
| MUNJUR | 80,000 | 1.84 |
| BOKO | 39,350 | 0.90 |
| TOTAL<br>39 Sites | 76,667,330 Square Feet<br>(2.75 Square Miles) | 1,760 Acres |




REGIONAL MAP
WESTERN MARSHALL ISLANDS

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No. 7
NOV. 1973

The main islands within the atoll were subjected to severe aerial and ship bombardment and damage in the American landings during World War II. Again, in 1958, many of the islands and islets of the atoll were subjected to ecological outrage and damage when utilized as a test range for nuclear devices. With exception of the island of Japtan (David), and three or four minor islands in the southwestern sector, there is little recognizable agricultural base remaining within the confines of the atoll.

## 3.2 CLIMATE

Despite an average annual precipitation ranging from 50 to 60 inches, Enewetak Atoll is considered arid due to the limited water capacity of the soil and the effects of windborne salt spray on the local vegetation. Reliable weather data are available for Enewetak from 1941 (U. S. Navy and U. S. Weather Bureau sources), and the basic data for rainfall, day length, daylight hours, and mean monthly temperature are shown in Table 3-2. Temperatures are quite uniform, ranging from a mean annual of 82.5$^{o}$F to a mean minimum of approximately 79$^{o}$F and a mean maximum of approximately 86$^{o}$F. The atoll is subject to the Pacific trade winds, generally from ENE to E, which during the period December to April average 18 mph, and from May to November average 12 mph (see Plate #8). Occasional westerly storms are experienced, although these are seldom destructive. The area is subject to infrequent hurricanes or typhoons, which can cause severe damage to plants and crops, and also may damage or destroy buildings and other facilities.

## TABLE 3-2

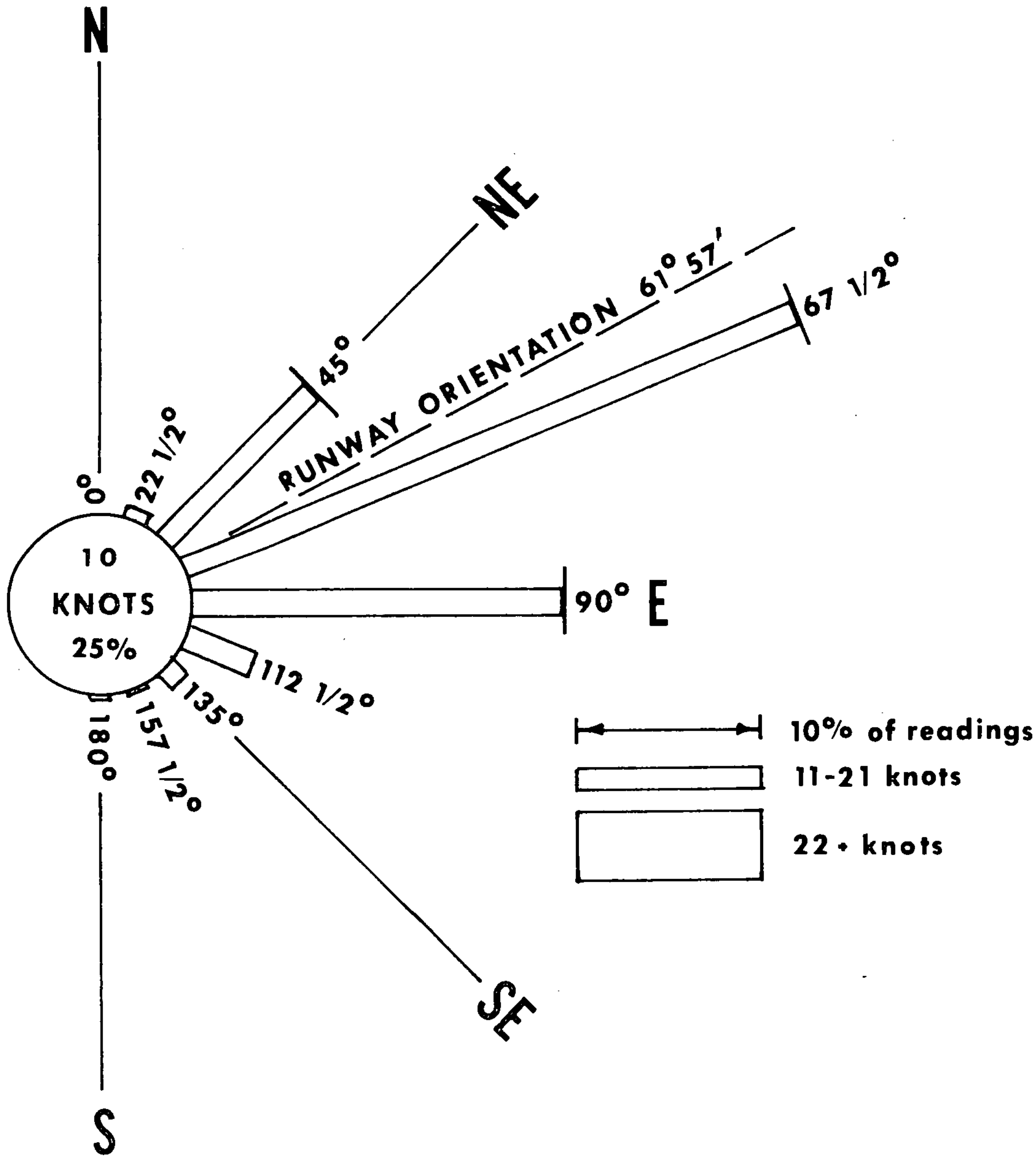
## CLIMATE DATA FOR ENEWETAK

| Month | Mean Temp. °F | Day Length (Min) | Days | % Sun-light Length | Evapotranspiration Potential (Consumptive Use) | | Evapotranspiration Potential (Deficit) |
|---|---|---|---|---|---|---|---|
| January | 81.2 | 683 | 31 | 8.67 | 4.22 | 0.99 | 3.23 |
| February | 80.9 | 702 | 28 | 8.05 | 3.91 | 1.88 | 2.03 |
| March | 81.3 | 722 | 31 | 9.16 | 4.47 | 1.78 | 2.69 |
| April | 82.1 | 742 | 30 | 9.11 | 4.49 | 1.66 | 2.83 |
| May | 82.4 | 760 | 31 | 9.85 | 4.87 | 5.11 | +0.24 |
| June | 82.8 | 770 | 30 | 9.46 | 4.70 | 4.11 | 0.59 |
| July | 82.8 | 766 | 31 | 9.72 | 4.83 | 7.37 | +2.54 |
| August | 83.0 | 751 | 31 | 9.53 | 4.74 | 7.22 | +2.48 |
| September | 83.3 | 732 | 30 | 8.99 | 4.49 | 7.16 | +2.67 |
| October | 83.0 | 710 | 31 | 9.01 | 4.49 | 9.90 | +5.41 |
| November | 82.6 | 692 | 30 | 8.49 | 4.21 | 6.37 | +2.16 |
| December | 82.0 | 682 | 31 | 8.65 | 4.26 | 3.45 | 0.81 |
| | | | | | 53.68 | 57.00 | +3.32 |

$$f = \frac{txp\ (k)}{100}$$

k = 0.61 approximate

U. S. Weather Bureau Climate Data




WIND DIRECTION AND VELOCITY
ANNUAL AVERAGE

# WIND ROSE - ENEWETAK ATOLL

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

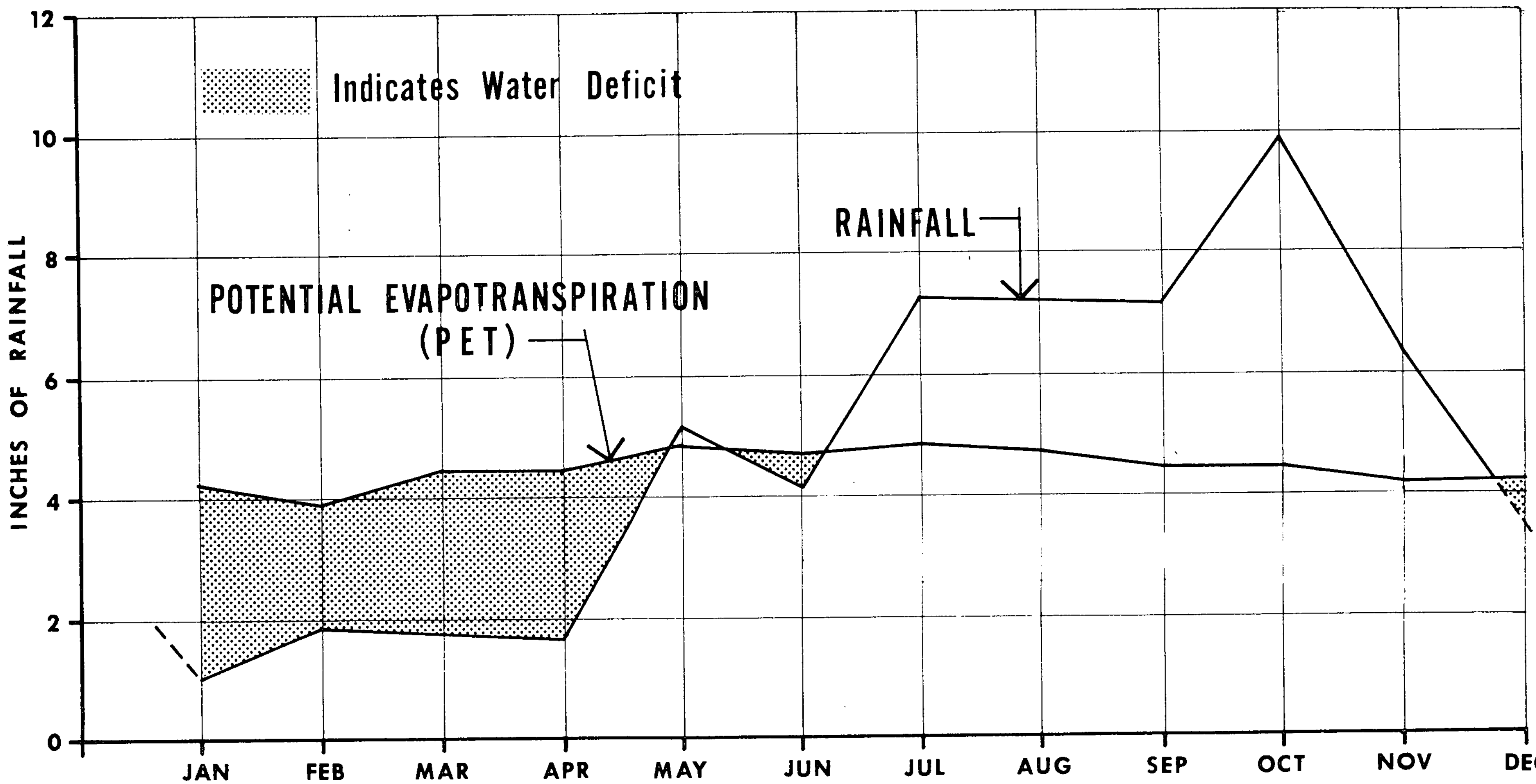
Plate No.
8
NOV. 1973

The most limiting factor for agriculture is rainfall, which averages 57 inches per year, ranging from a recorded low of 24.4 inches in 1953 to a high of 73.9 inches in 1971.

### 3.3 WATER RESOURCES - RAINWATER AND WELLS

The mean monthly rainfall for Enewetak has been calculated and is shown in Plate #9. Potential evapotranspiration (PET) for this area has also been estimated by the Blaney-Criddle Method, which gives a reasonable approximation of the consumptive use of water by plants within the ecology. These results have also been shown on Plate #9. The combined rainfall and PET parameters define the probable periods during the year of water deficit and water availability and thus indicate the optimum periods for tree planting and vegetative rehabilitation of the atoll.

Although little or no serious investigation has been reported, the limited records of current and past use of shallow wells on some islands in the atoll suggest that shallow basal lenses of brackish water exist under some of the larger islands. The extent of these basal lenses is not known at this time, but verbal reports of inhabitants at Ujelang suggest that shallow wells were regularly utilized as domestic sources principally for washing clothes, etc., and in times of severe shortage, for drinking. It is suggested that careful investigation and cautious exploitation of this water resource may provide irrigation for limited areas of some valuable crops. Overutilization of this extremely limited water source may destroy it through intrusion of saltwater from the surrounding ocean; thus, great care must be exercised in both investigations and use of the basal water.




# MEAN MONTHLY RAINFALL
# ENEWETAK ATOLL

TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
HOLMES & NARVER, INC.

Plate No. 9

NOV. 1973

A survey of the hydrological conditions on those islands designated for growing subsistence crops (Engebi, Medren, Japtan, and Enewetak) is essential. The available brackish groundwater will largely determine the extent and method of subsistence agricultural development. Such a survey would be performed by utilizing a small, mobile drill rig to drill shallow holes (deep enough to penetrate the water table) along transecting lines which would be determined by the size and shape of the particular island. Water samples would be taken from each drill hole to determine salinity, alkalinity, and other properties. The limits of the brackish water lens would be defined by abrupt changes in the saline content of the individual samples.

In the event that groundwater sources prove infeasible, it is suggested that suitable water catchments and a water reservoir with a holding capacity of 50,000 to 75,000 gallons be constructed for irrigation of plant nurseries and areas of especially valuable or desirable crops.

Should Enewetak Island be leased for commercial development, it is probable that fresh water in large quantities will be required. It is feasible to consider a rainwater catchment system in the airport runway area as the basic source of fresh water, since approximately 120 acre-feet of water can be accumulated in this area in a year's time.

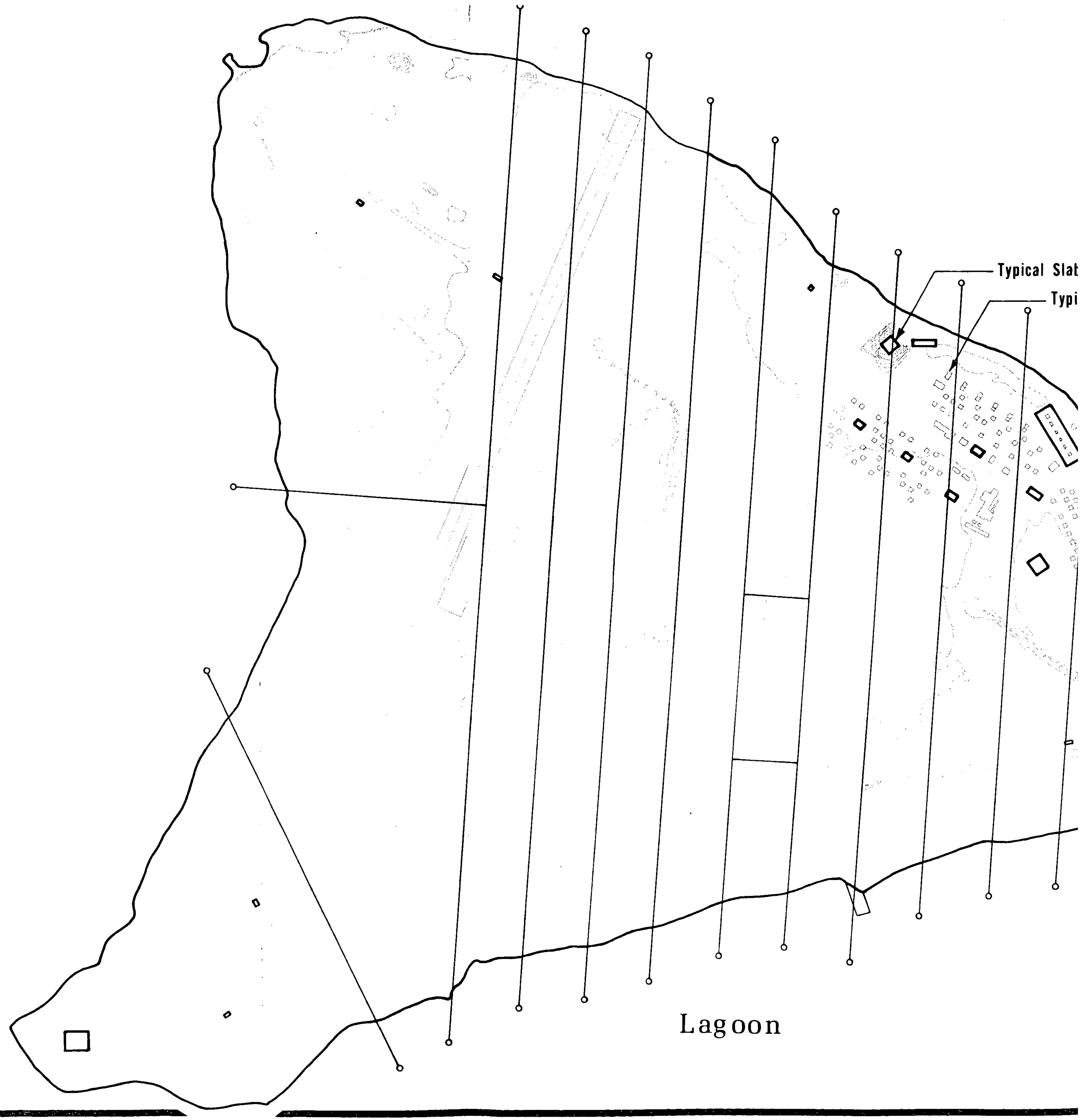
## 3.4 EXISTING CONDITIONS - ENEWETAK ATOLL

The post cleanup condition of all the islands in the atoll will directly affect the magnitude of the rehabilitation in such activities as land clearing, slab removal, and general demolition work. The conditions on Enjebi and Medren will be of special concern as they are designated as the sites for the two permanent communities. Enewetak, which is an alternate community island, and Japtan, where the council and work force will be housed during the cleanup and rehabilitation operations also will require attention.

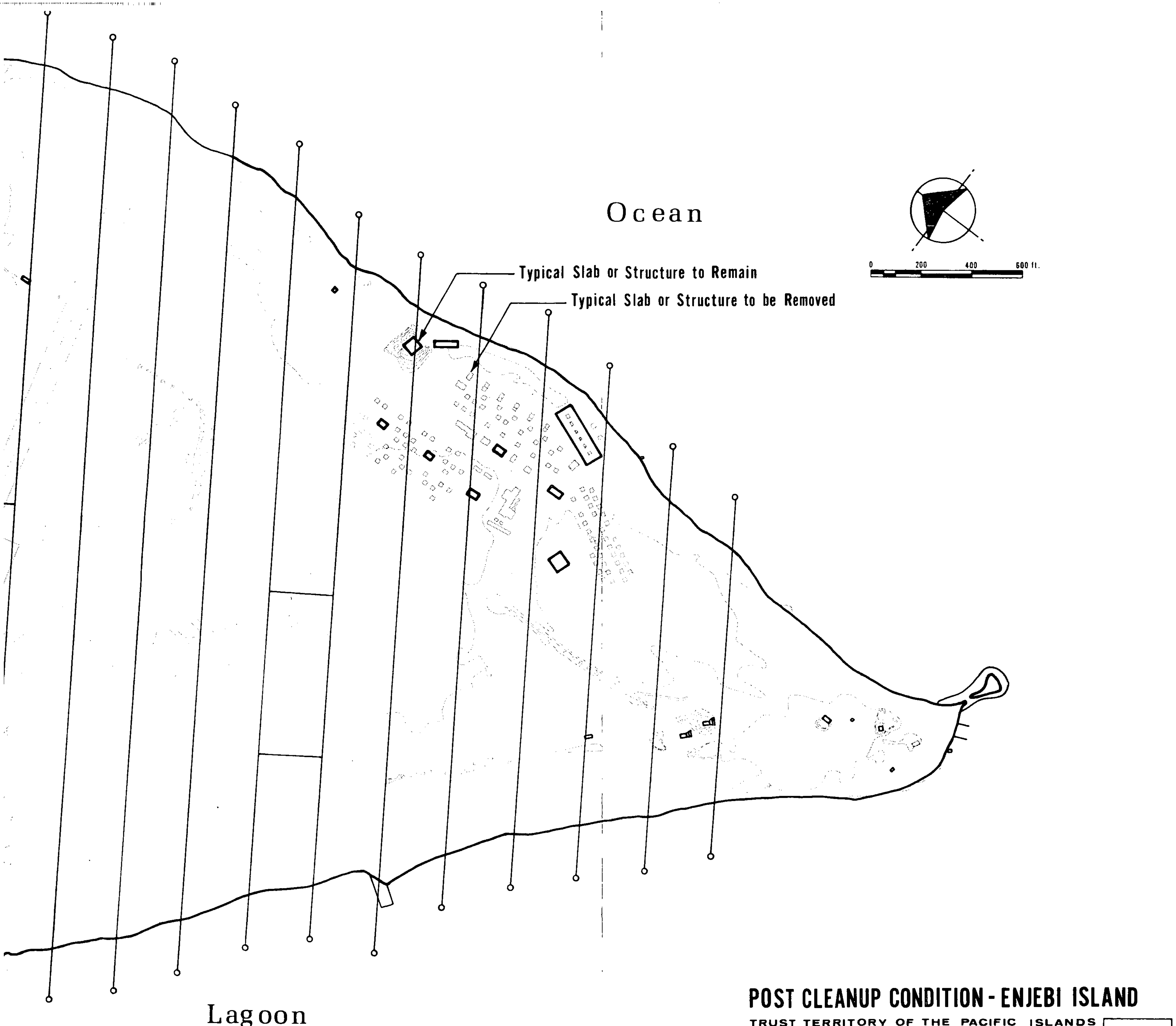
There will be a number of concrete slabs and concrete structures remaining on Enjebi following the cleanup. Approximately seven acres of land will be denuded and plowed to reduce residual radiation levels. Those slabs which are obstructions to the agricultural development of the island will be removed during the rehabilitation operation. The concrete structures remaining after cleanup will be left in place. Plate #10 shows the conditions on Enjebi following the cleanup.

On Medren numerous concrete slabs will remain in place after the cleanup operation and some metal buildings will be left. Of these, Building No. 1209 will be used in place for the school and part of Building No. 1437 will become the recreation facility. Building No. 1453, a concrete block structure formerly used as a computer center, will become the council house. In addition to meeting rooms, it will contain the magistrate's office and the radio transceiver and weather equipment. Other buildings in the community center complex will be erected on existing concrete slabs. Several of the metal buildings will be salvaged and used for community facilities on Enjebi. The slabs and structures remaining in place after cleanup are shown on Plate #11.

Enewetak Island will be the headquarters for the cleanup operation. Therefore, the major portion of the existing buildings and facilities will remain in place following the cleanup operation. Since these structures and equipment will have been rehabilitated for use as a support camp during cleanup, they should be in reasonably good condition. If Enewetak is used as the base for commercial



Typical Slat
Typi
Lagoon




# POST CLEANUP CONDITION - ENJEBI ISLAND

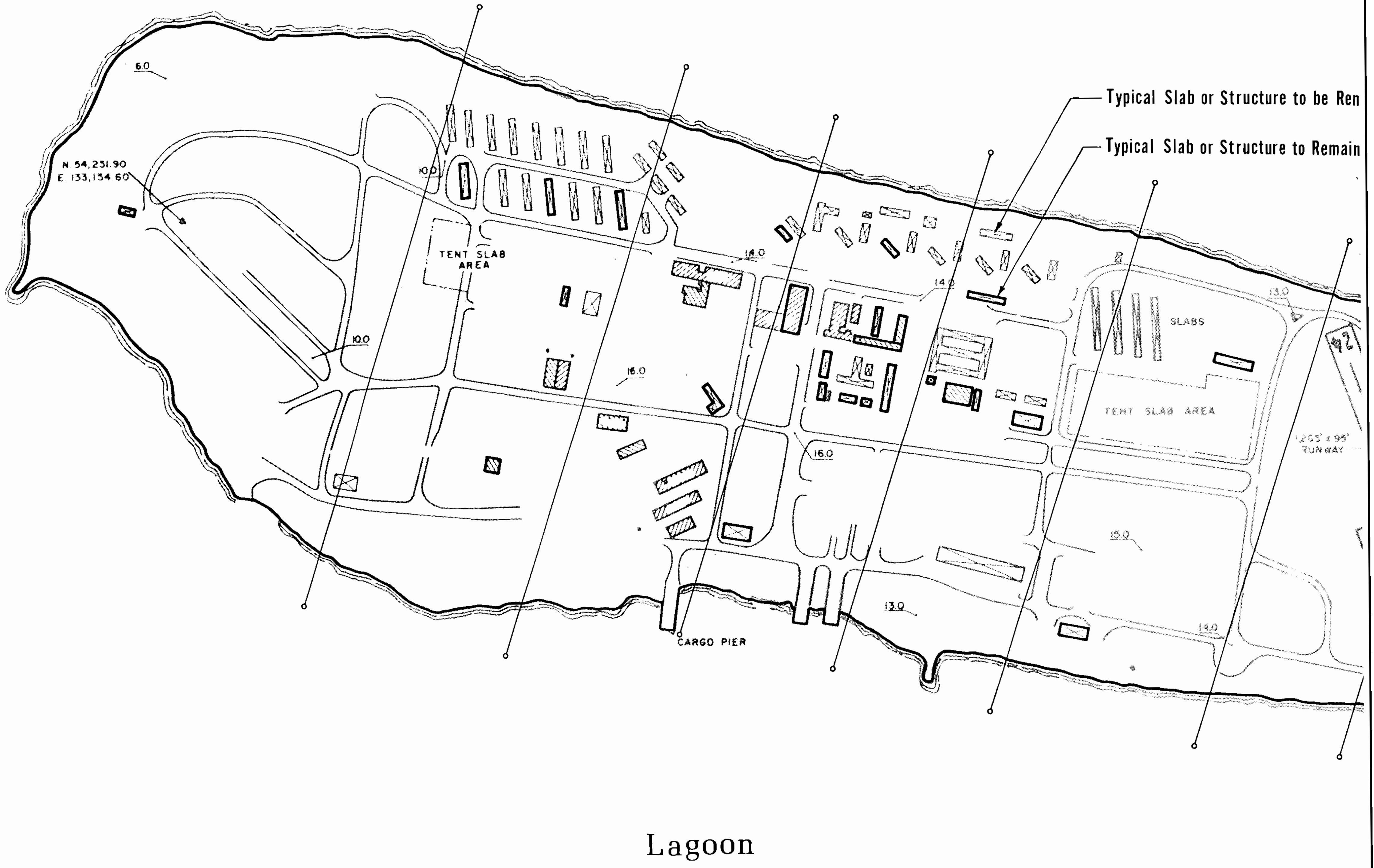
TRUST TERRITORY OF THE PACIFIC ISLANDS

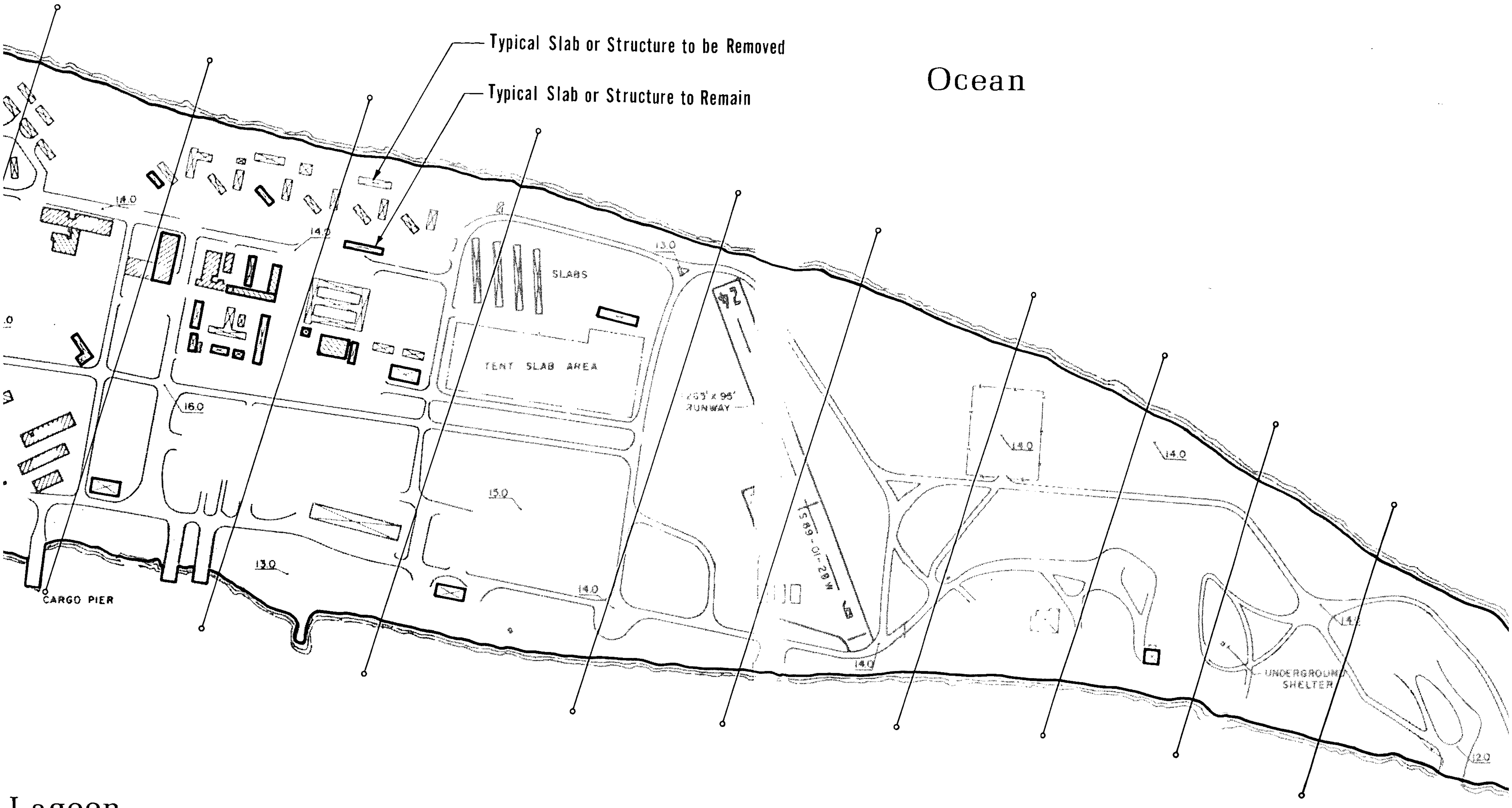
ENEWETAK ATOLL MASTER PLAN

HOLMES & NARVER, INC.

Plate No. 10

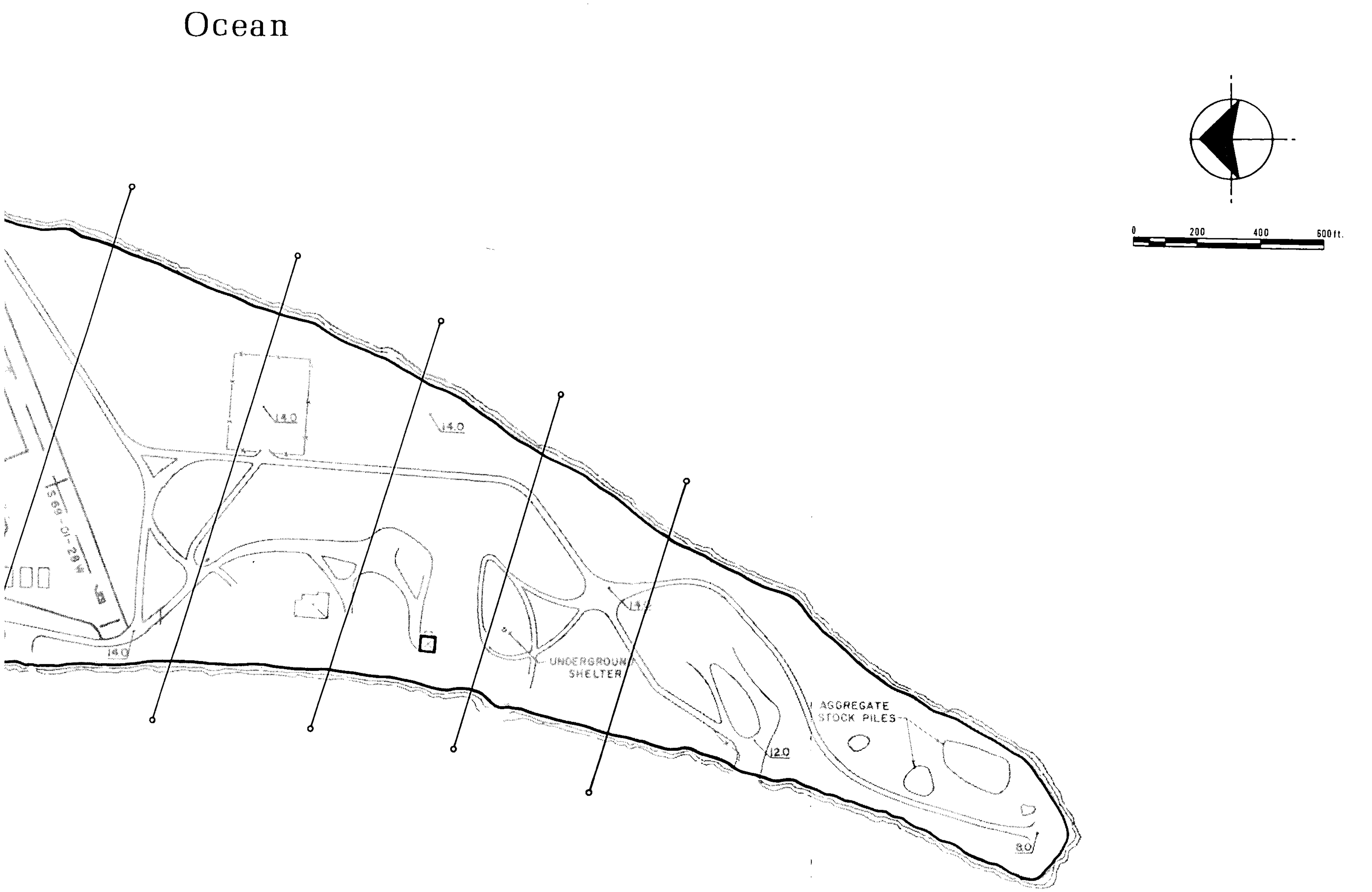
NOV. 1973


Typical Slab or Structure to be Ren
Typical Slab or Structure to Remain
6.0
N 54,231.90
E 133,134.60
10.0
10.0
TENT SLAB AREA
14.0
14.0
16.0
16.0
CARGO PIER
13.0
SLABS
TENT SLAB AREA
1,263' x 95' RUNWAY
15.0
13.0
14.0
Lagoon



Typical Slab or Structure to be Removed
Typical Slab or Structure to Remain
Ocean
Lagoon
SLABS
TENT SLAB AREA
RUNWAY
UNDERGROUND SHELTER
CARGO PIER
14.0
16.0
15.0
13.0
12.0

ved




# POST CLEANUP CONDITION - MEDREN ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

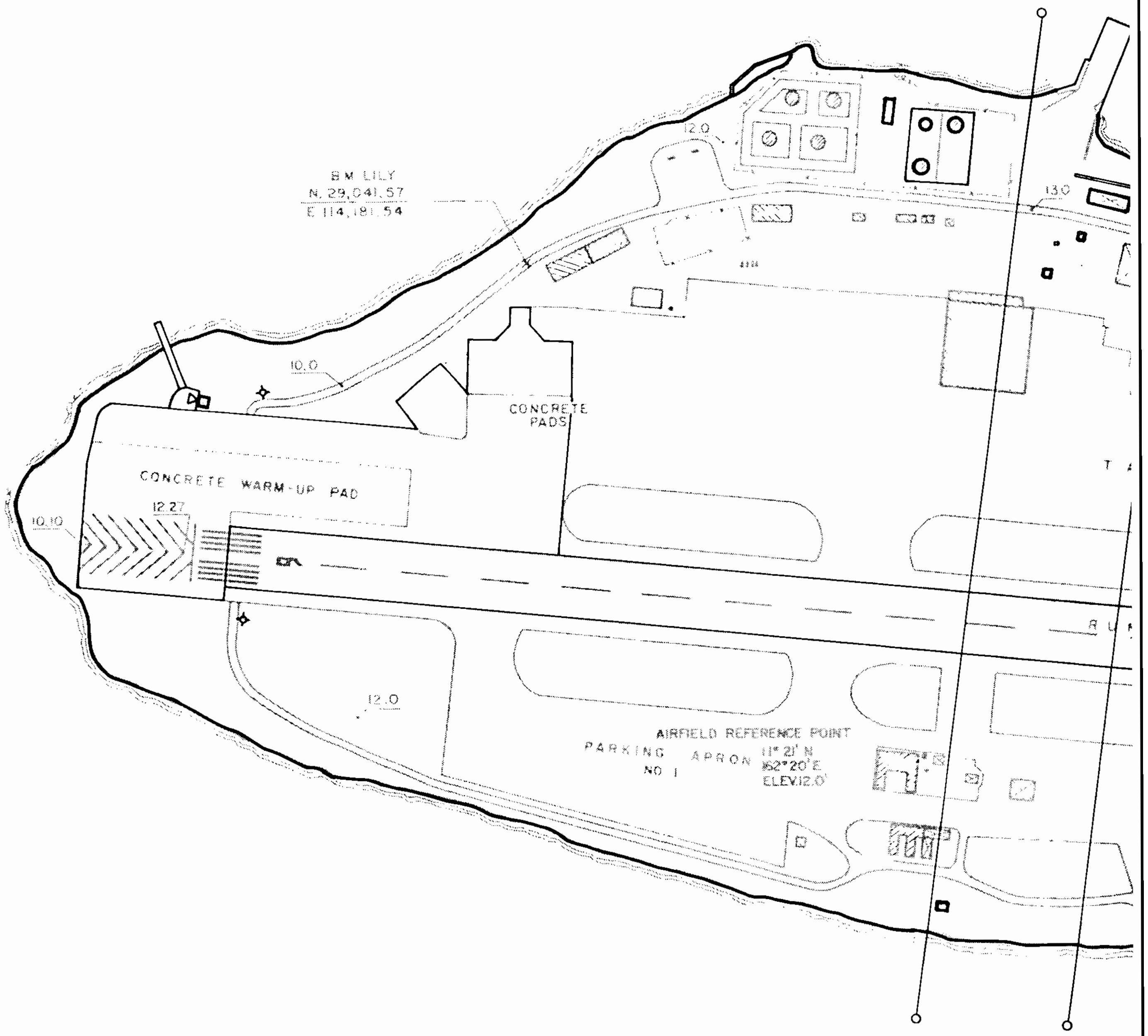
Plate No.

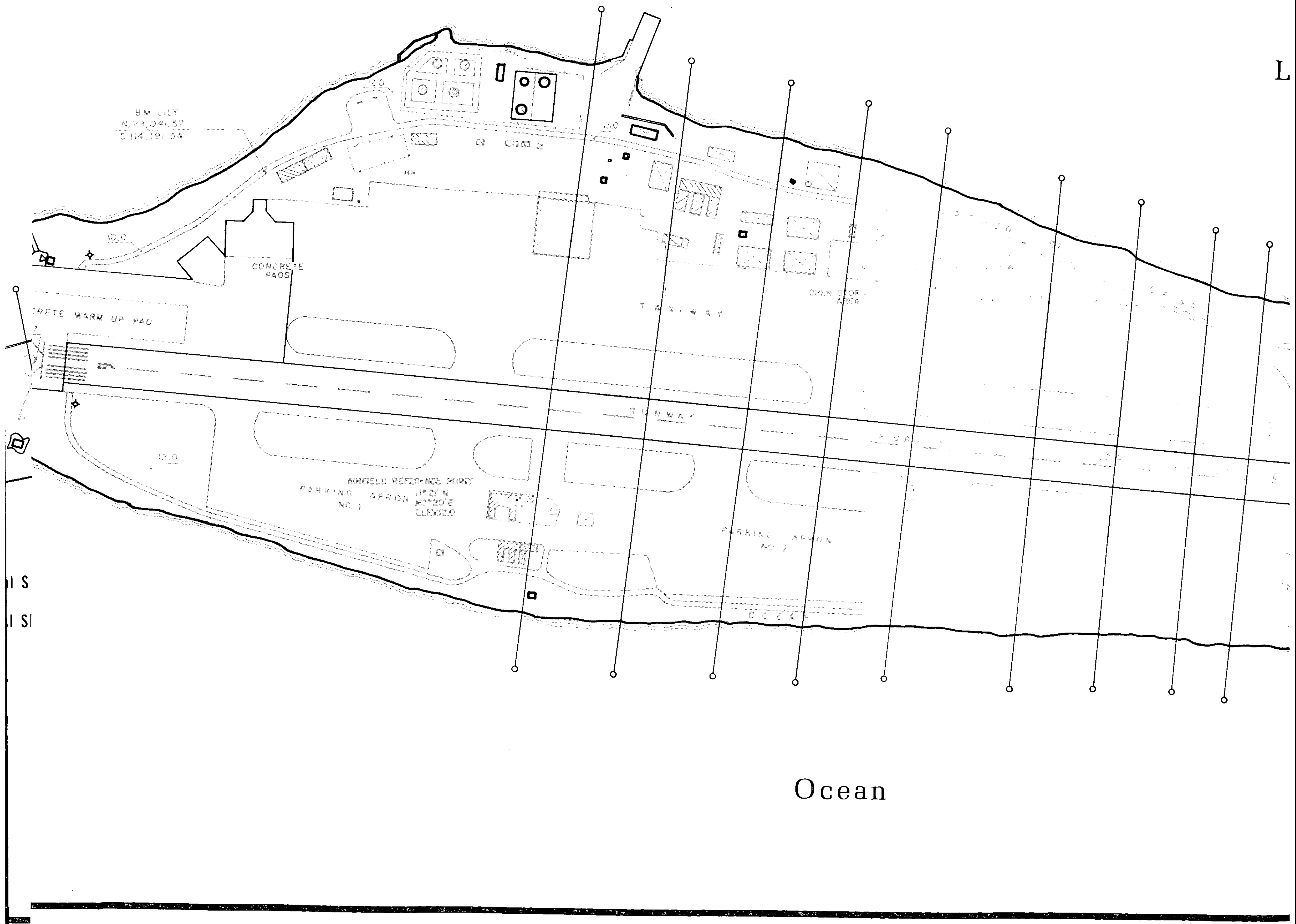
11

NOV. 1973

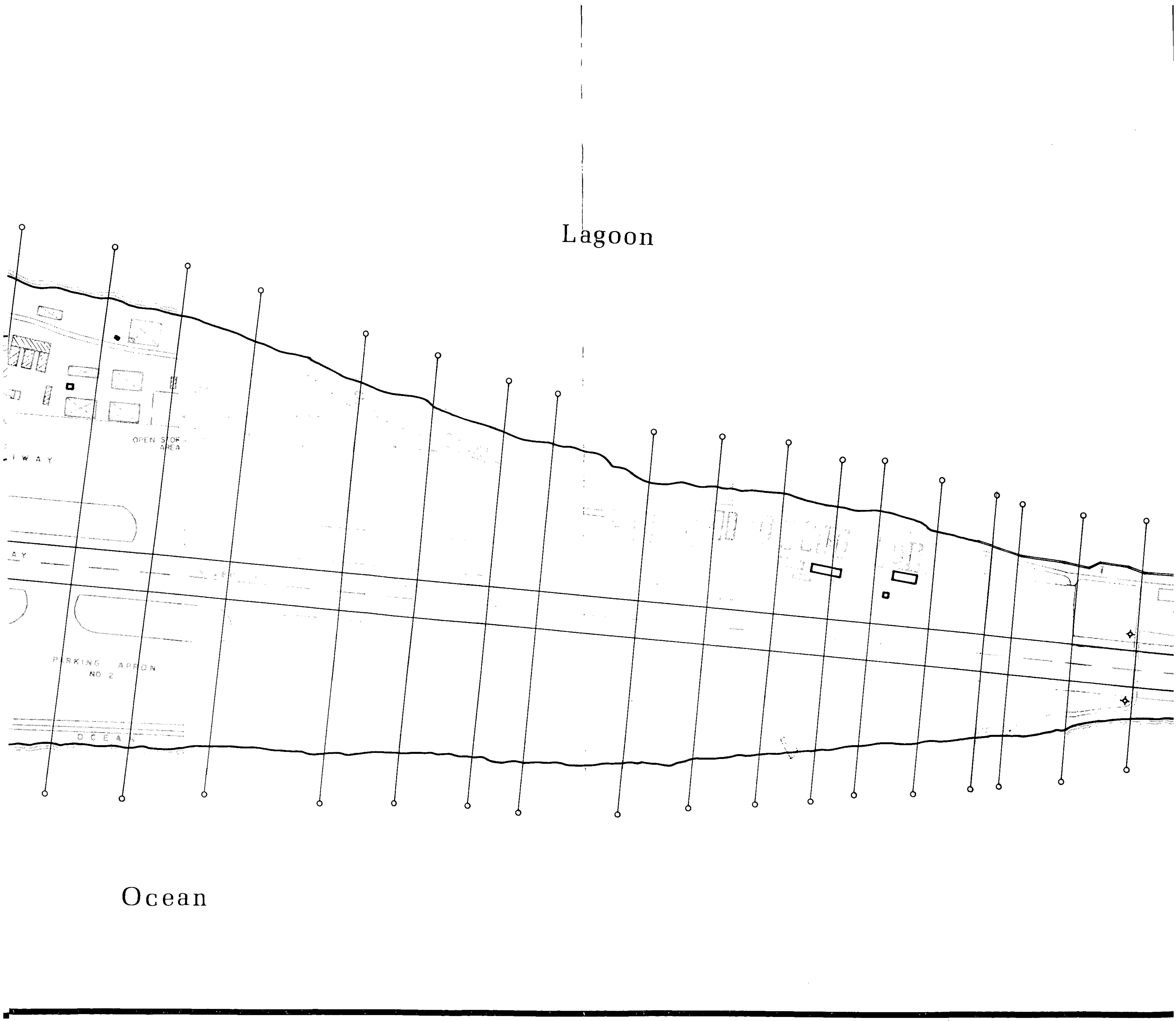
development, it is conceivable that a number of these facilities can be used. However, if the island is used for residential purposes most of the existing facilities will have to be cleared away. Plate #12 shows the conditions which will exist on Enewetak Island after the cleanup operation.

Japtan will be used as a temporary community site for the Enewetak planning council and work force and their families during both the cleanup operation and the atoll rehabilitation program. All of the existing metal buildings and the concrete block MILS building will be rehabilitated for use during this period. In the event that additional housing is required, salvaged buildings from Medren and Enewetak will be erected. All except a few of the concrete slabs on the island will be removed during the cleanup. Plate #13 shows the post cleanup conditions on Japtan.


B M LILY
N. 29,041.57
E 114,181.54
12.0
13.0
10.0
CONCRETE PADS
CONCRETE WARM-UP PAD
12.27
10.10
12.0
AIRFIELD REFERENCE POINT
PARKING APRON
NO 1
11° 21' N
162°20' E
ELEV.12.0'

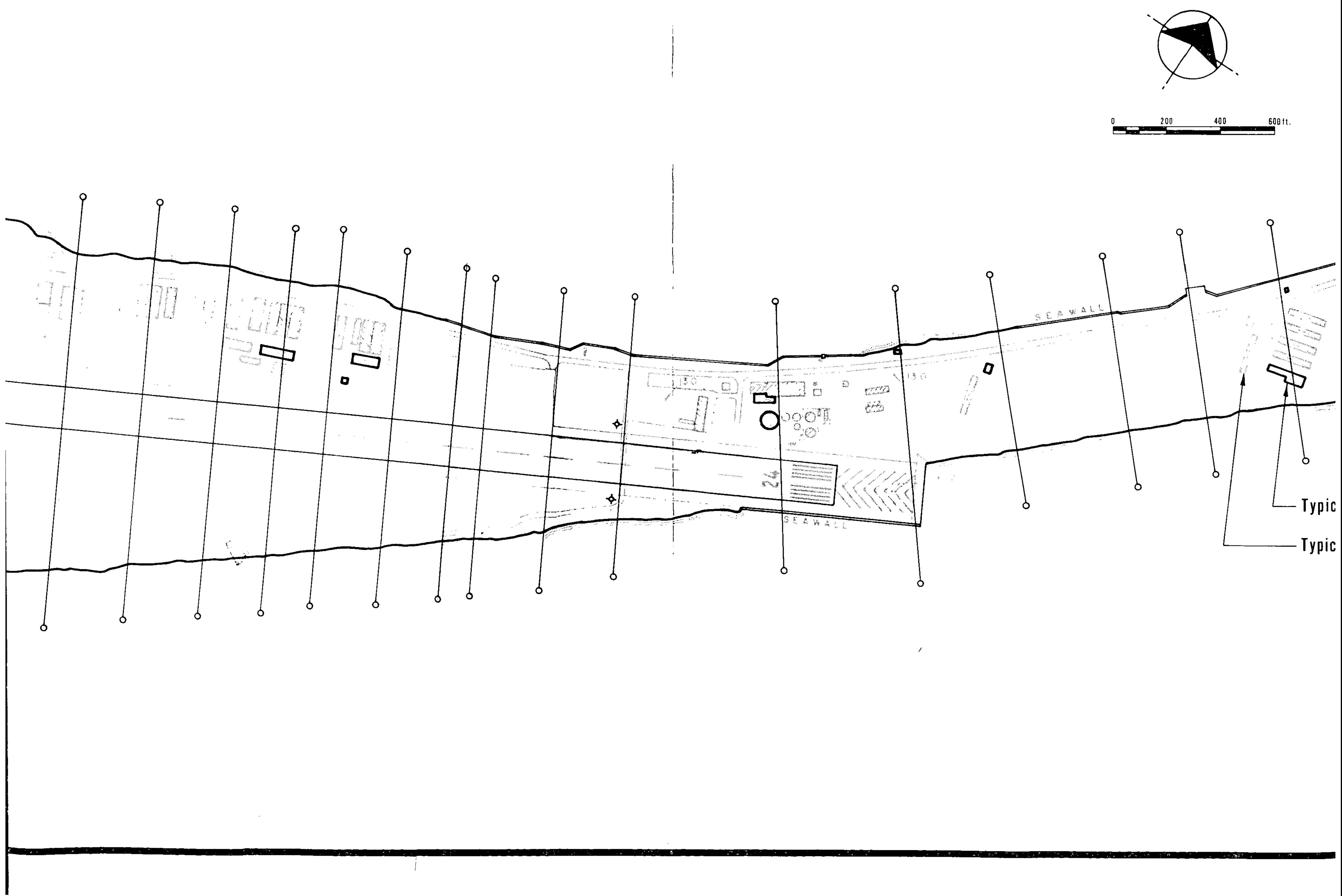


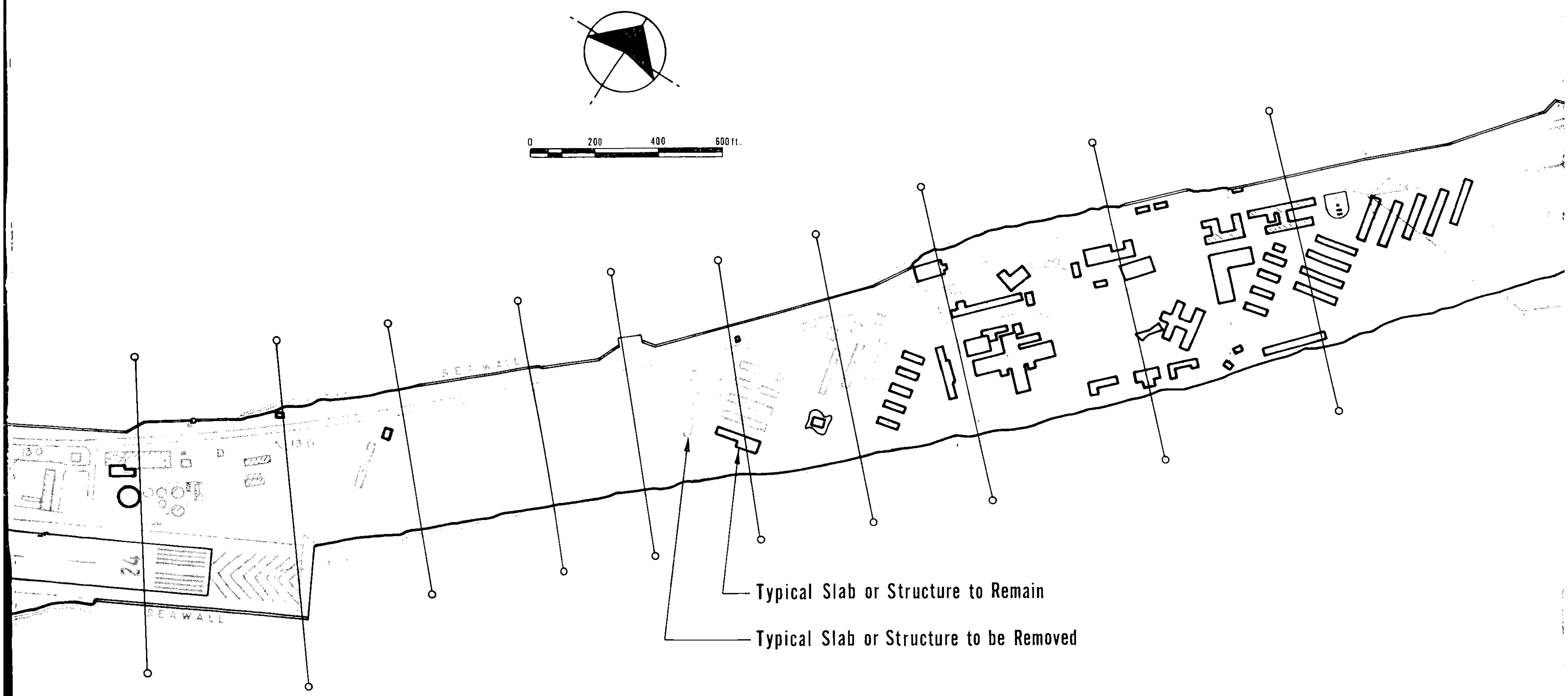
L
BM LILY
N 29,041.57
E 114,181.54
12.0
13.0
10.0
CONCRETE PADS
CRETE WARM-UP PAD
TAXIWAY
OPEN STOR. AREA
RUNWAY
AIRFIELD REFERENCE POINT
11° 21' N
162° 20' E
ELEV. 12.0'
PARKING APRON NO. 1
PARKING APRON NO. 2
OCEAN
Ocean

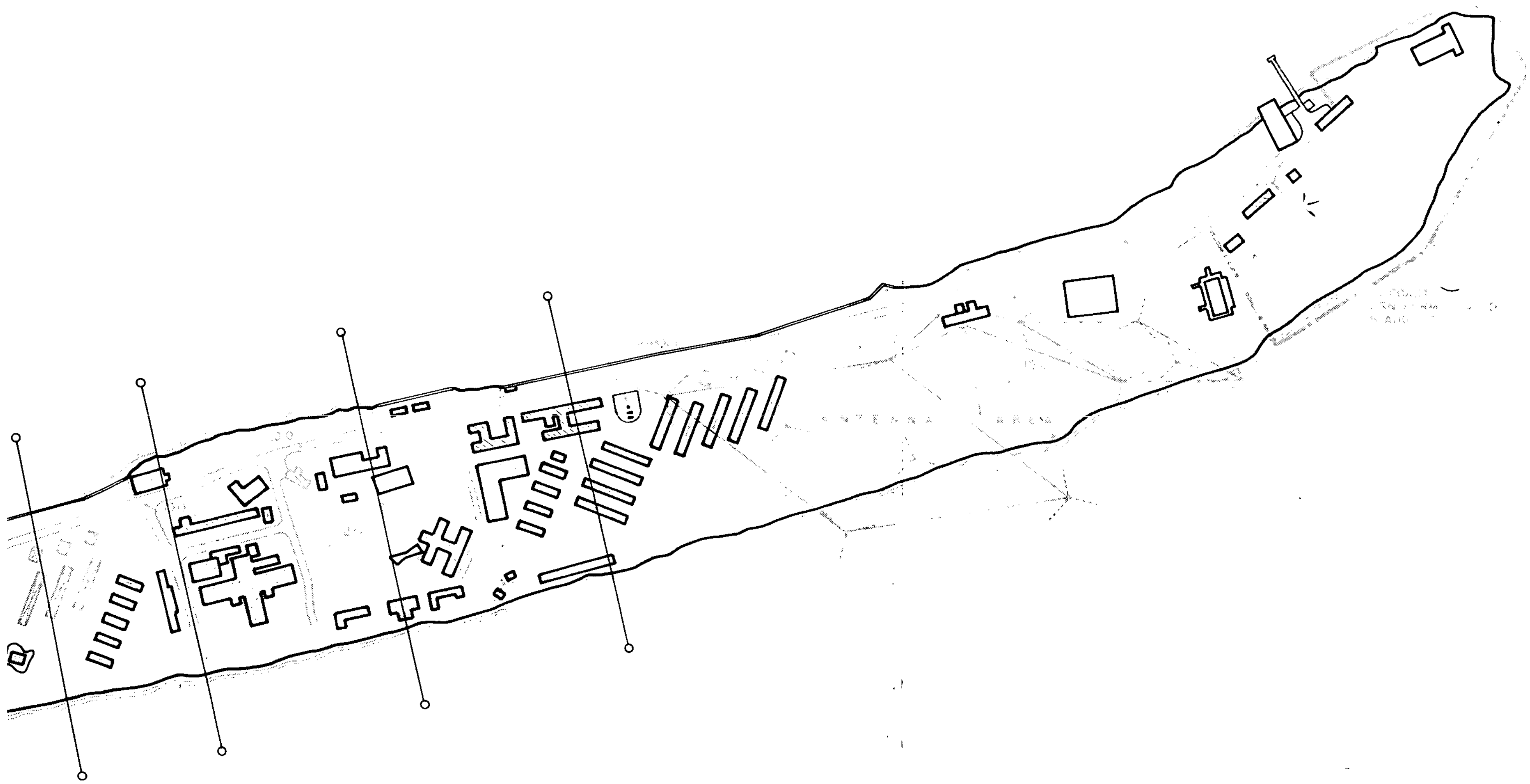


Lagoon
OPEN STOR
AREA
PARKING APRON
NO 2
OCEAN
Ocean

agoon




0 200 400 600 ft.
SEAWALL
Typical Slab or Structure to Remain
Typical Slab or Structure to be Removed



Slab or Structure to Remain

Slab or Structure to be Removed

# POST CLEANUP CONDITION - ENEWETAK ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

A RESOURCE SCIENCES COMPANY
TECHNOLOGY & CONSTRUCTION
ANAHEIM, CALIFORNIA

| Plate No. |
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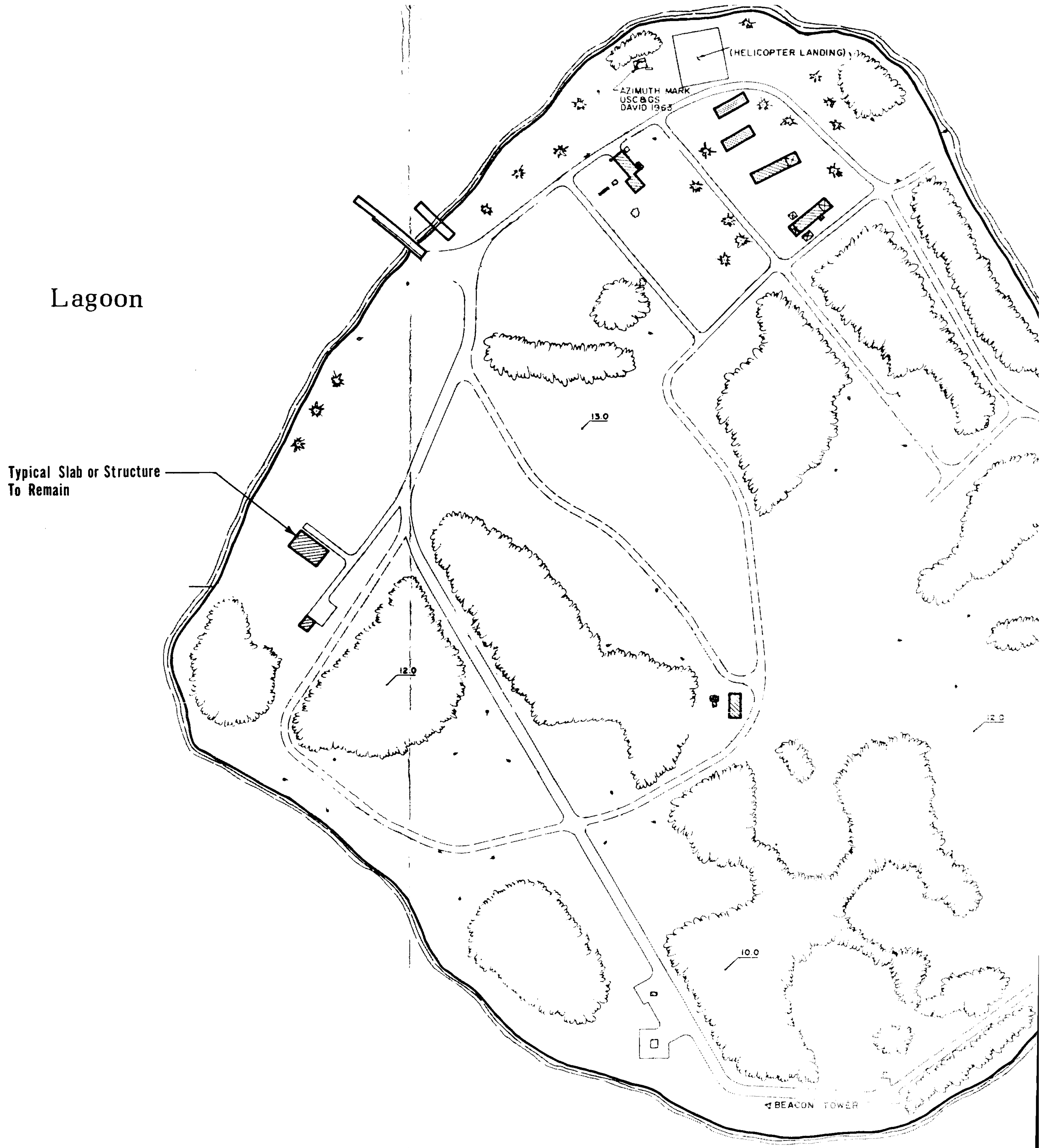
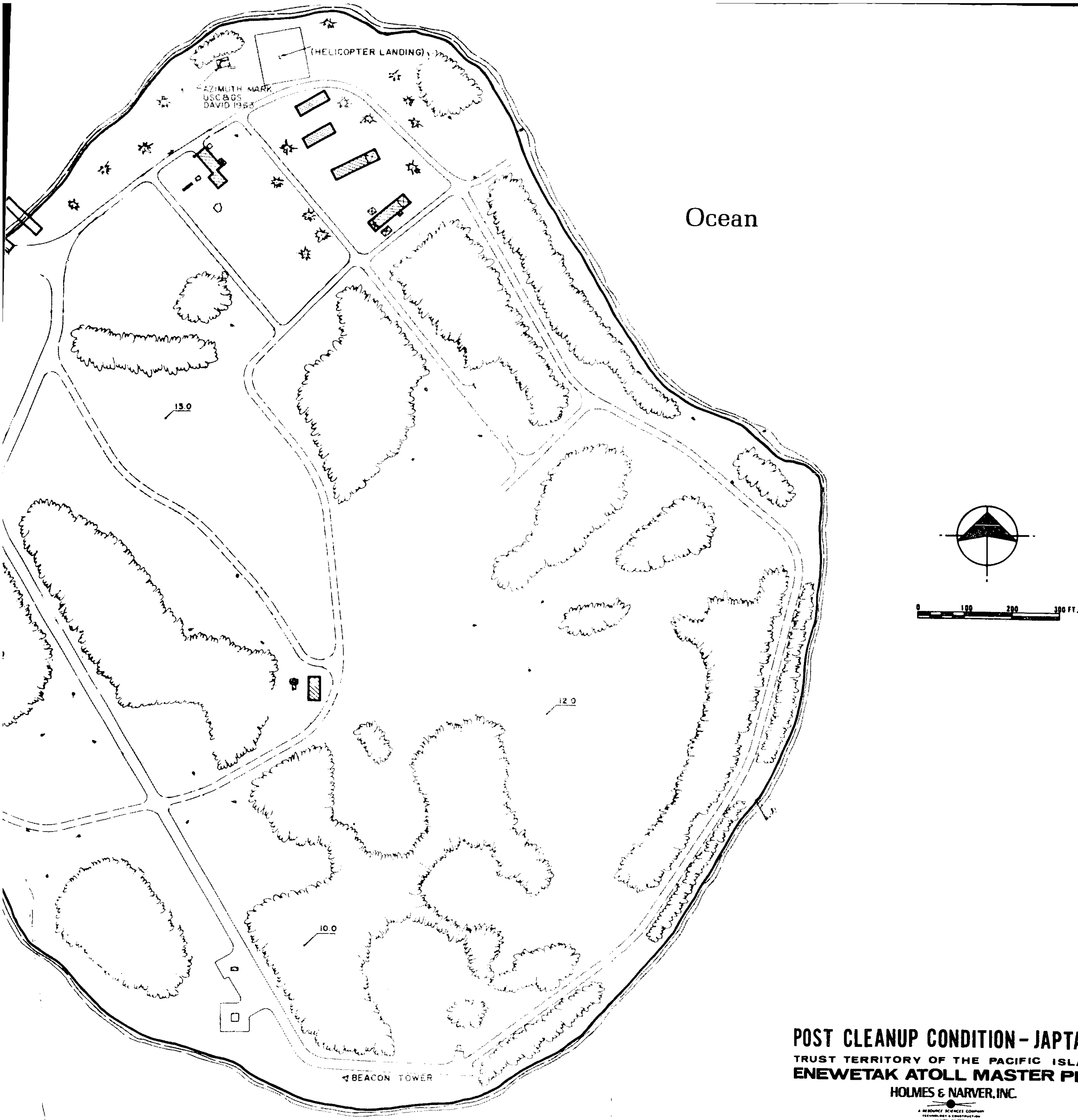
| 12 |
| NOV. 1973 |



Lagoon
Typical Slab or Structure
To Remain
(HELICOPTER LANDING)
AZIMUTH MARK
USC&GS
DAVID 1963
13.0
12.0
12.0
10.0
BEACON TOWER




POST CLEANUP CONDITION - JAPTAN ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS

ENEWETAK ATOLL MASTER PLAN

HOLMES & NARVER, INC.

Plate No. 13

NOV. 1973

# 4. ELEMENTS OF THE PLAN

# 4. ELEMENTS OF THE PLAN

## 4.1 LAND USE

The master plan divides the islands of the atoll into three categories reflecting the primary functional use of each island. The islands designated as inhabited, agricultural and food gathering, and picnic sites were decided upon by the Enewetak people. Table 4-1 lists the islands under each of these headings and Plate #14 shows their spatial arrangement in the atoll.

The first group of islands, those designated as centers of habitation, include Enjebi, Medren, Japtan, and Enewetak (as an alternate to Medren). Enjebi and Medren will serve as permanent residential sites, while Japtan will be used for temporary quarters during cleanup and rehabilitation. Enewetak Island will replace Medren as the home of the driEnewetak, if plans for its economic development do not mature. Extensive agricultural planting will complement the community development on these islands. Details of land use on these four islands are shown on Plates #15, #16, #17, and #18.

Of the eight islands selected for agricultural usage only two, Runit and Ananij, are in the southern sector of the atoll. The others in the northern sector include Alembel, Aomon, Bijile, Lojwa, Lujor, and Aej. The apparent imbalance between the larger number of agricultural islands in the north and the two in the south is offset to a degree by the relatively larger areas on Japtan, Medren, and Enewetak which will be under cultivation.

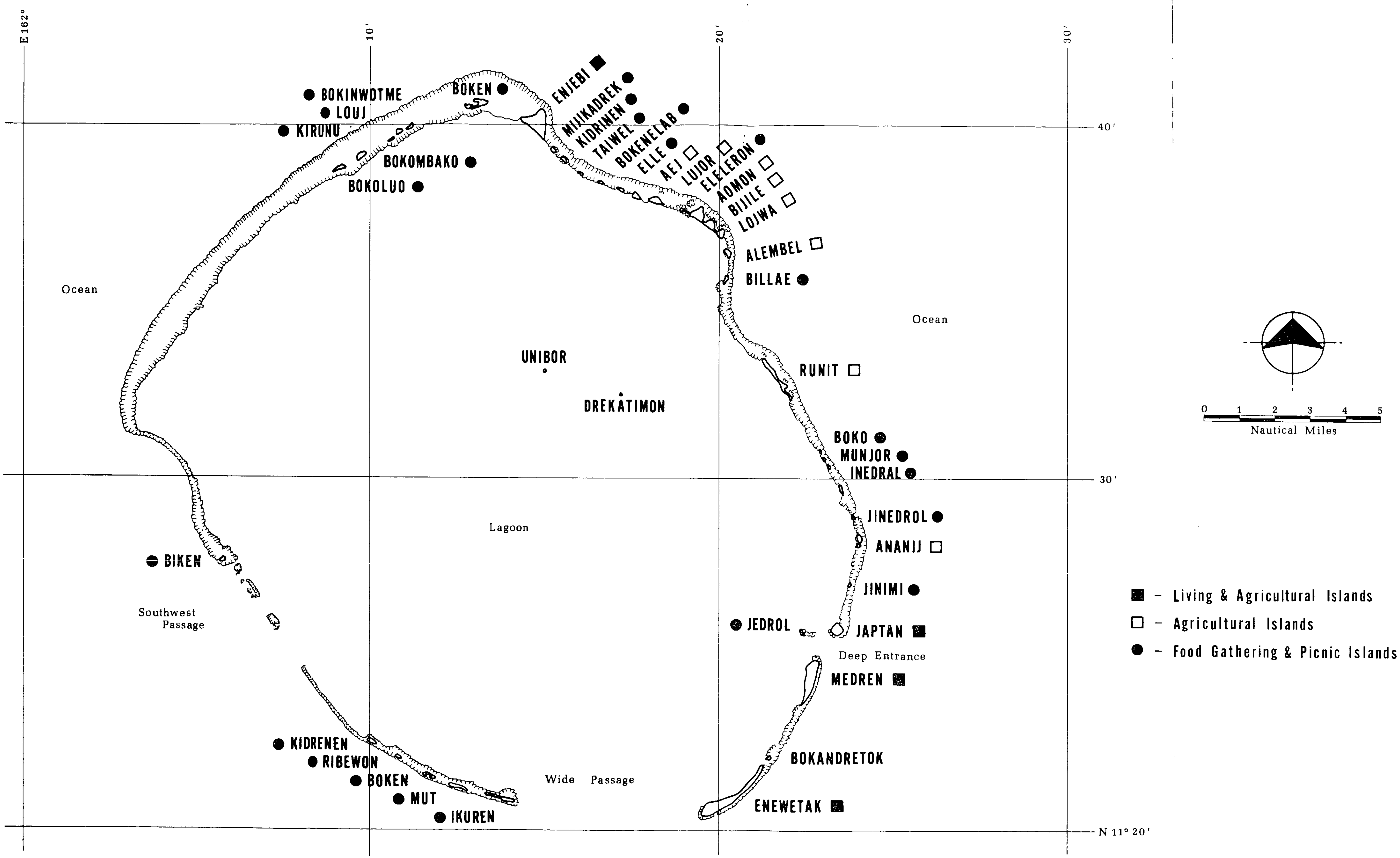
The Enewetakese anticipate using the remaining 27 islands for hunting and fishing, as well as for recreational purposes. No permanent habitations are planned for these islands.

TABLE 4-1

ISLAND DEVELOPMENT PRIORITIES*

| | Estimated Acreage Total | Estimated Acreage Usable |
|---|---|---|
| I. Major Inhabited Islands | | |
| Enjebi | 291 | 210 |
| Medren | 220 | 193 |
| Enewetak | 322 | 166 |
| Japtan | 79 | 63 |
| II. Intensive Agricultural Uses | | |
| Runit | 91 | 41 |
| Alembel | 38 | 23 |
| Lojwa | 40 | 25 |
| Aomon | 99 | 126 |
| Bijile | 52 | 34 |
| Lujor | 54 | 38 |
| Aej | 40 | 28 |
| Ananij | 25 | 13 |
| III. Food Gathering and Temporary Uses | | |
| Elle | 11 | 5 |
| Bokenelab | 12 | 6 |
| Kidrinen | 24 | 13 |
| Mijikadrek | 16 | 12 |
| IV. Food Gathering and Temporary Uses | | |
| Biken | 14 | |
| Kidrenen | 19 | |
| Ribewon | 19 | |
| Boken | 29 | |
| Mut | 40 | |
| Ikuren | 41 | |
| V. Food Gathering and Temporary Uses | | |
| Louj | 21 | |
| Kirunu | 7 | |
| Bokombako | 31 | |
| Bokoluo | 22 | |
| VI. Food Gathering and Temporary Uses | | |
| All other islets | 64 | |

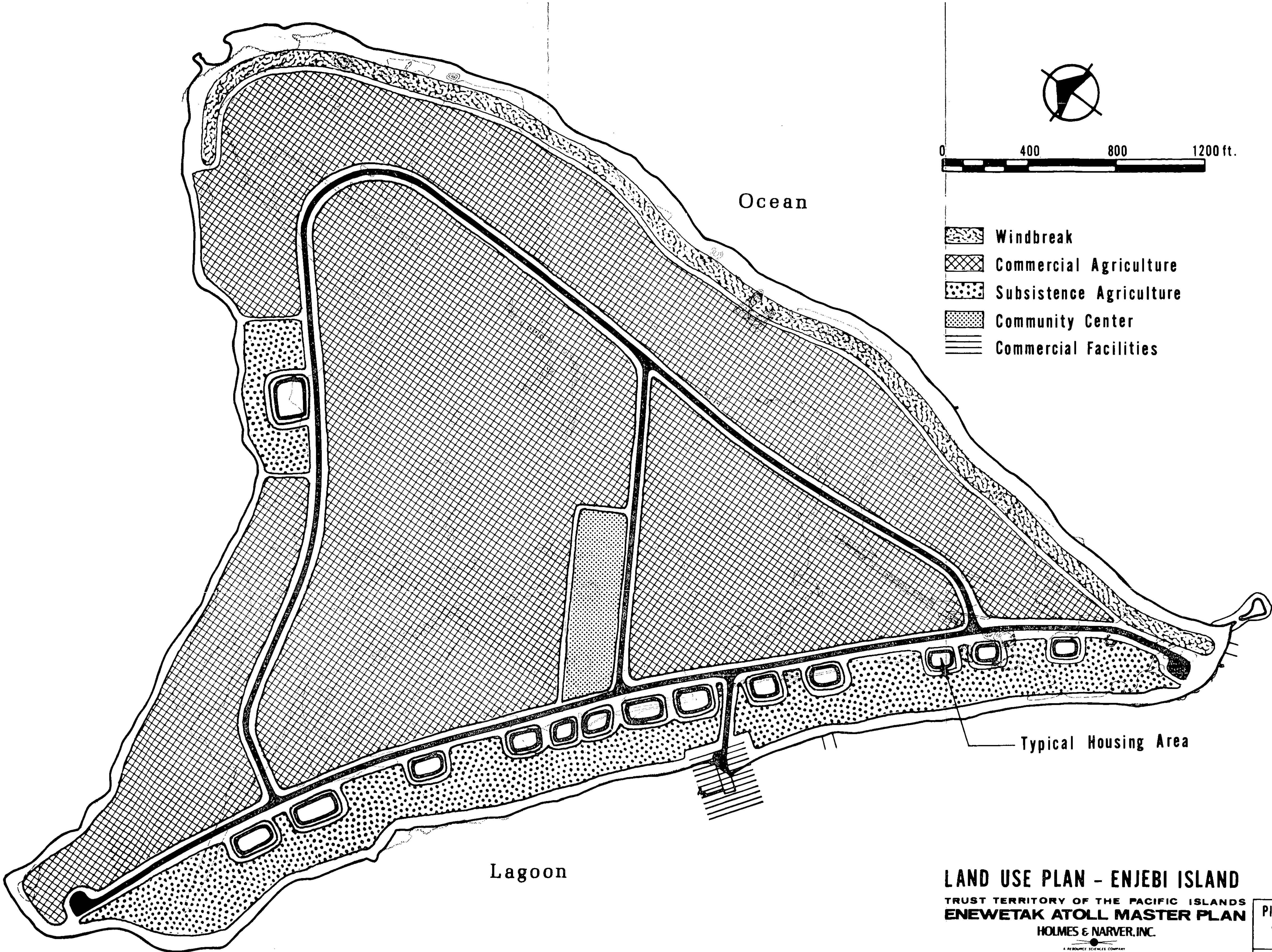
*NOTE: Priorities expressed by Enewetakese in residence at Ujelang on August 2, 1973.




## LAND USE PLAN – ENEWETAK ATOLL

TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
HOLMES & NARVER, INC.

Plate No.
14
NOV. 1973

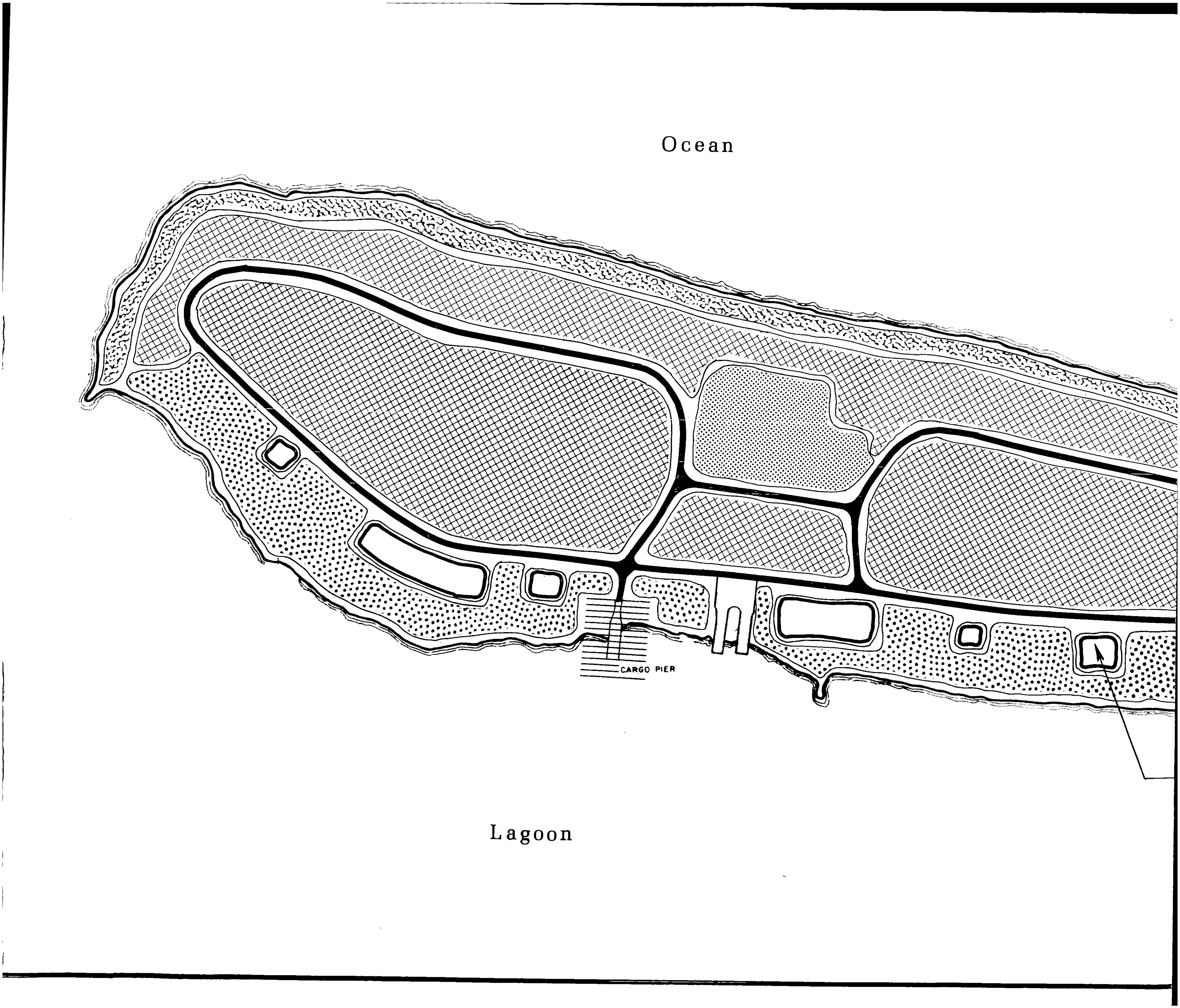


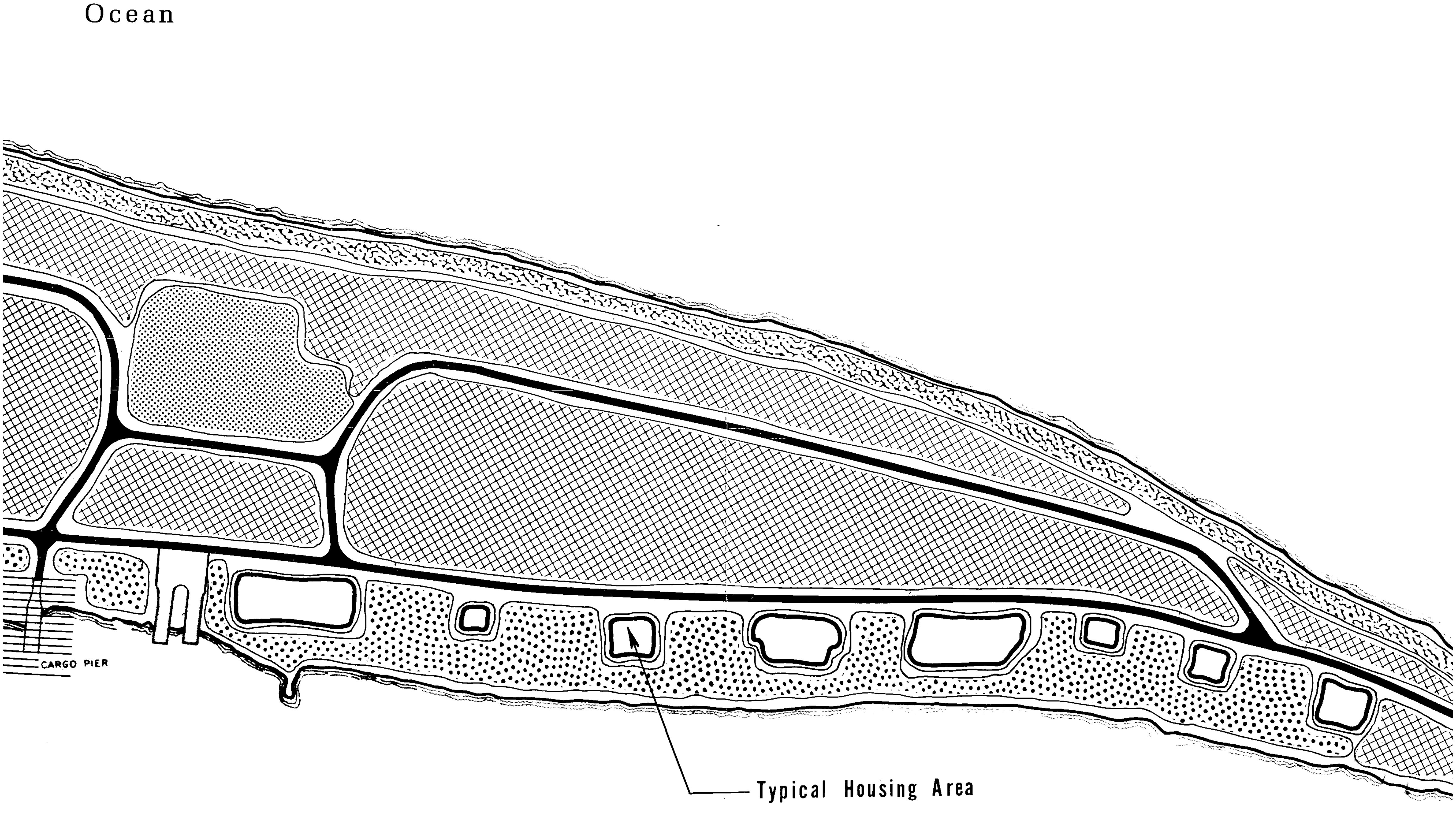

LAND USE PLAN - ENJEBI ISLAND

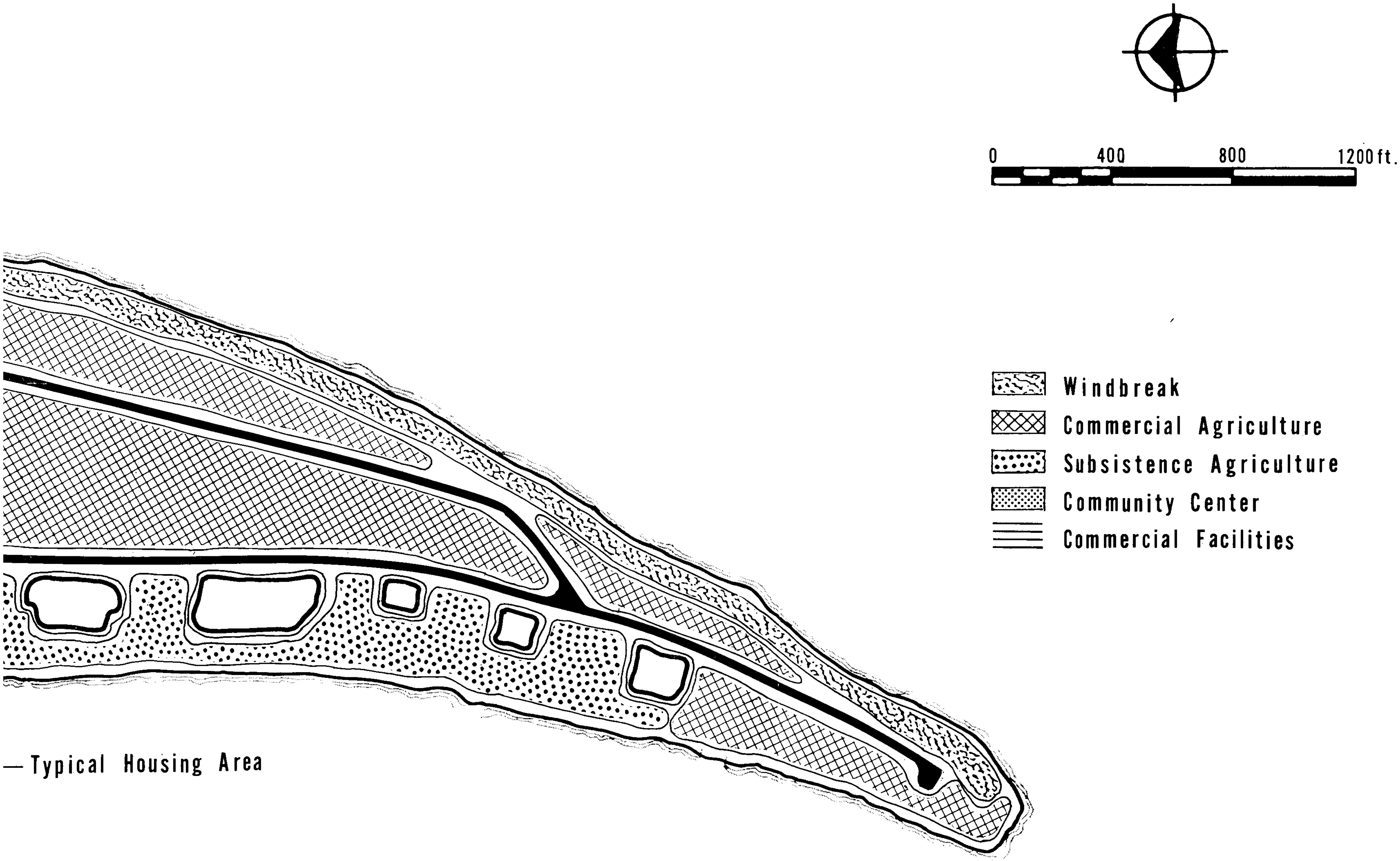
TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No. 15

NOV. 1973


Ocean
CARGO PIER
Lagoon


Ocean
CARGO PIER
Typical Housing Area




# LAND USE PLAN - MEDREN ISLAND

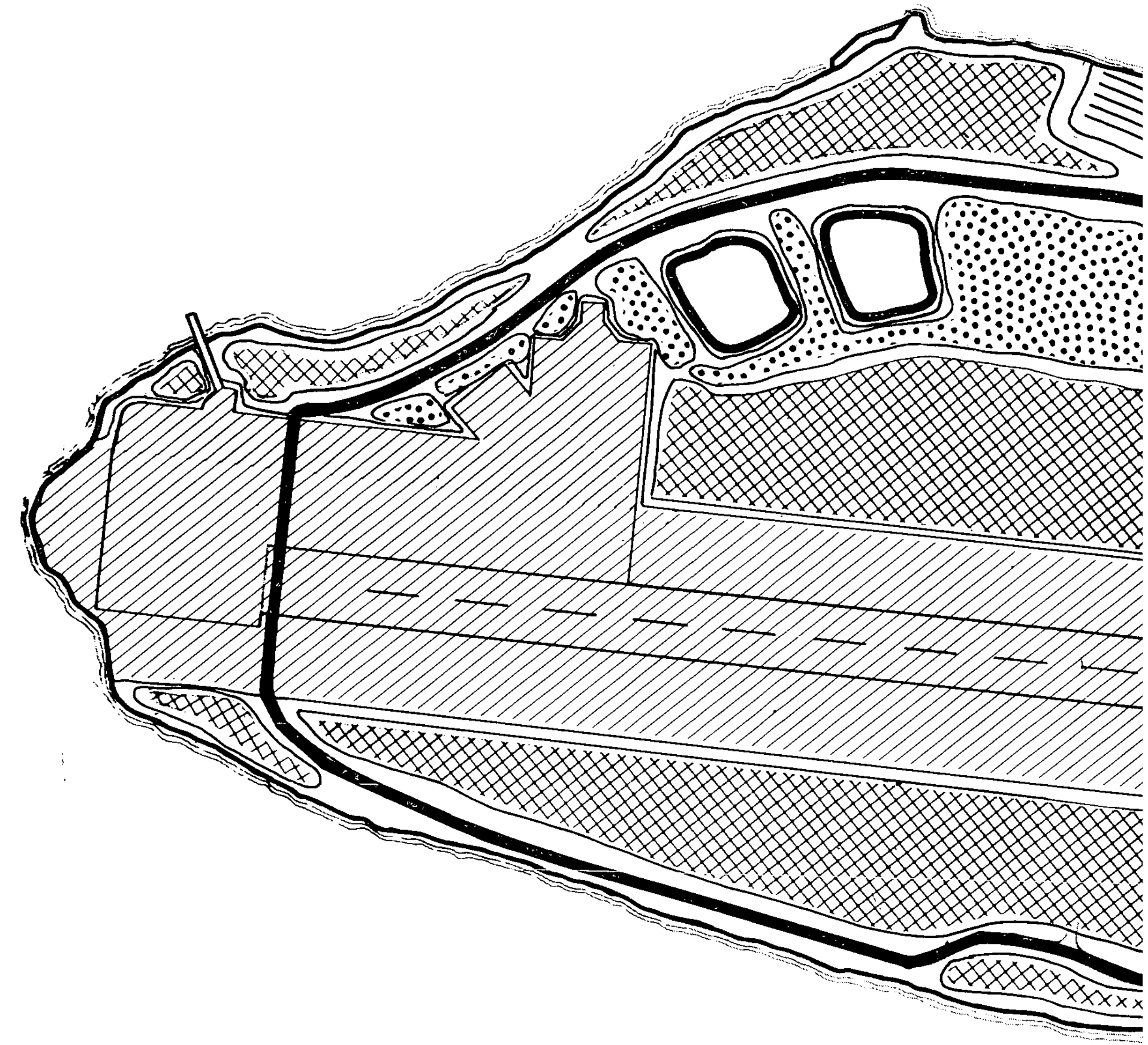
TRUST TERRITORY OF THE PACIFIC ISLANDS

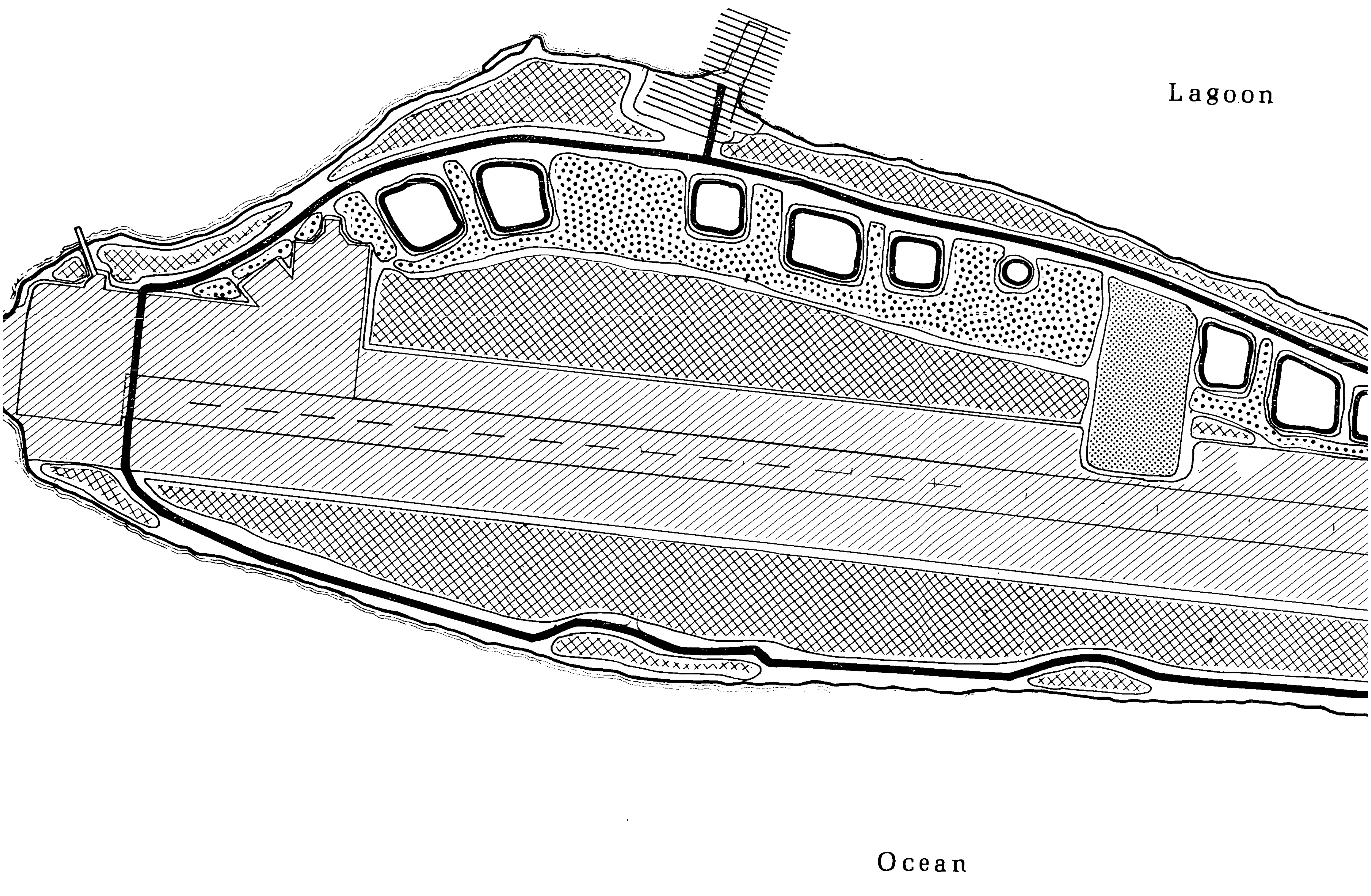
**ENEWETAK ATOLL MASTER PLAN**

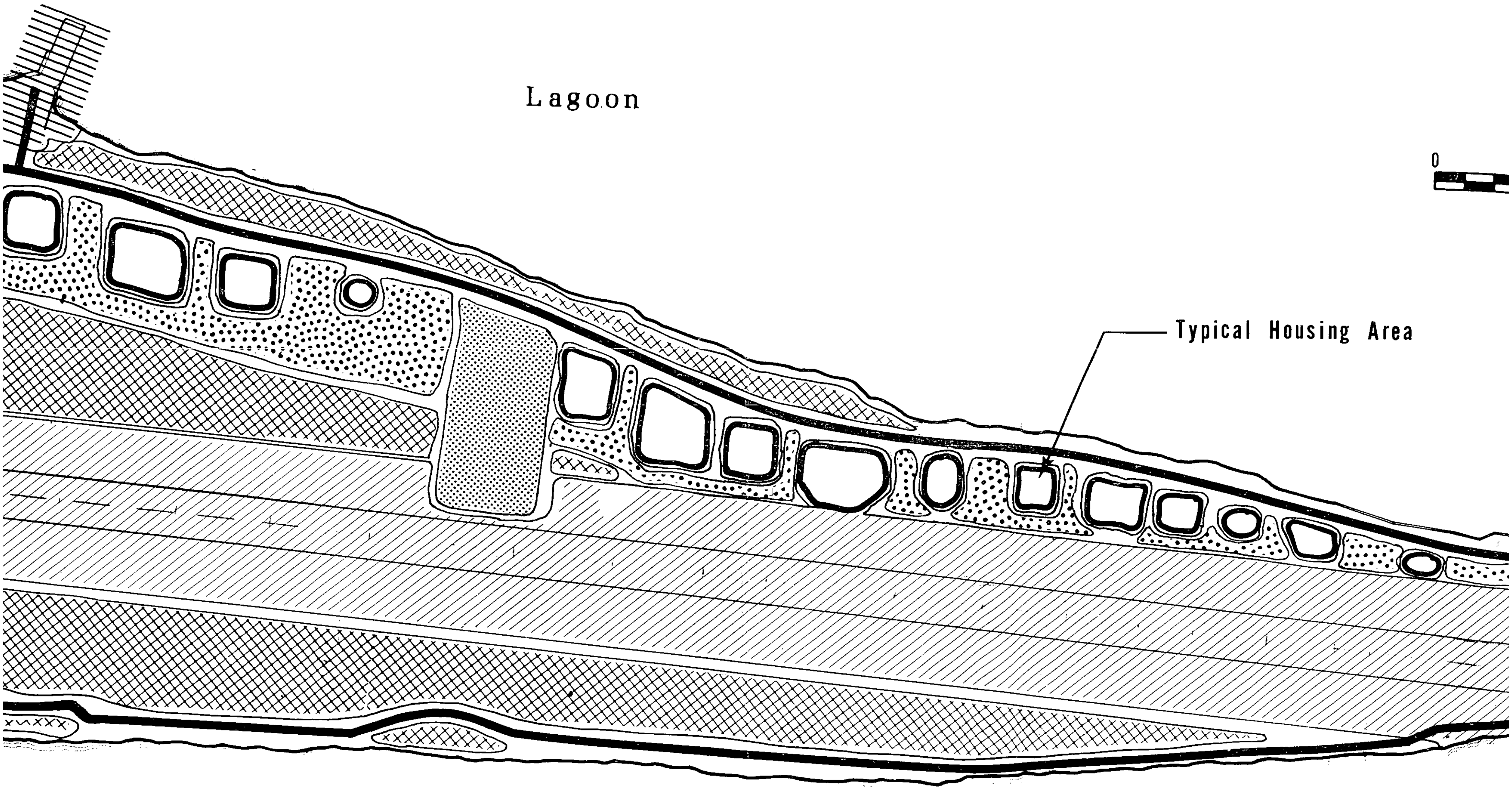
HOLMES & NARVER, INC.

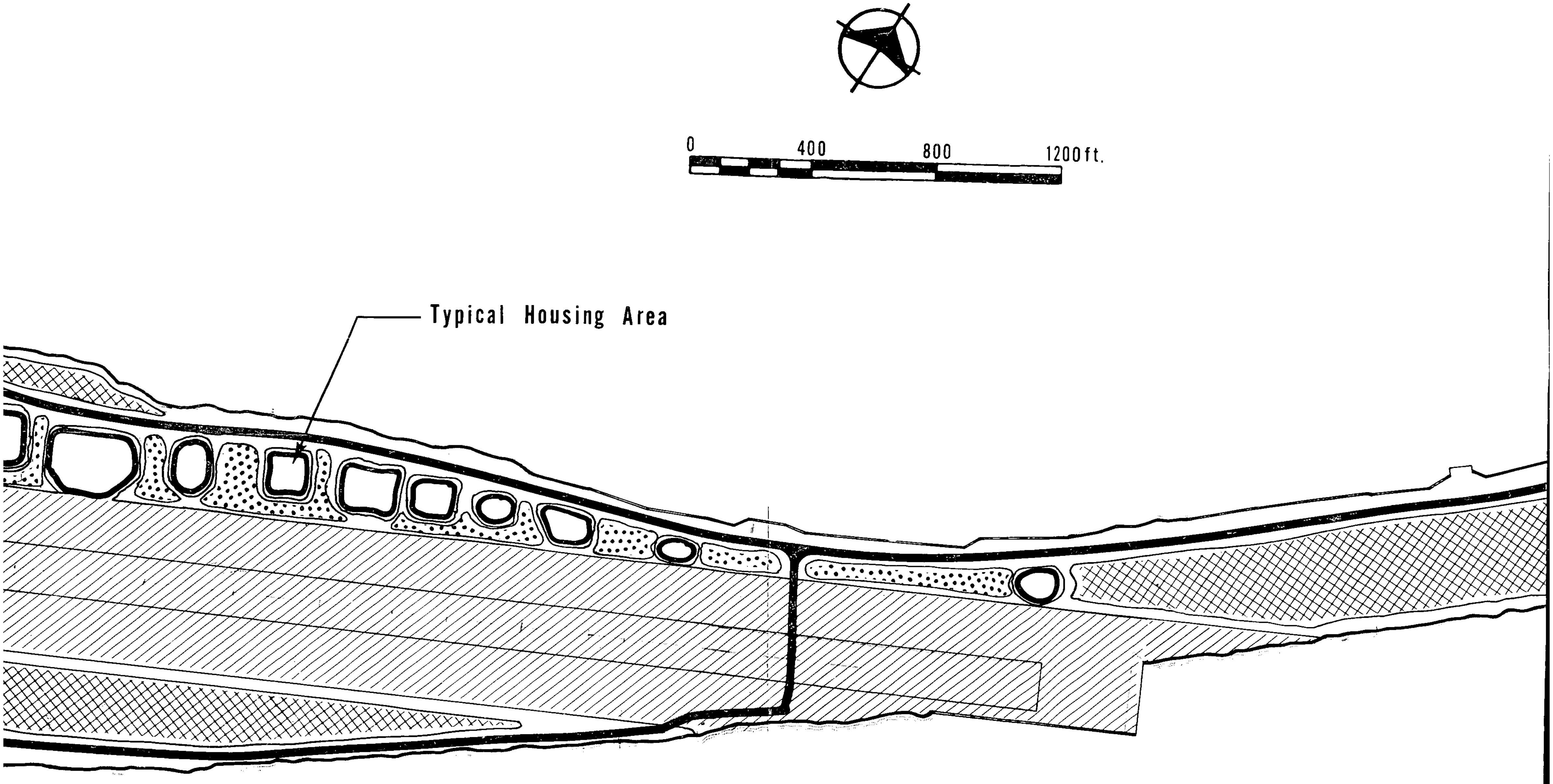
Plate No.
16

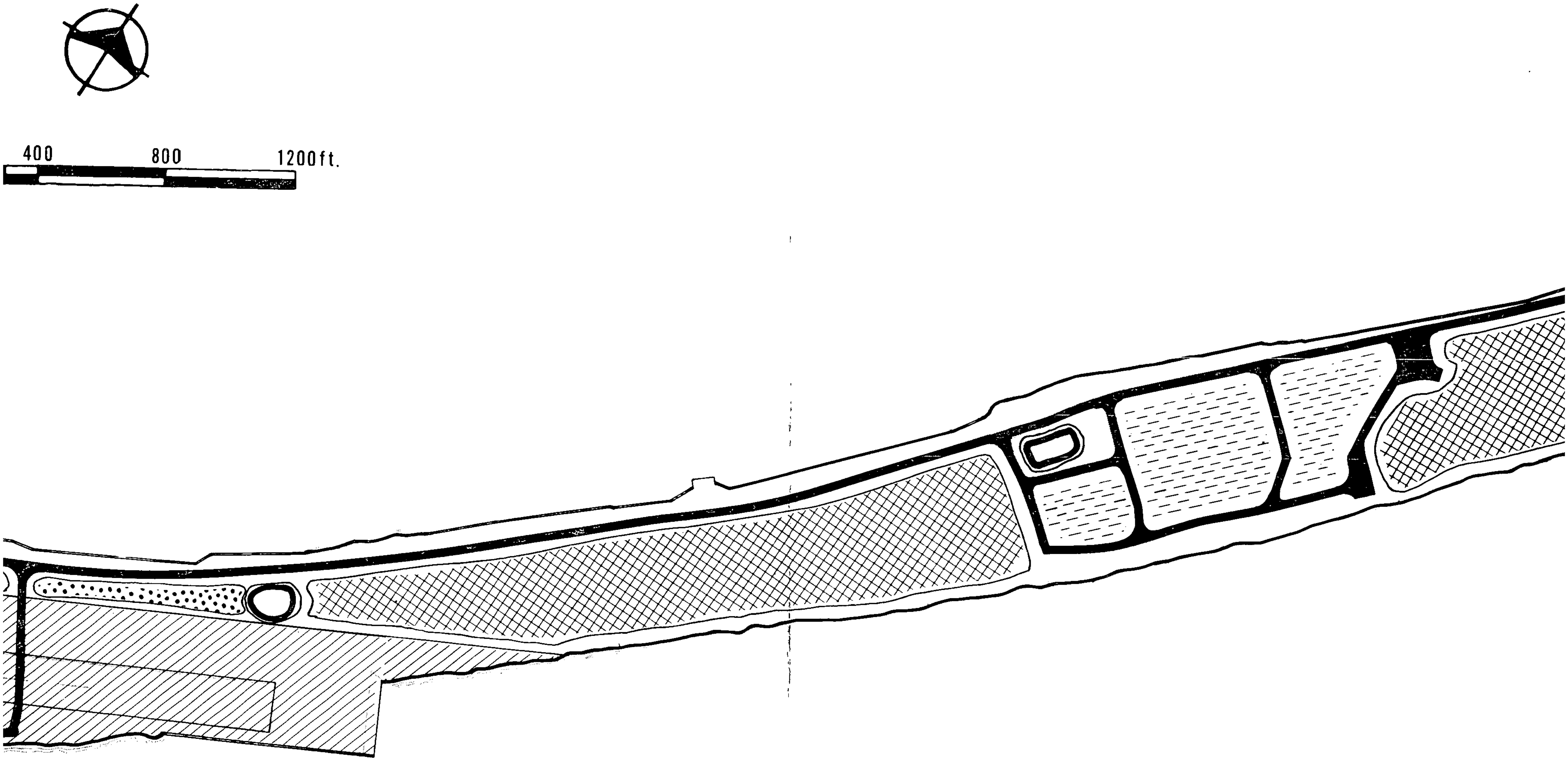
NOV. 1973

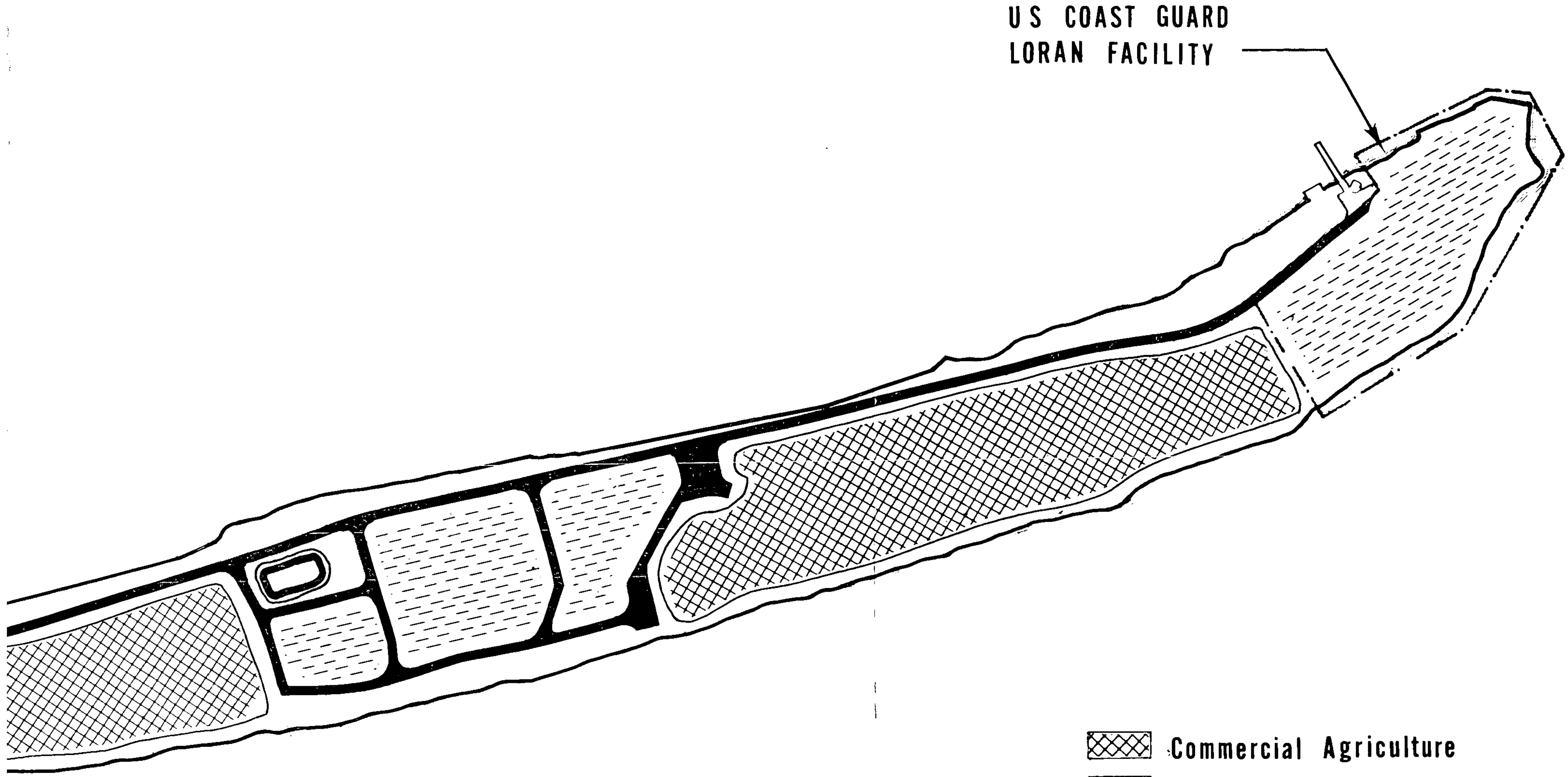



Lagoon
Ocean


Lagoon
Typical Housing Area
0
Ocean


0
400
800
1200 ft.
Typical Housing Area


400
800
1200ft.

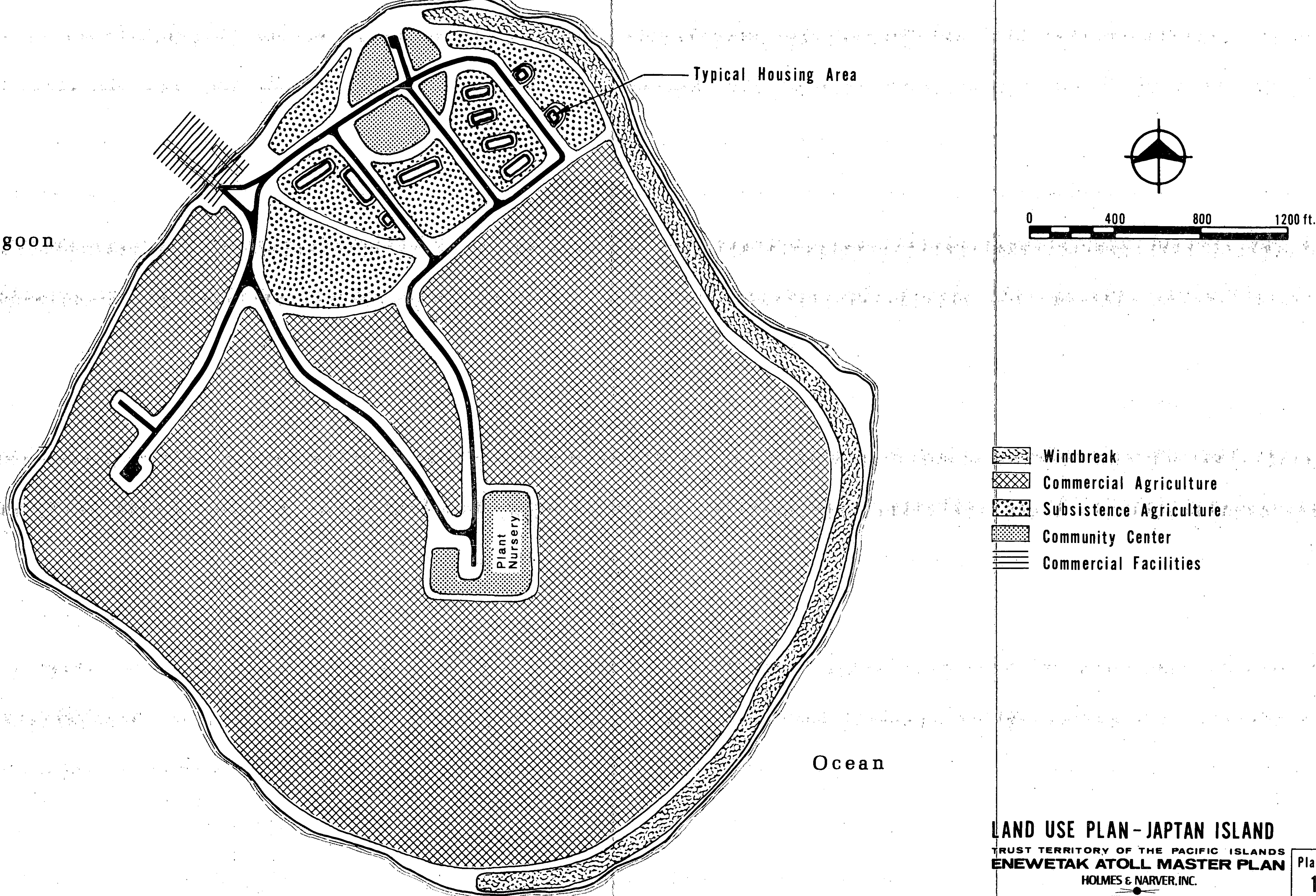



Commercial Agriculture
Subsistence Agriculture
Community Center
Commercial Facilities
Commercial Development
Aircraft Runway Clear Area

## LAND USE PLAN - ENEWETAK ISLAND
## (ALTERNATE)

TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
HOLMES & NARVER, INC.

Plate No. 17
NOV. 1973




# LAND USE PLAN - JAPTAN ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No. 18
NOV. 1973

It should be noted that agriculture on the inhabited islands in Group 1 will consist of both subsistence and cash crops, while the agricultural islands in the second group will be devoted almost entirely to cash crops.

## 4.2 ISLAND COMMUNITIES

The Enewetak people through their planning council have chosen Enjebi and Medren islands as the sites of the two permanent communities. They also have indicated that Enewetak Island should be developed for commercial use if possible. However, in the event that the planned development for Enewetak Island fails to materialize, the driEnewetak have expressed the desire to settle there, rather than on Medren. The preliminary master plan includes an alternate for the community development of Enewetak. The plan also considers the development of Japtan as a temporary community for the Enewetakese people who have expressed a desire to participate in the cleanup and rehabilitation of the atoll.

Wāto plans for Enjebi, Medren, and Enewetak are outlined in this section. Residential housing and community facilities are discussed in this section as well as in Sections 4.3 through 4.7 of this document. Plans for the development of agriculture on the community islands are discussed in detail in Section 4.8.5.1.

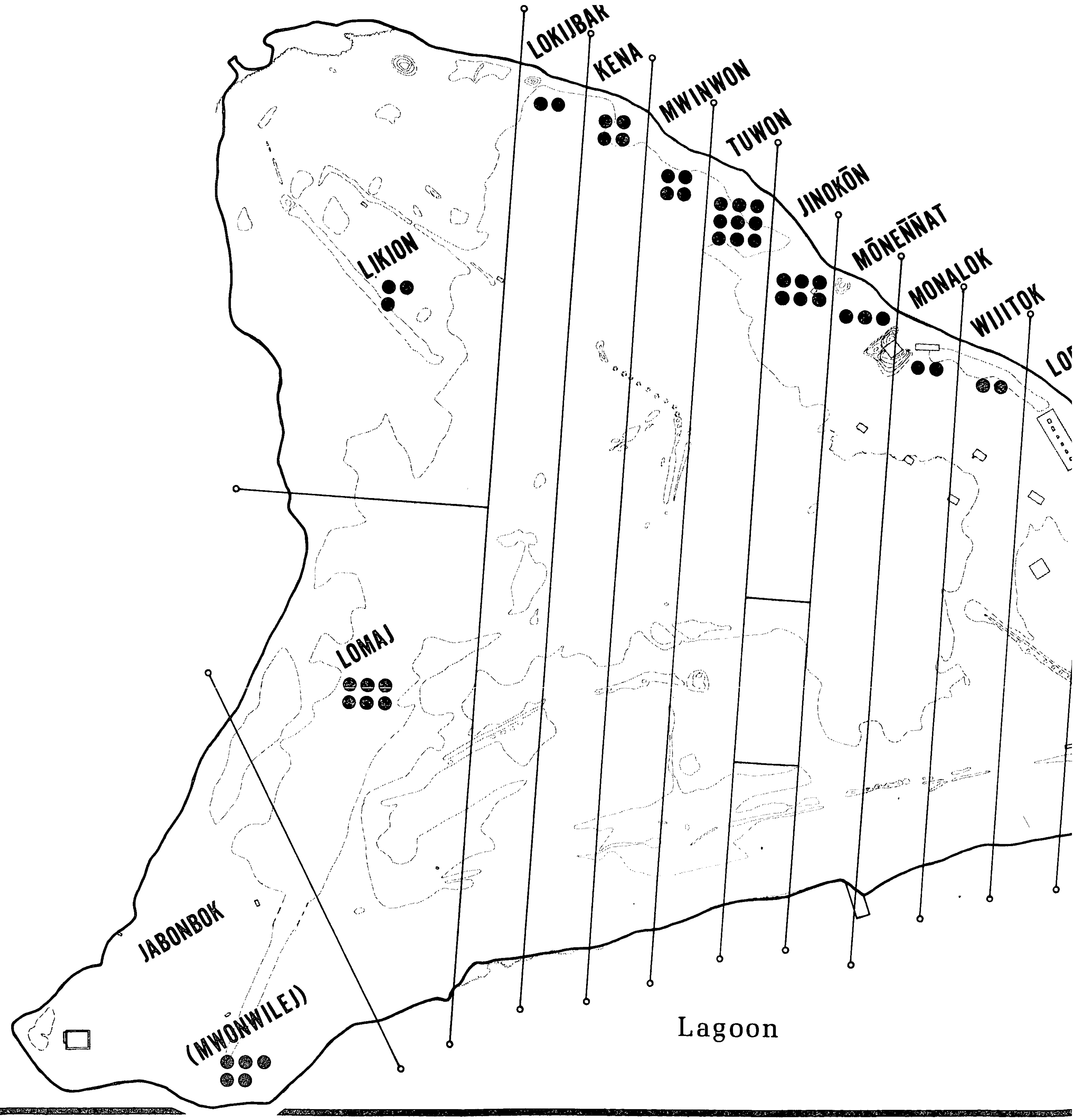
Tentative plans have been prepared which delineate the Wāto boundaries on Enjebi, Medren, and Enewetak. These were determined in meetings with the Enewetak people on Ujelang in July, 1973. Field confirmation of the Wātos by on-site surveys will be required prior to construction.

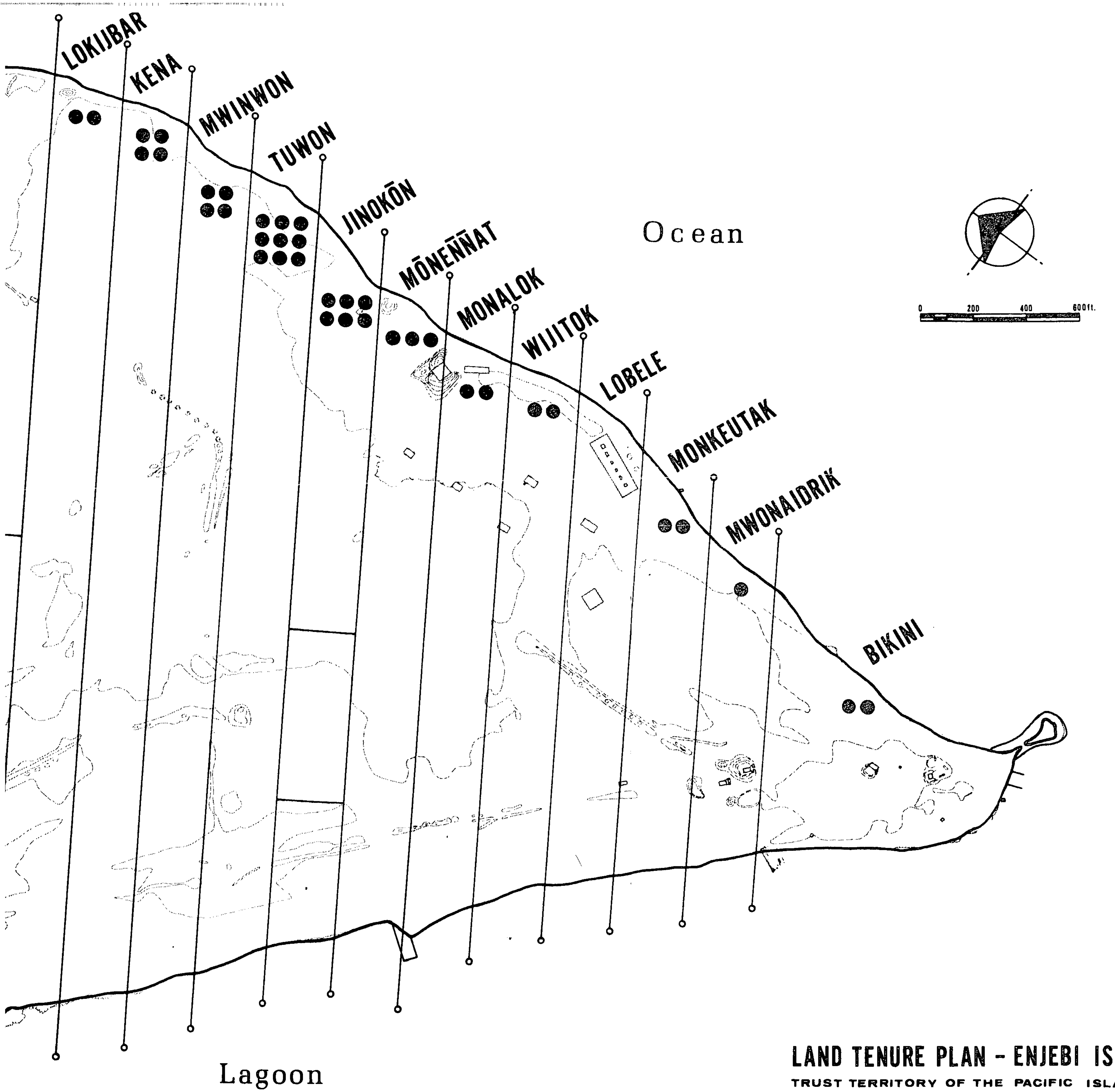
Plate #19 shows the Wātos on Enjebi with the number of houses on each Wāto as indicated by the Enewetak people. Plates #20 and #21 depict the Wātos and housing density on Medren and Enewetak islands, respectively. There is no Wāto plan for Japtan although it is understood to be of multiple ownership as are all of the smaller islands. On Japtan, existing metal buildings augmented by additional structures as required will be modified to accommodate workers' families. Plate #22 indicates the proposed arrangement.

## 4.3 RESIDENTIAL DEVELOPMENT

The island residences are arranged in clusters with houses of the extended family on each Wāto grouped around a common courtyard. This courtyard acts as a focal point for social intercourse among the family groups for it is here that the younger children play, Kiemem(s) (1st year birthday party) and other celebrations are given, and daily gossip exchanged. The number of houses in any one cluster grouping varies, but in cases where there are eleven or twelve families living on one Wāto, two clusters of five or six houses each are provided. Plate #23 shows a representative housing cluster plan. A perspective sketch showing a typical common courtyard with surrounding houses is shown on Plate #24.

The clusters are situated along the lagoon side of the island just off the main road which runs parallel to the shoreline and about 350 feet inland, except for Enewetak Island where the road is between the lagoon and the clusters. Food gathering would take place in and around the immediate area of the housing clusters, in the strip of land between the road and the lagoon. Privies (benjos), gardens, and animal pens are located around the periphery of the clusters.

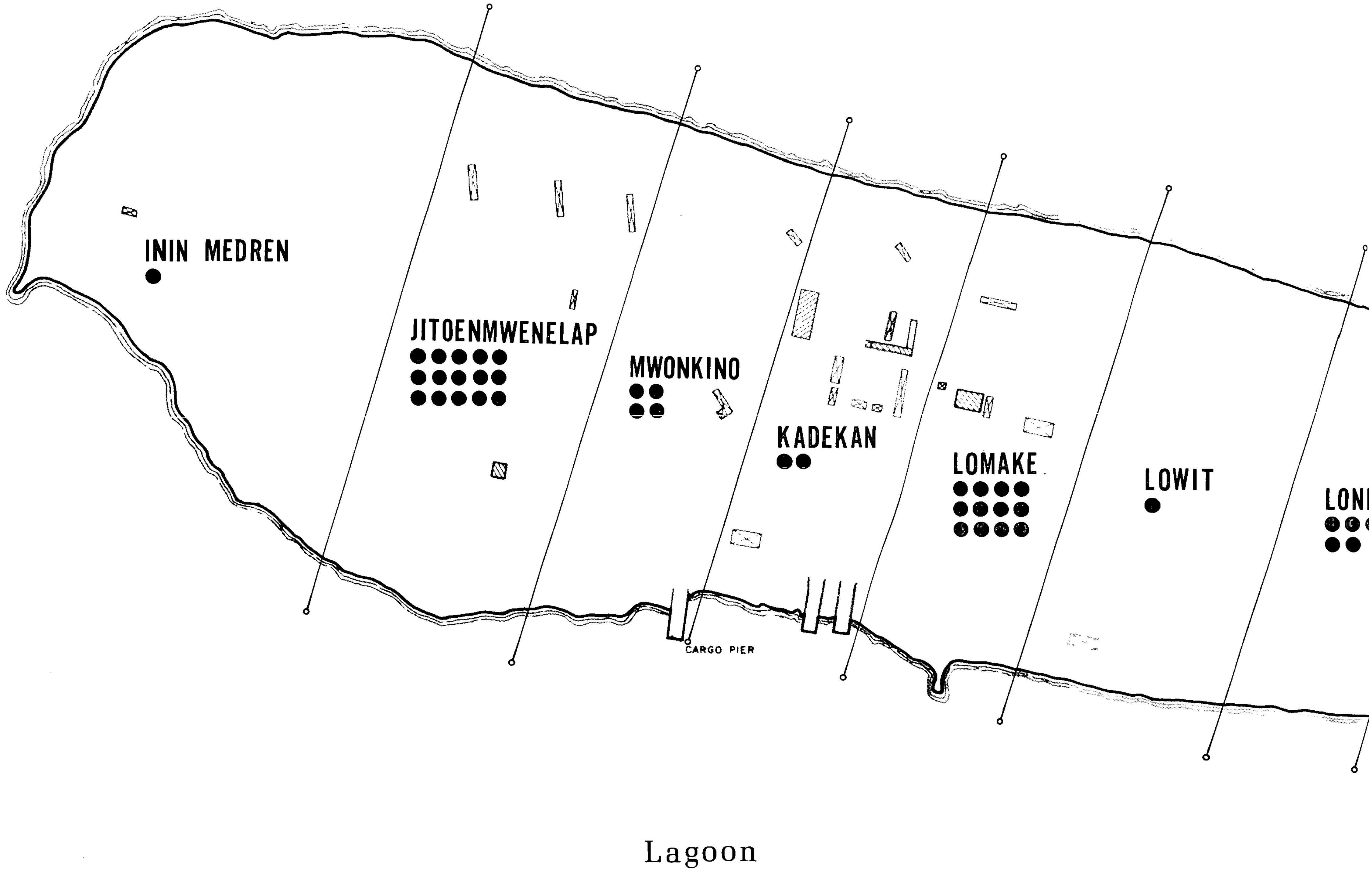

LOKIJBAR
KENA
MWINWON
TUWON
JINOKŌN
MŌNEÑÑAT
MONALOK
WIJITOK
LIKION
LOMAJ
JABONBOK
(MWONWILEJ)
Lagoon

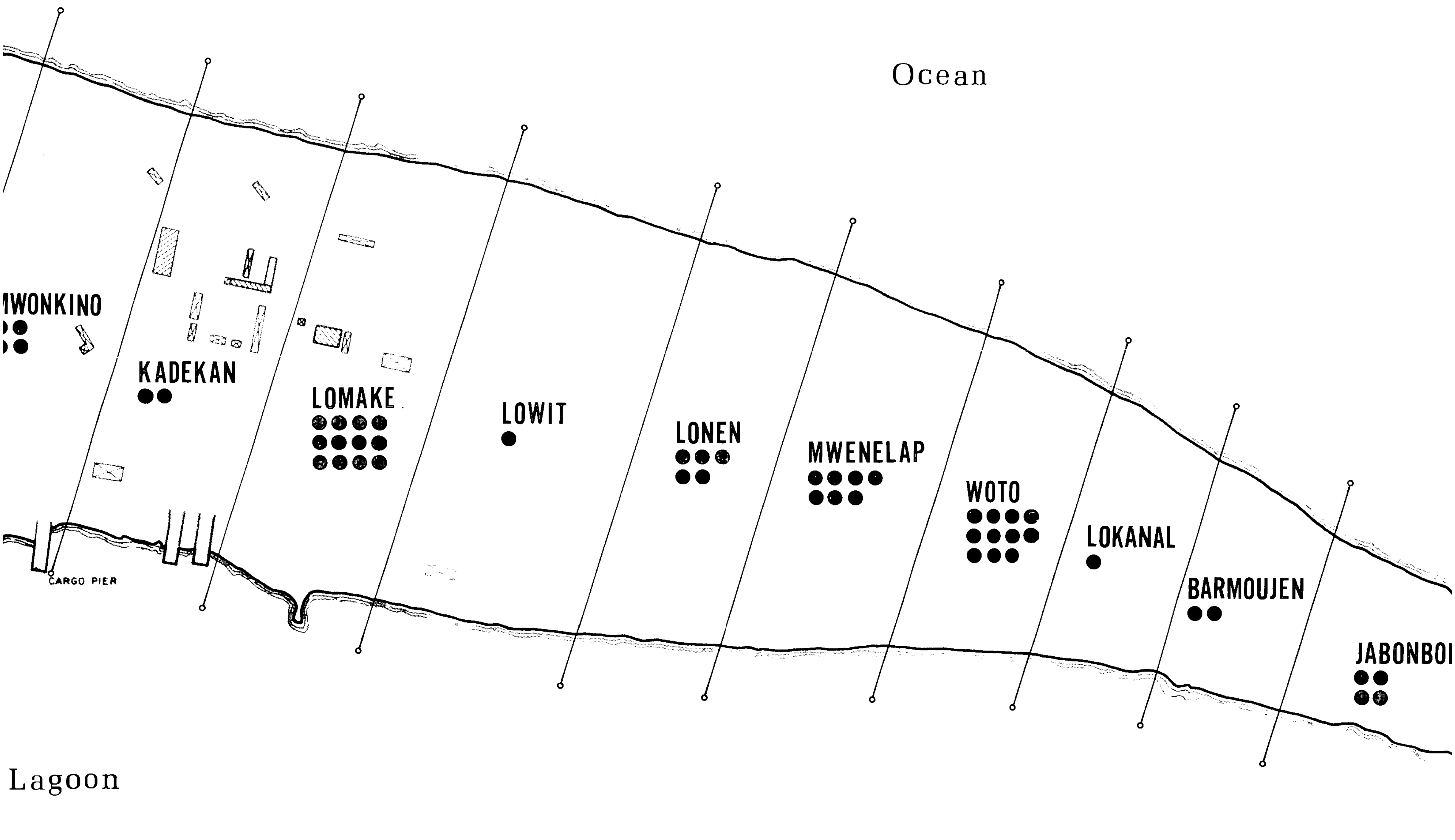


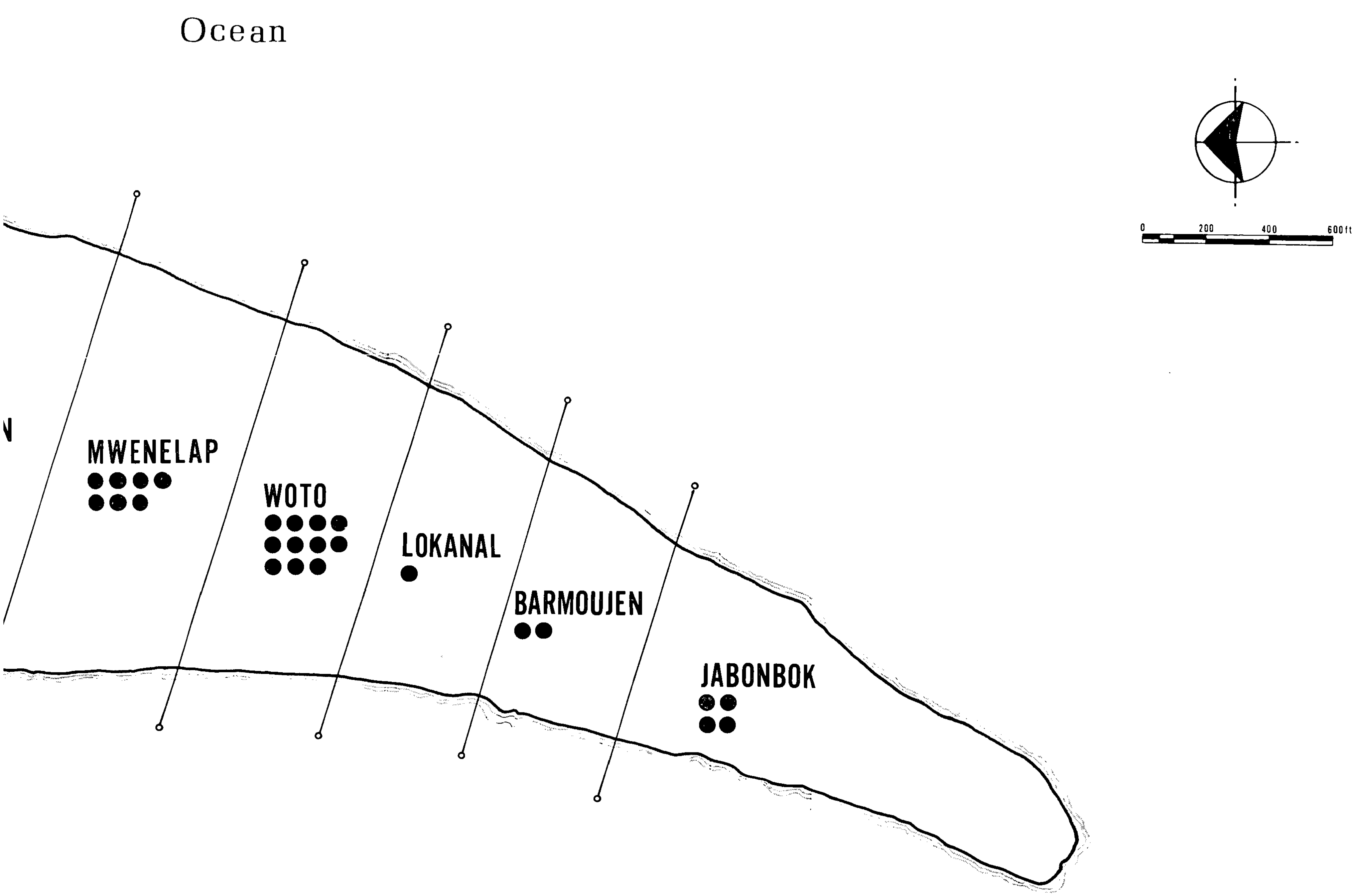

# LAND TENURE PLAN - ENJEBI ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No.
19
NOV. 1973


ININ MEDREN
JITOENMWENELAP
MWONKINO
KADEKAN
LOMAKE
LOWIT
CARGO PIER
Lagoon


Ocean
MWONKINO
KADEKAN
LOMAKE
LOWIT
LONEN
MWENELAP
WOTO
LOKANAL
BARMOUJEN
JABONBOI
CARGO PIER
Lagoon




## LAND TENURE PLAN – MEDREN ISLAND

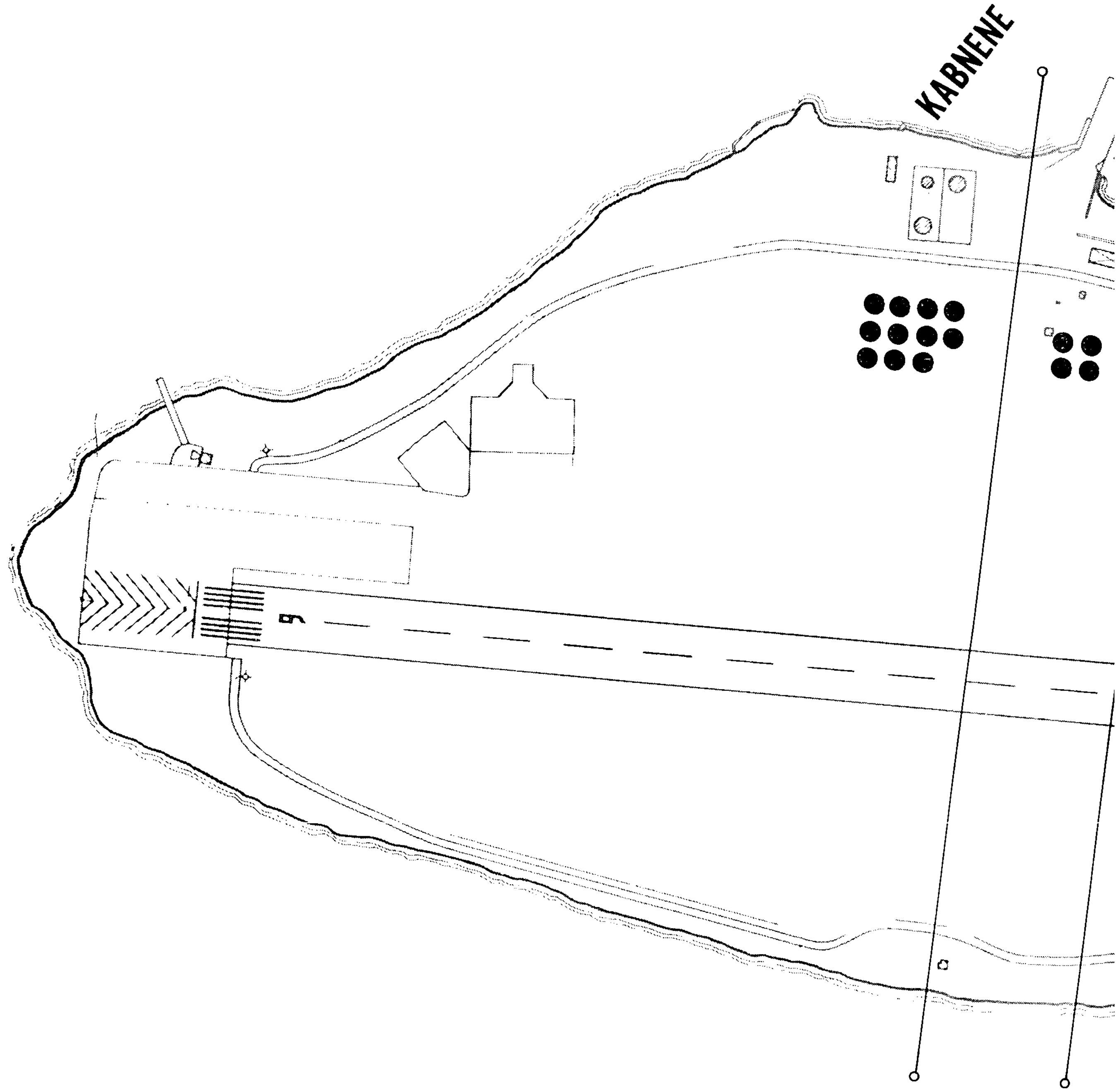
TRUST TERRITORY OF THE PACIFIC ISLANDS

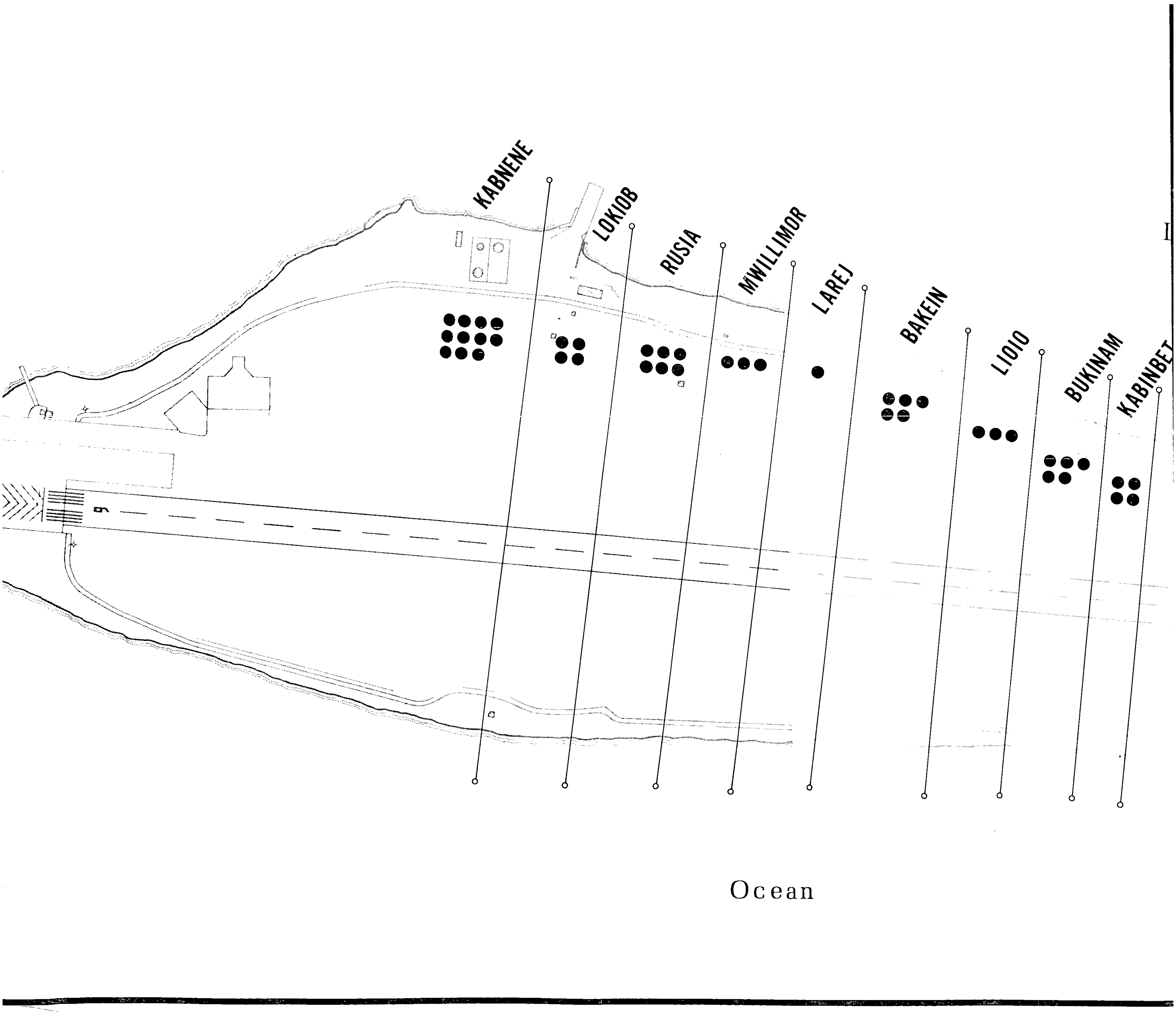
**ENEWETAK ATOLL MASTER PLAN**

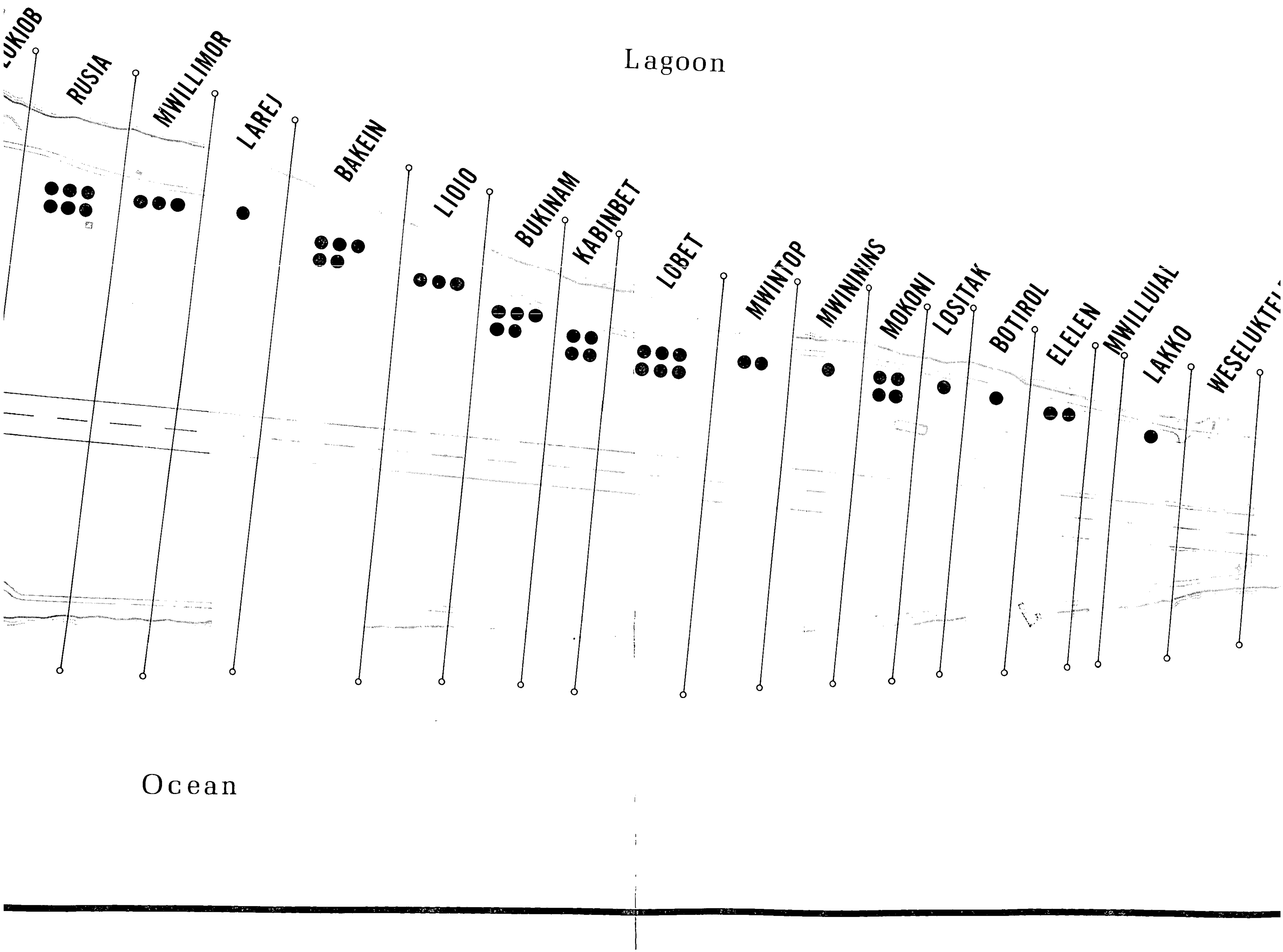
HOLMES & NARVER, INC.

Plate No. 20

NOV. 1973

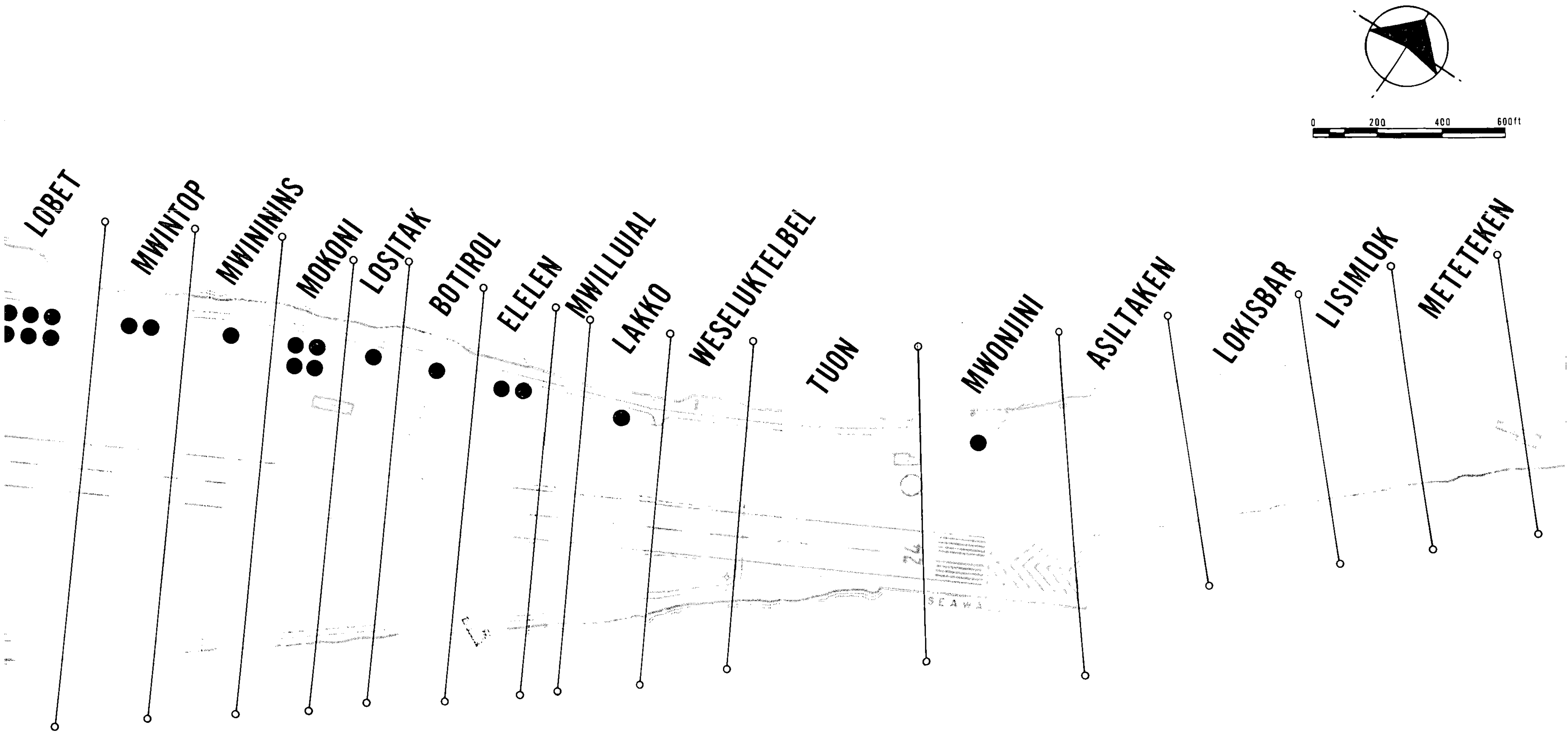

KABNENE
9

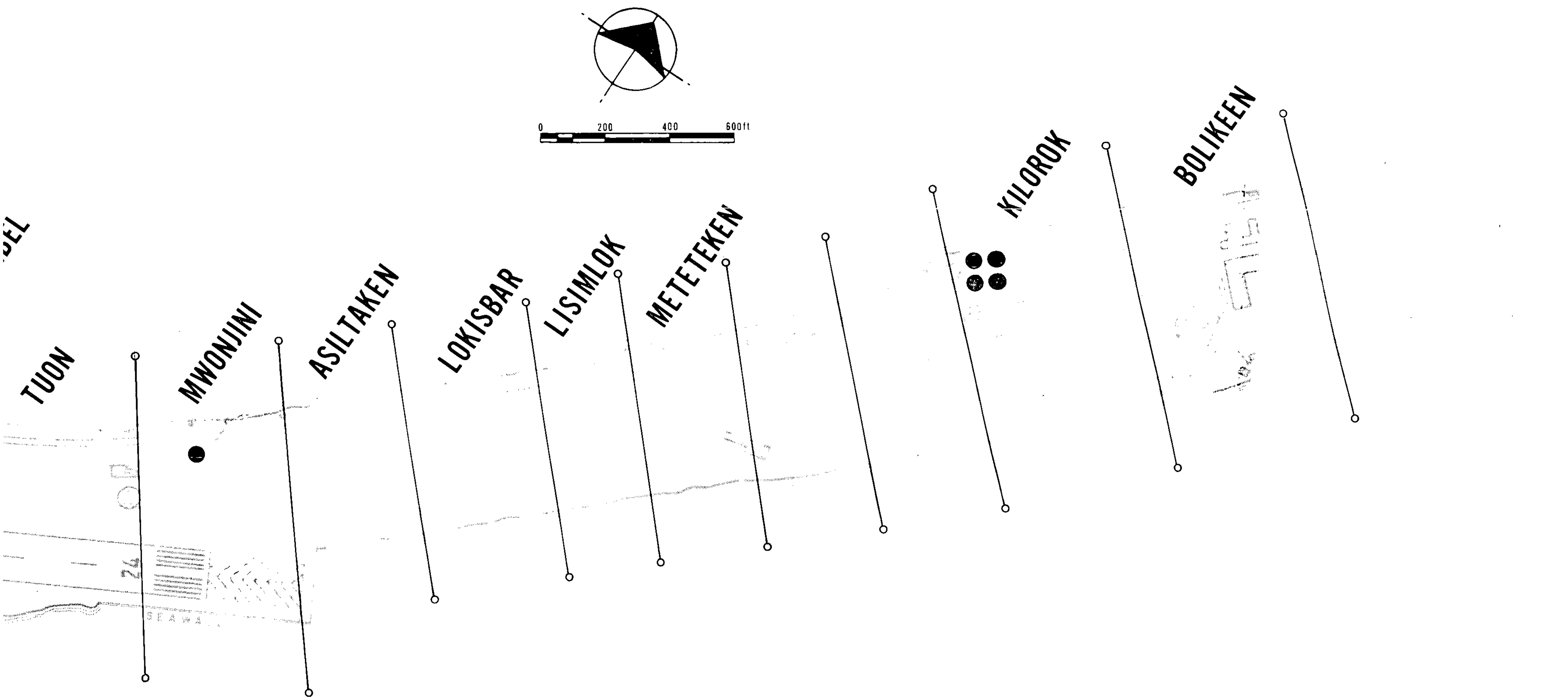

KABNENE
LOKIOB
RUSIA
MWILLIMOR
LAREJ
BAKEIN
LIOIO
BUKINAM
KABINBET
6
Ocean



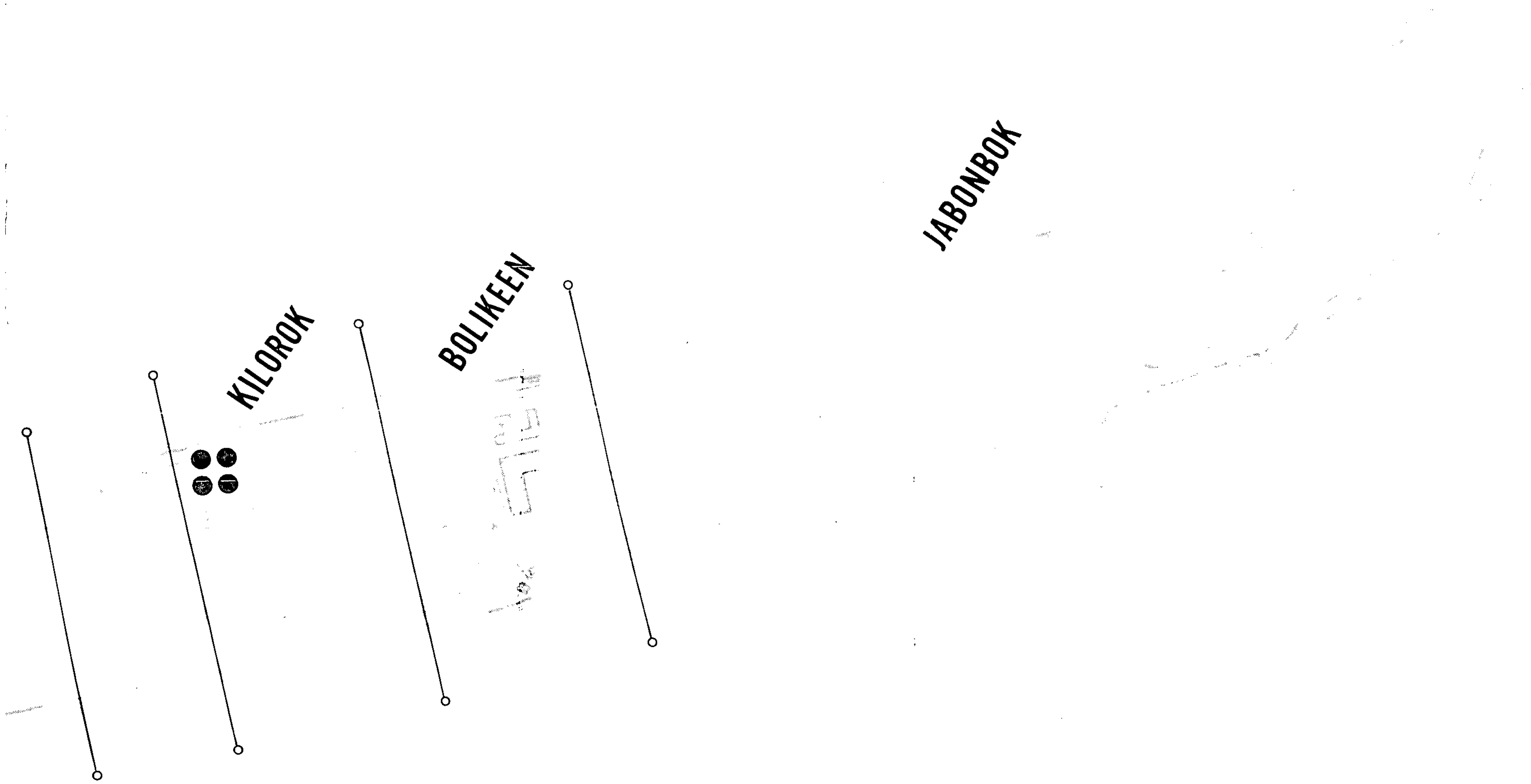
Lagoon
RUSIA
MWILLIMOR
LAREJ
BAKEIN
LIOIO
BUKINAM
KABINBET
LOBET
MWINTOP
MWININ-INS
MOKONI
LOSITAK
BOTIROL
ELELEN
MWILLUIAL
LAKKO
Ocean

agoon


0
200
400
600ft
LOBET
MWINTOP
MWINININS
MOKONI
LOSITAK
BOTIROL
ELELEN
MWILLUIAL
LAKKO
WESELUKTELBEL
TUON
MWONJINI
ASILTAKEN
LOKISBAR
LISIMLOK
METETEKEN



0
200
400
600ft
TUON
MWONJINI
ASILTAKEN
LOKISBAR
LISIMLOK
METETEKEN
KILOROK
BOLIKEEN




# LAND TENURE PLAN - ENEWETAK ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS

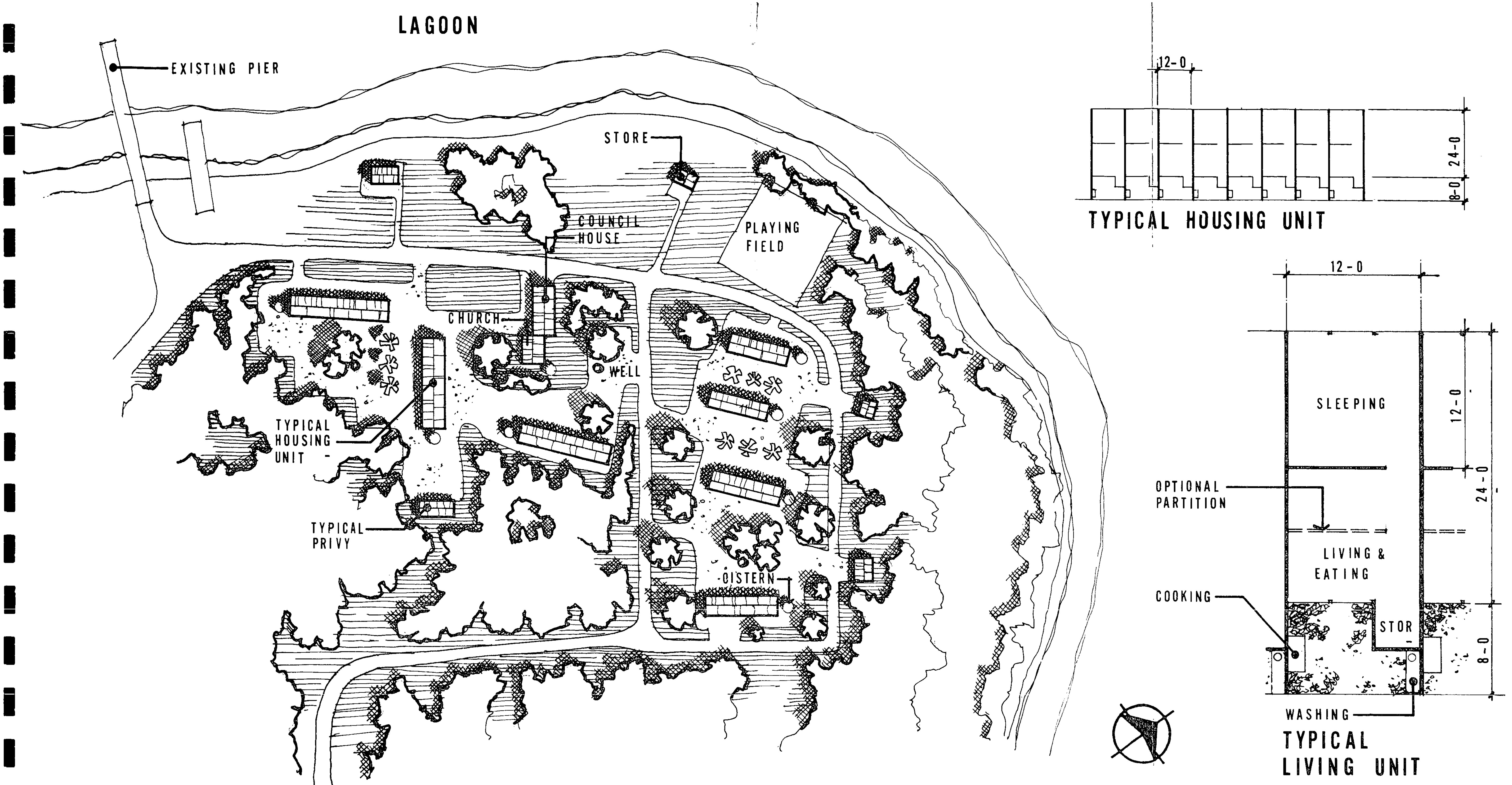
ENEWETAK ATOLL MASTER PLAN

HOLMES & NARVER, INC.

A RESOURCE SCIENCES COMPANY
TECHNOLOGY & CONSTRUCTION
ANAHEIM, CALIFORNIA

Plate No. 21

NOV. 1973




TEMPORARY LIVING AREA

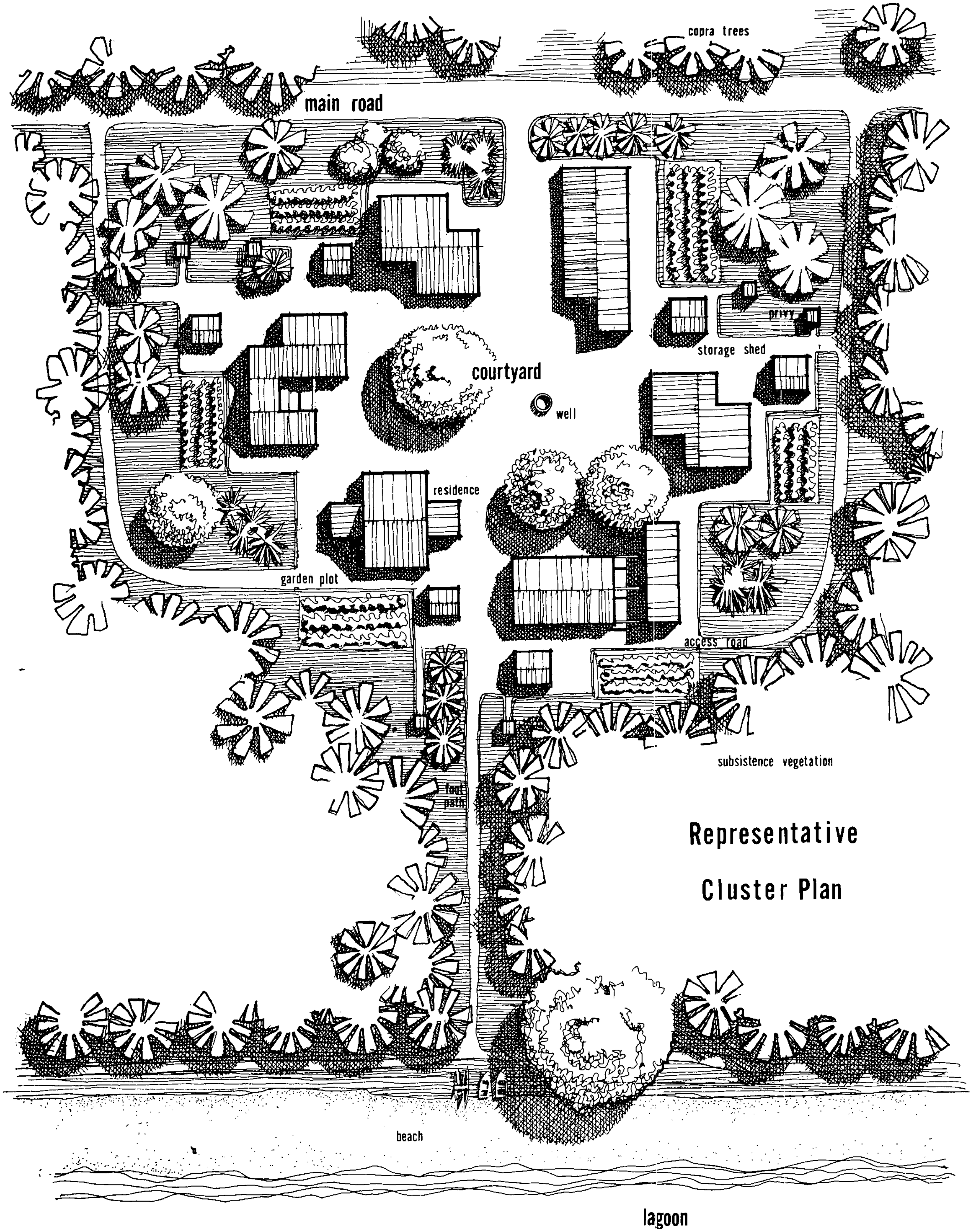
JAPTAN ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS

ENEWETAK ATOLL MASTER PLAN

HOLMES & NARVER, INC.

| Plate No. |
|---|
| 22 |
| NOV. 1973 |




TRUST TERRITORY OF THE PACIFIC ISLANDS

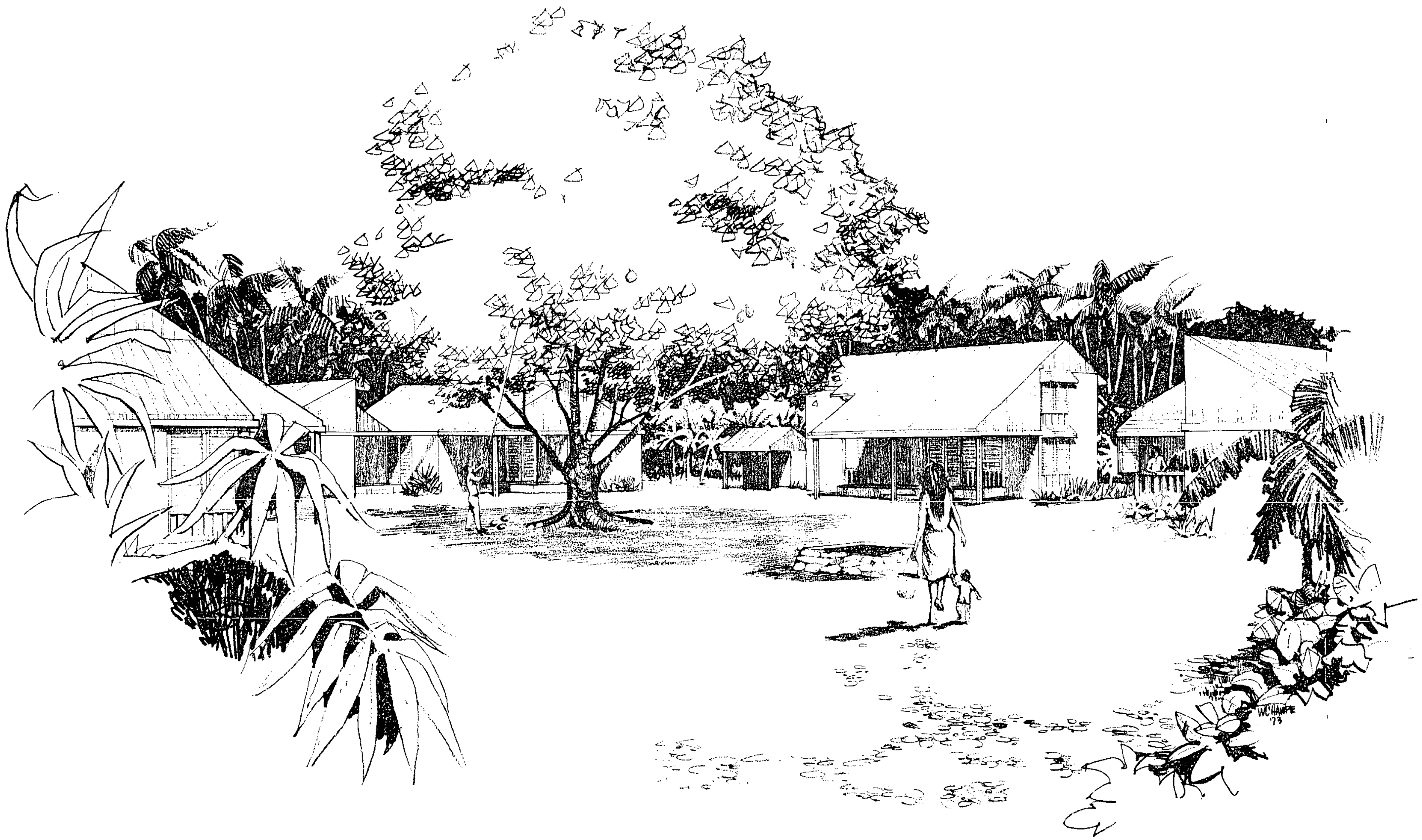
**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

A RESOURCE SCIENCES COMPANY
TECHNOLOGY & CONSTRUCTION
ANAHEIM, CALIFORNIA

Plate No. 23

NOV. 1973



HOUSING CLUSTER
PERSPECTIVE

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No. 24
NOV. 1973

The housing density on Enjebi indicates a double residential cluster on the Tuwon Wāto, while the other Wātos will contain single clusters; and the housing density on Medren Island indicates that multiple residential clusters will be required on at least three, and possibly four, Wātos.

The housing density for the alternate community location on Enewetak Island indicates the need for a residential cluster complex only on the Kabnem Wāto, at the southwest end of the island. All other housing can be grouped in single clusters.

4.3.1 Housing Plans and Concepts

4.3.1.1 Cultural Aspects. According to information obtained from the Enewetak Planning Council during the Ujelang Field Trip of July, 1973, the Enewetak people have decided to depart from the separated structures concept which traditionally have housed individual residential functions. In the past, separate buildings were utilized for cooking, sleeping, washing, and sanitary purposes. The space between the separate structures, which was usually sheltered by shade trees, became the living area. Roofs and walls served only as protection from the elements and intruders. Most of these buildings were of wood construction with metal or thatched roofs and provided doubtful security for the inhabitants during severe storms.

The new housing proposed for Enewetak collects these separated functions into unified arrangements under one roof, with the exception of the toilets which are housed in separate privies. The type of construction which is proposed will afford the inhabitants better protection from the elements as well as from unwanted visitors. The residential clusters on the Wātos will vary in size with the requirements of the families. The central courtyard contains shade trees as well as

subsistence vegetation, and a brackish water well for use of all families in the area.

In a further break with tradition, the planning council has requested that some furniture, mainly tables and chairs for the dining and living areas, be provided for the houses. This is indicative of change in the peoples' living patterns, as furnishings in the past have been limited to pandanus sitting and sleeping mats and foot lockers for clothes. The sleeping areas will not require furniture as mats or mattresses on the floor are preferred, as are foot lockers in lieu of closets.

4.3.1.2 Environmental Considerations. Although the yearly climate and temperature around Enewetak remains relatively constant, consideration must be given to seasonal extreme conditions with high wind, rain, and solar radiation. Even though Enewetak is out of the typhoon belt, it is nevertheless susceptible to them and buildings will be designed accordingly. The people with first-hand knowledge of these conditions have requested the houses to be of concrete for greater resistance to typhoons. A minimum design load of 35 psf on walls and roofs will be required to achieve this. To avoid water damage during such storms the ground floors are raised approximately 2 feet off grade using a perimeter wall footing with slab on fill.

Window openings are designed for maximum flexibility of ventilation, with a full floor to ceiling height and 6-foot width. The window unit itself consists of wood-louvered shutters set above a 2-foot 6-inch balustrade. Sliding vertical slats under the balustrade provide ventilation at floor level and also prevent entry of animals as well as night prowlers and demons. No glass is recommended in the window areas and louvers, slats, and hardware must be of sturdy construction for minimum maintenance. Individual requirements and siting conditions may alter window placement and frequency from unit to unit, but window type and dimensions would remain constant.

Bolted-on sun shades over windows project a minimum of 3 feet from the outside walls. The bolted-on sun shades would be preferable during storm conditions since their loss would not affect the basic roof structure.

4.3.1.3 Economics. Three types of residential construction have been investigated. The types of construction are: masonry block, reinforced concrete cast in place, and modular reinforced concrete construction called the W-panel System.

The W-panel System is recommended since it most closely satisfies all design criteria. The panel itself is a welded steel wire 3-dimensional space frame 4-feet by 8-feet by 2-inches thick. The center of the modular space frame is filled with plastic foam leaving the face frame wire revealed approximately one-half inch from the face of its foam core on either side. These panels weigh only 25 pounds each, permitting easy handling at the construction site.

The erection procedure is relatively simple and consists of setting the panels in place and hand wiring them together, then sealing the vertical joint between the plastic foam edges with a bead of mastic. When complete, the resulting structure is then coated with a 1-inch thick layer of Portland cement plaster on both sides using a plaster spray gun or hand plastering methods. This coating completes the structural composite of wire reinforcing, foam insulation, and cement plaster.

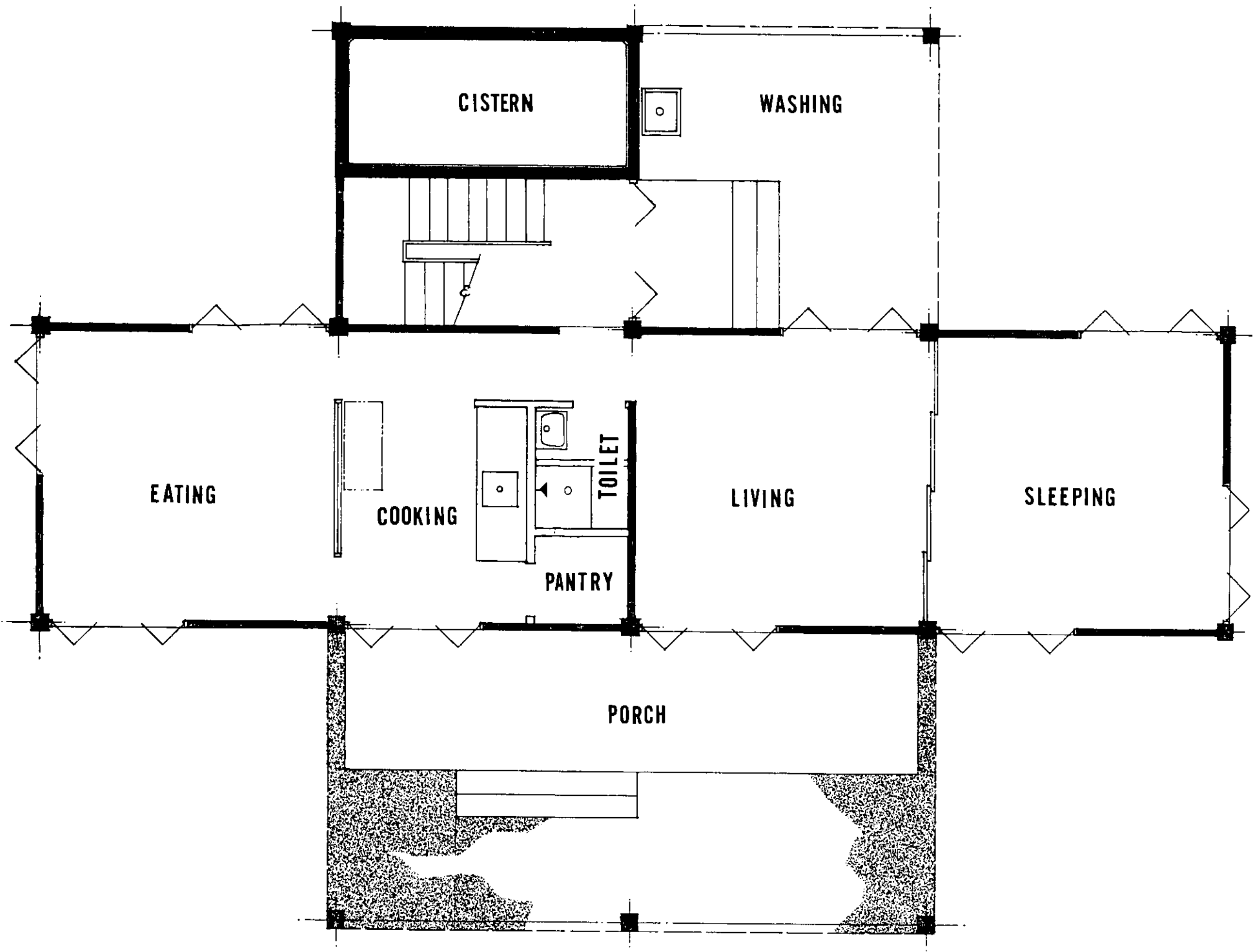
Roofs as well as walls can be constructed using this method resulting in the building becoming a true monolithic structure. Ceilings are not required since the plastic foam core in the roof panels contains adequate insulation. Some advantages of this type of construction are:

- Elimination of formwork.
- Long range structural life of reinforced cement construction.
- High insulation factor due to plastic foam core.
- Fire resistance.
- Low maintenance requirement for cement plaster.
- Waterproof.
- Impervious to termite, fungus, dry rot.
- Durability and adaptability to use of esthetically desirable finishes and textures or cement plaster.
- Excellent resistance to typhoons, earthquakes, and floods.
- Anticipated lower construction cost.

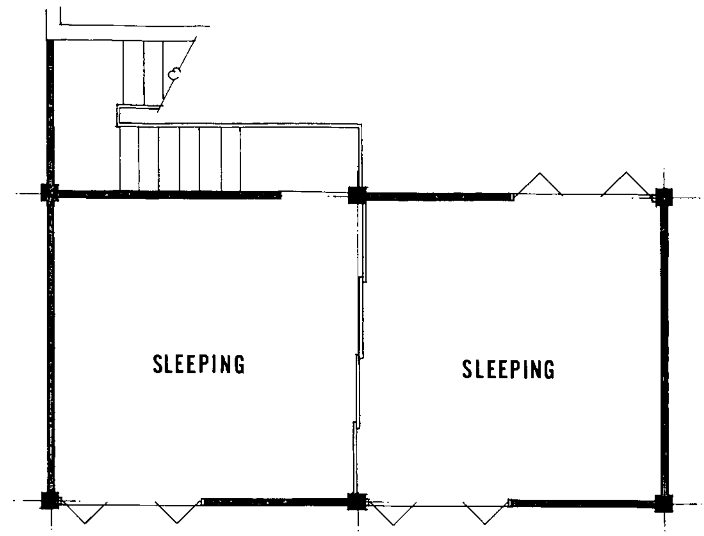
4.3.2 Description of Housing

4.3.2.1 Modular Approach. There are six different house types (Plates #25, #26, #27, #28, #29, and #30), which are based on the same space designations and sizes but with different plan arrangements to accommodate individual tastes and needs. Included are two 2-story, two 1-story single unit, and two 1-story split unit designs. All designs are based on a 12-foot building module and contain the same amount of usable space.

The number of residents per house to be constructed at Enewetak Atoll averages only four, a relatively low number for a typical Marshallese household. However, it is anticipated that population growth will be rapid and that the number of occupants per house could double in the next ten to twenty years. Therefore, provisions for altering room sizes and uses and future expansion of enclosed space have been considered. To maintain flexibility in multiuse of spaces,

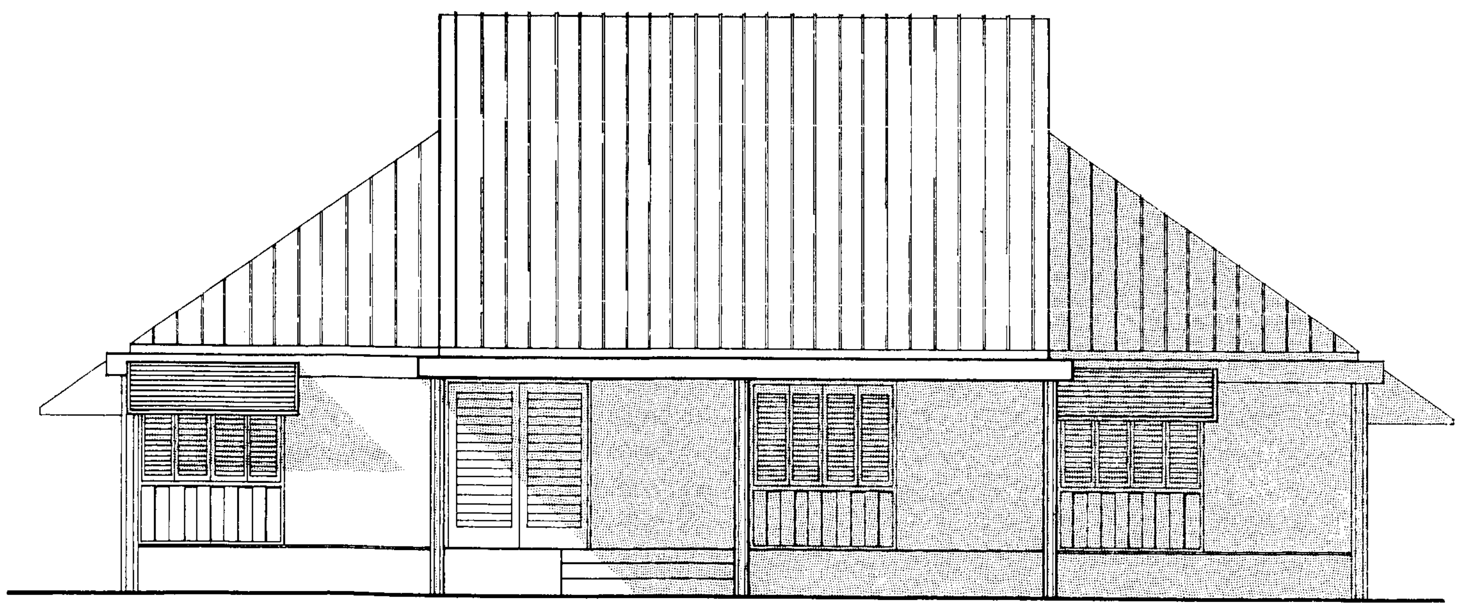



FIRST FLOOR PLAN

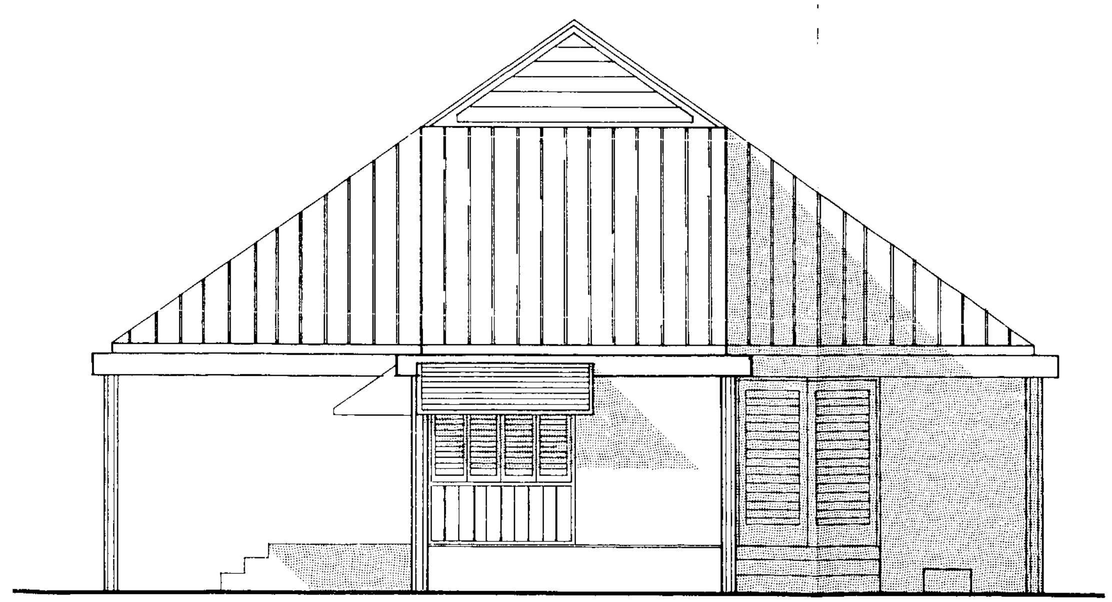



SECOND FLOOR PLAN

| | |
|---|---|
| gross area | 1626SF |
| enclosed area | |
| first floor | 732SF |
| second floor | 407SF |



FRONT ELEVATION



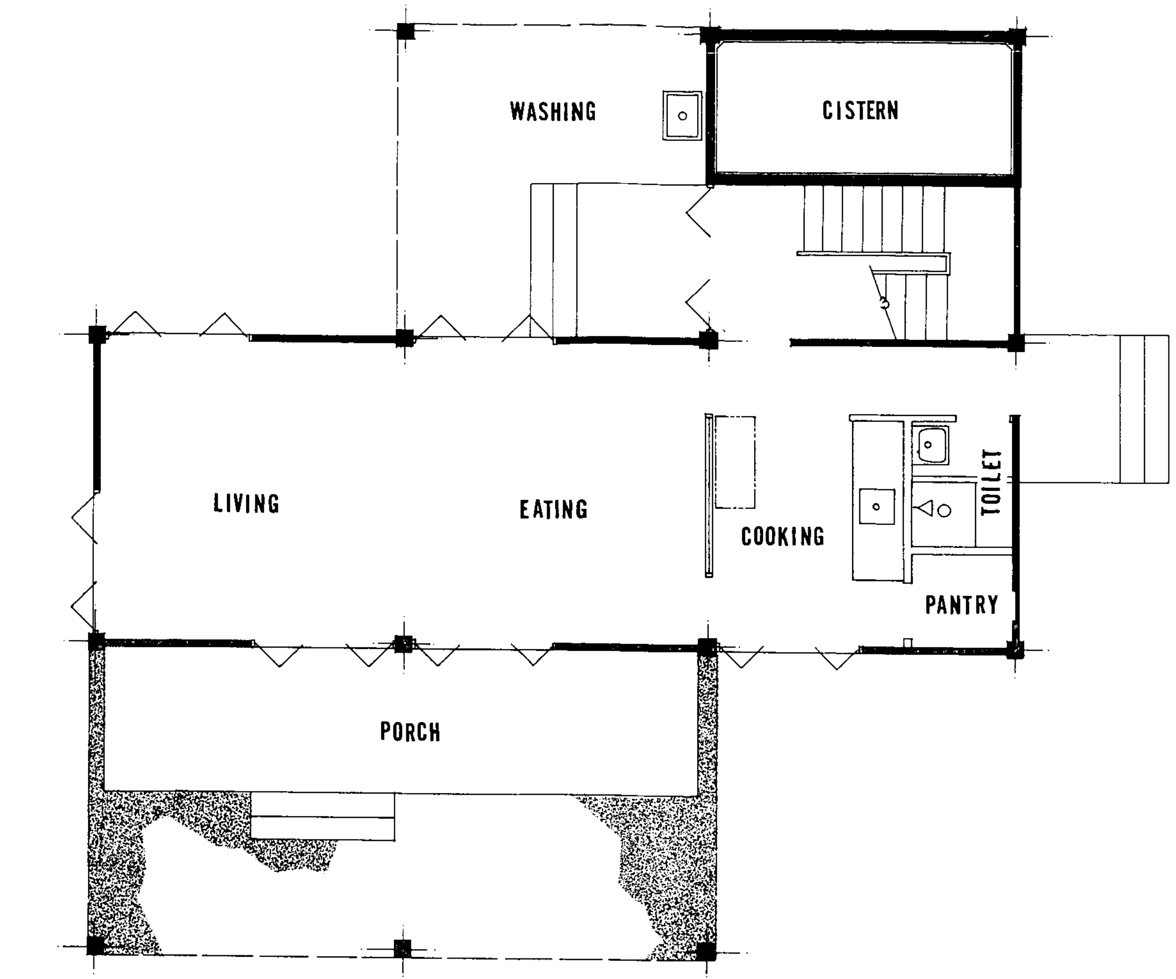
RIGHT SIDE ELEVATION

## MODEL A

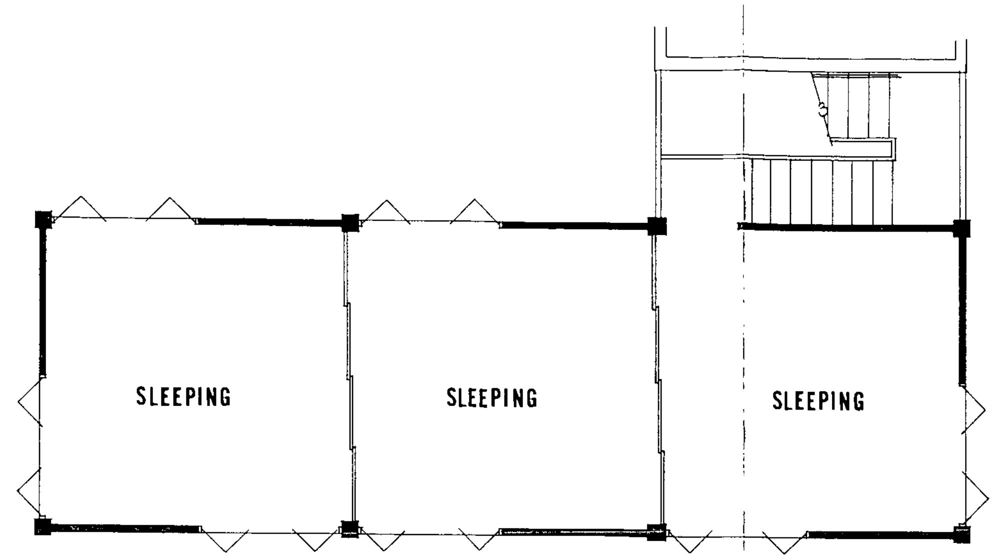
TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No. 25

NOV. 1973

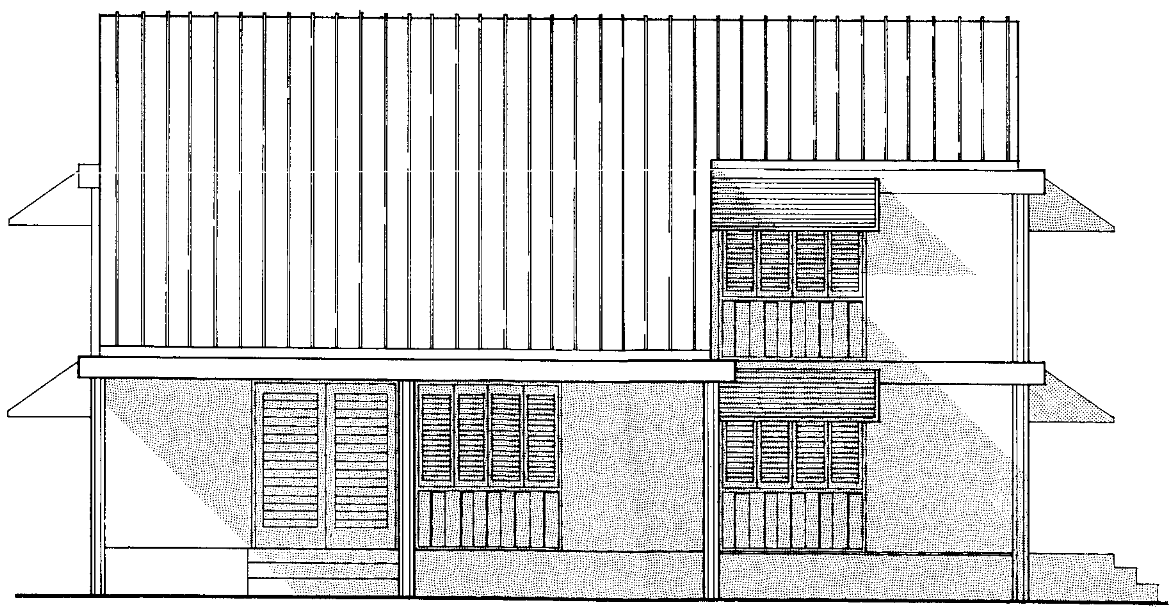



FIRST FLOOR PLAN

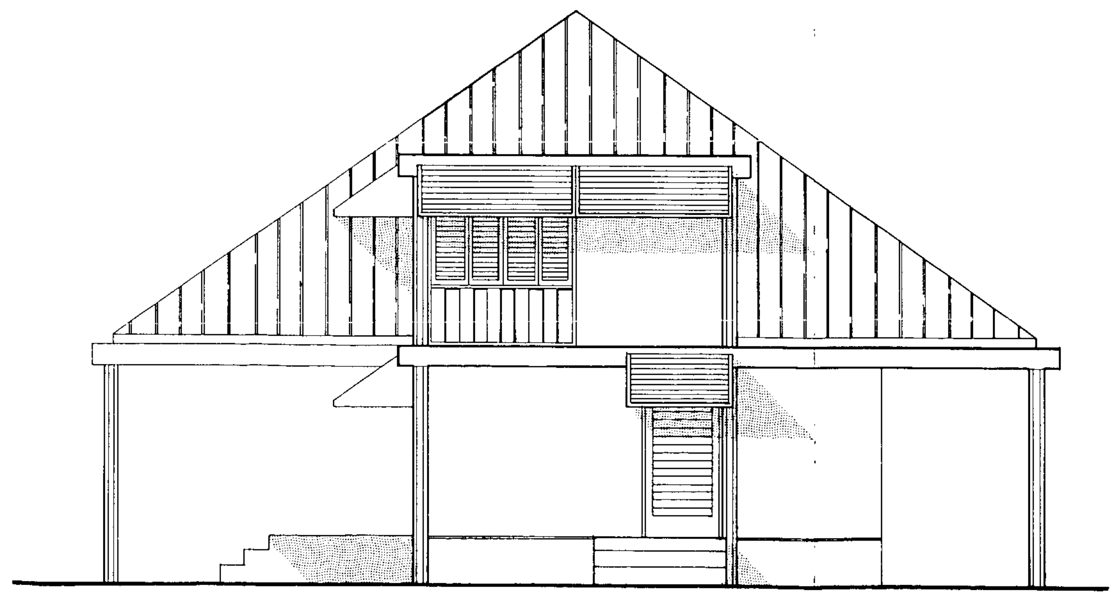



SECOND FLOOR PLAN

| | |
|---|---|
| gross area | 1626SF |
| enclosed area | |
| first floor | 487SF |
| second floor | 487SF |



FRONT ELEVATION



RIGHT SIDE ELEVATION

**MODEL B**

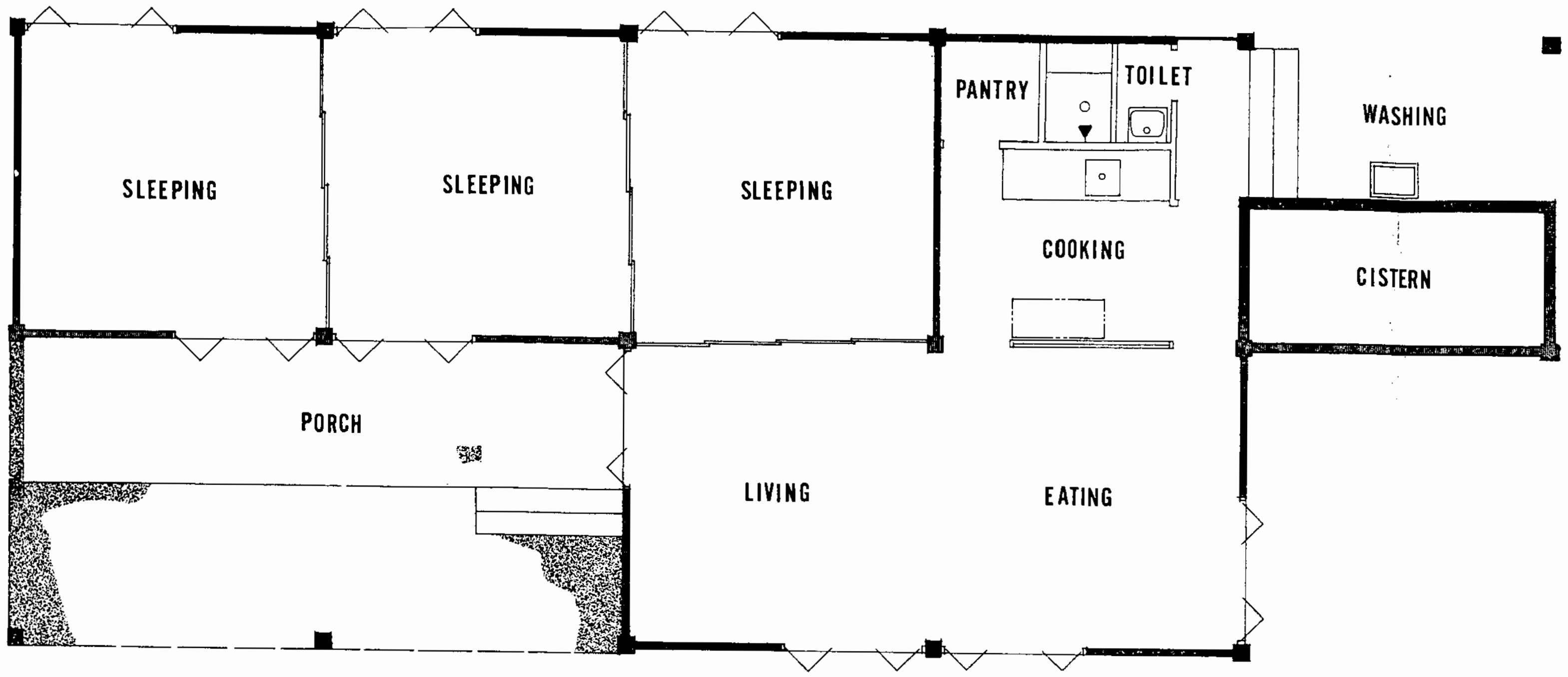
TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

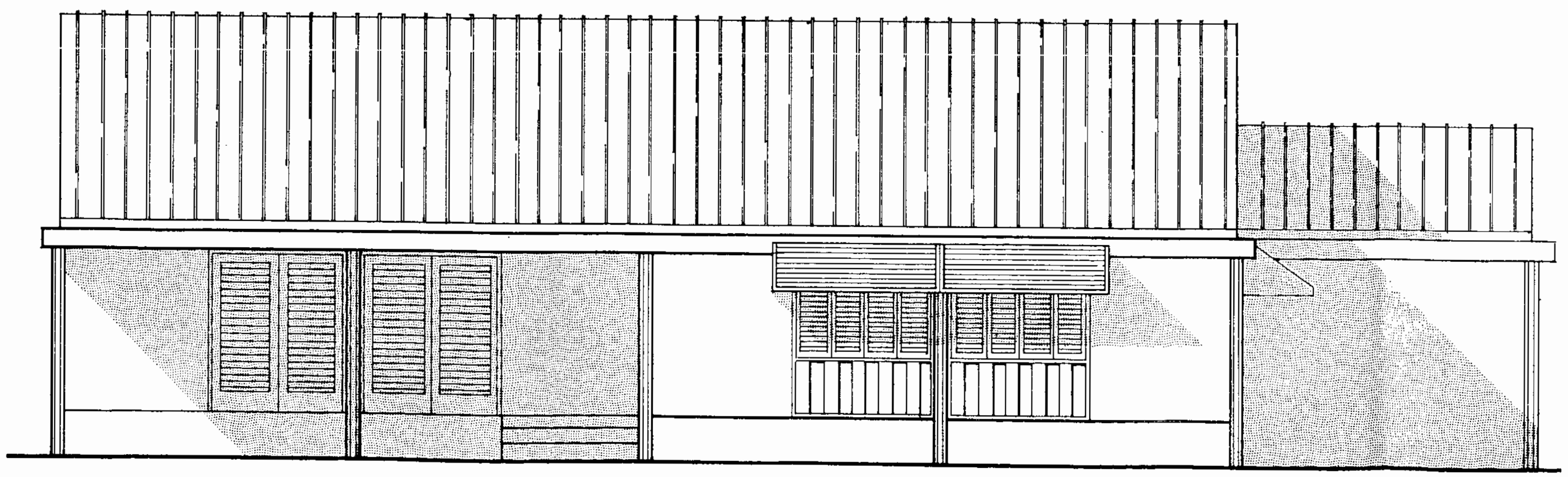
Plate No. 26

NOV. 1973

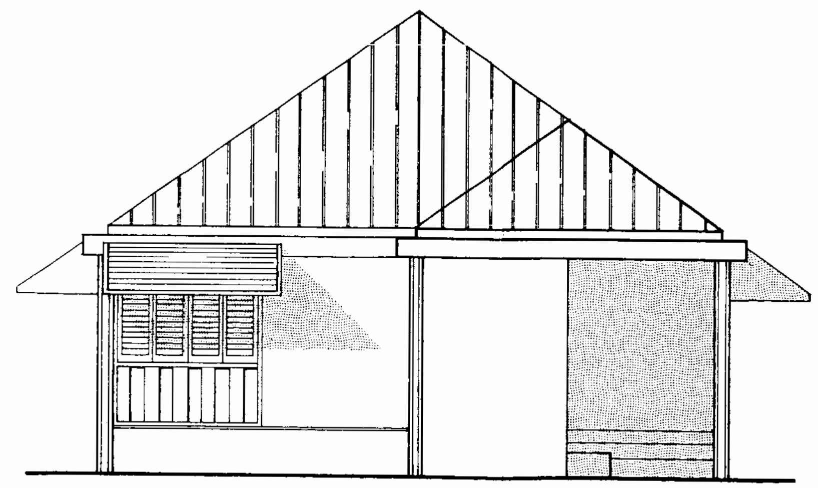



FLOOR PLAN

| | |
|---|---|
| gross area | 1463SF |
| enclosed area first floor | 976SF |



FRONT ELEVATION



RIGHT SIDE ELEVATION

**MODEL C**

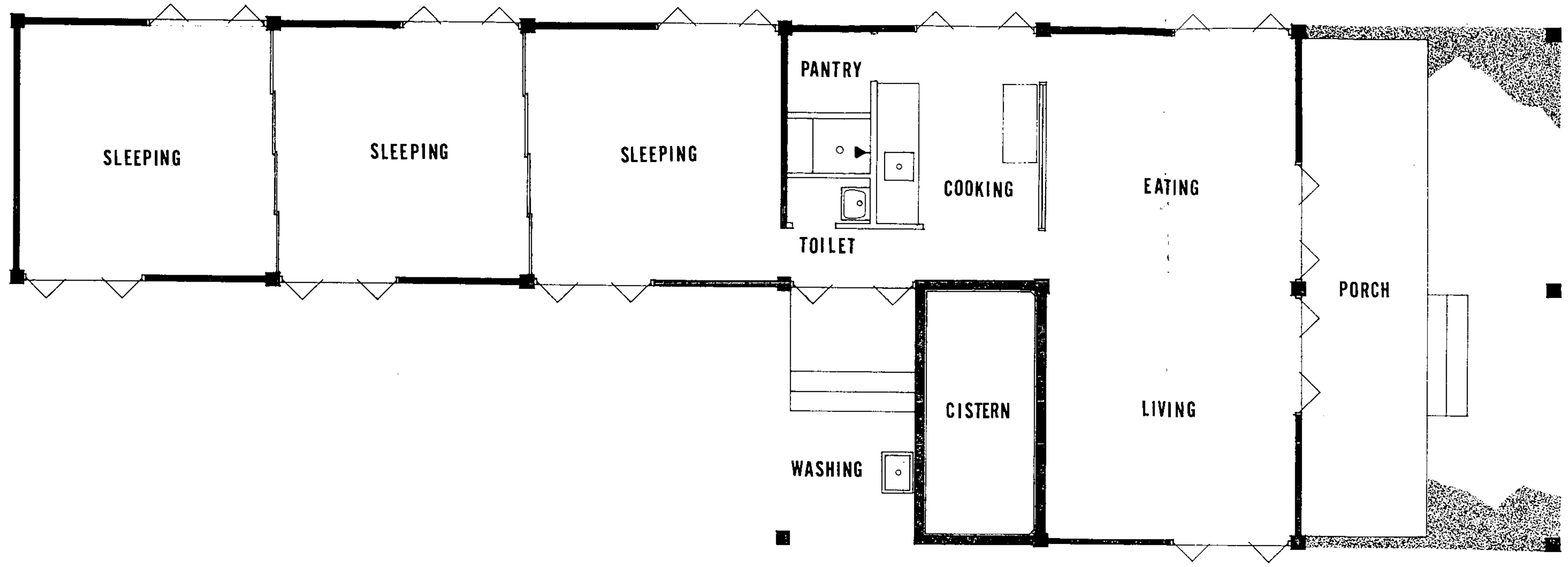
TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

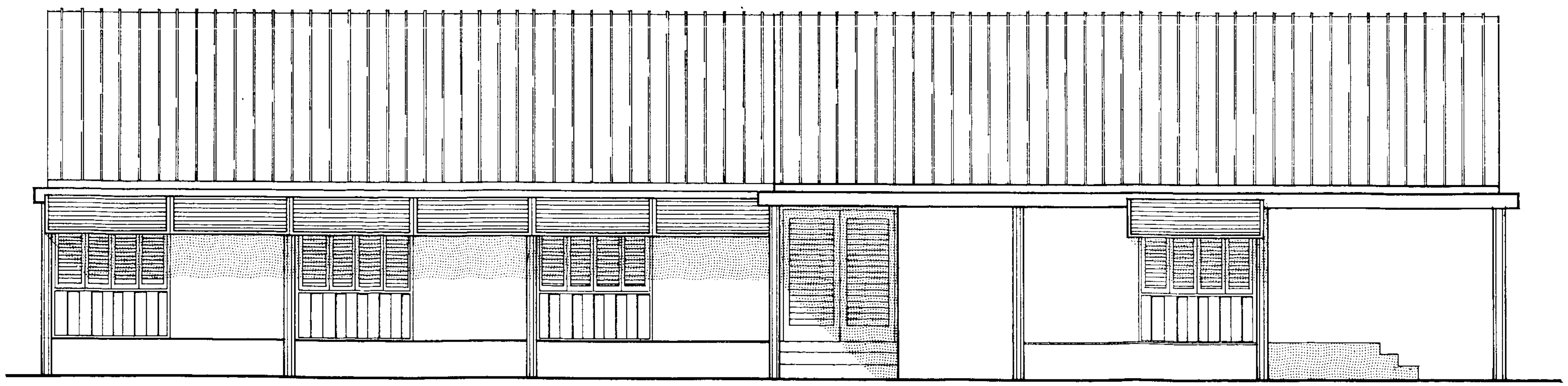
Plate No. 27

NOV. 1973

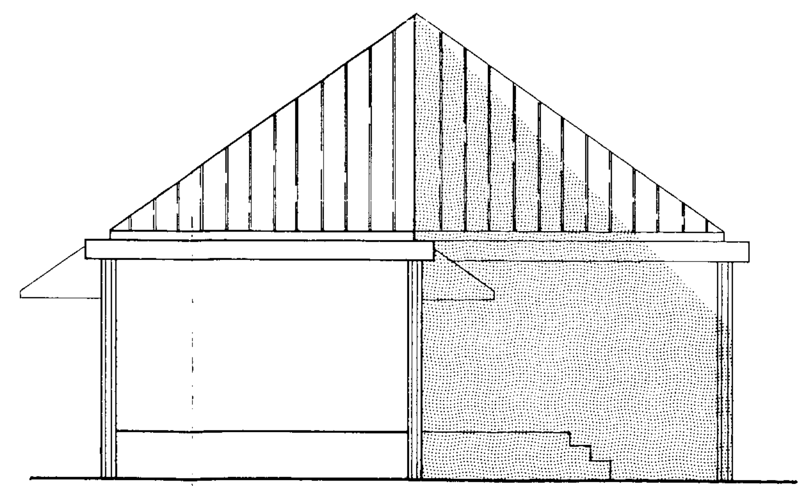



FLOOR PLAN

| | |
|---|---|
| gross area | 1463SF |
| enclosed area first floor | 976SF |



FRONT ELEVATION

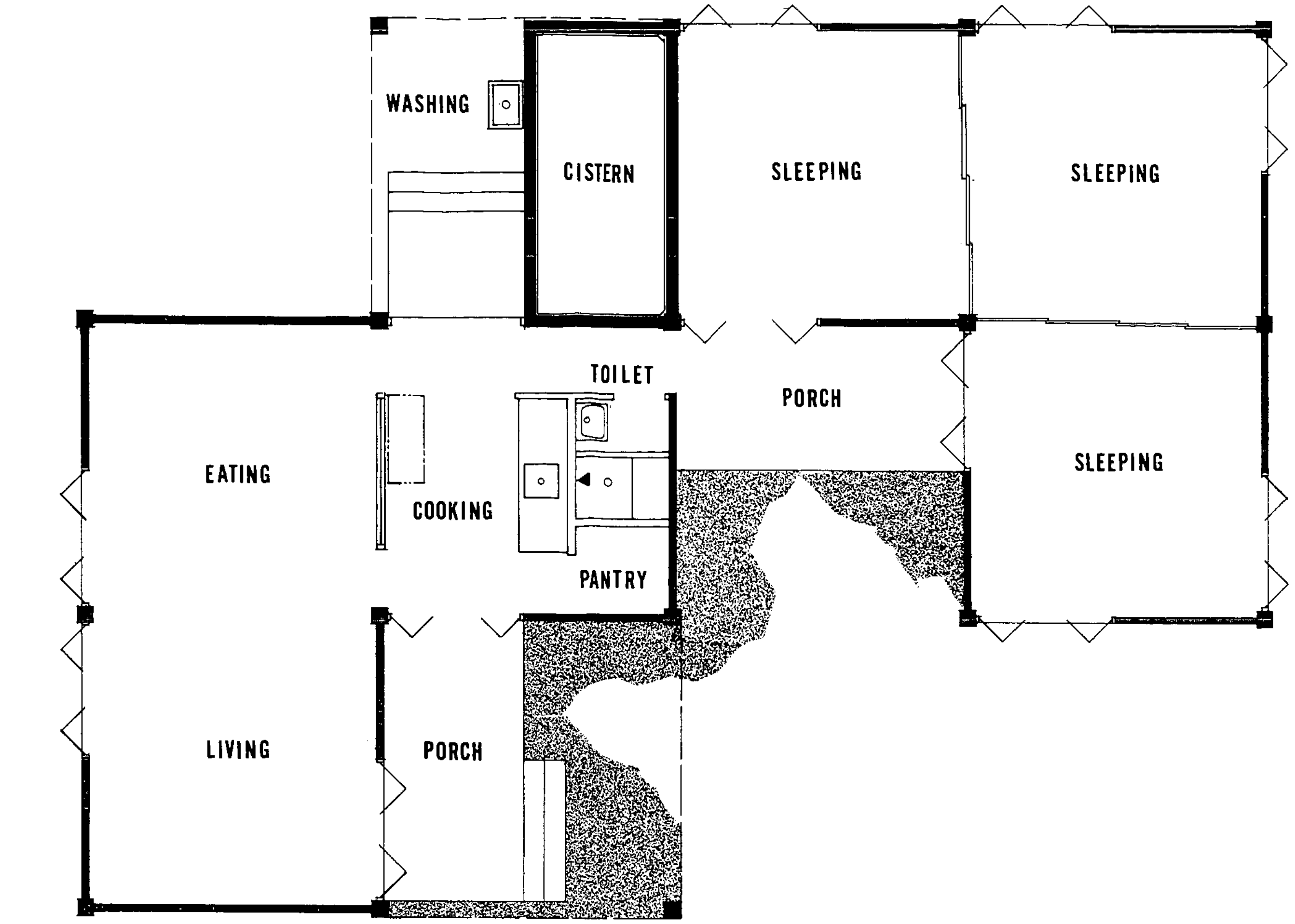


LEFT SIDE ELEVATION

**MODEL D**

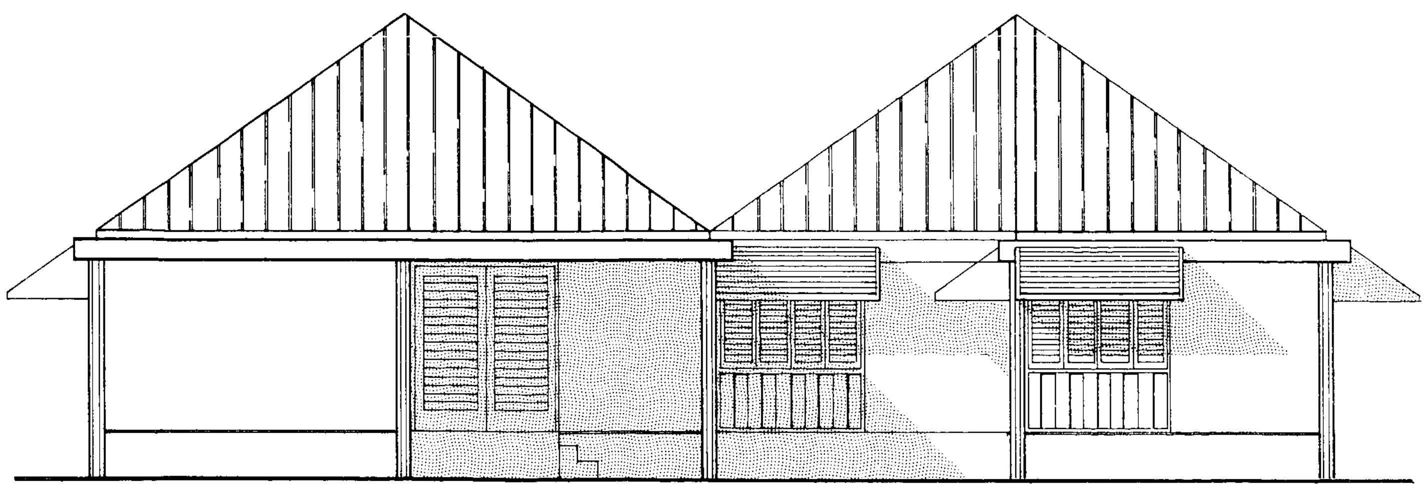
TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
HOLMES & NARVER, INC.

| Plate No. |
|---|
| 28 |
| NOV. 1973 |

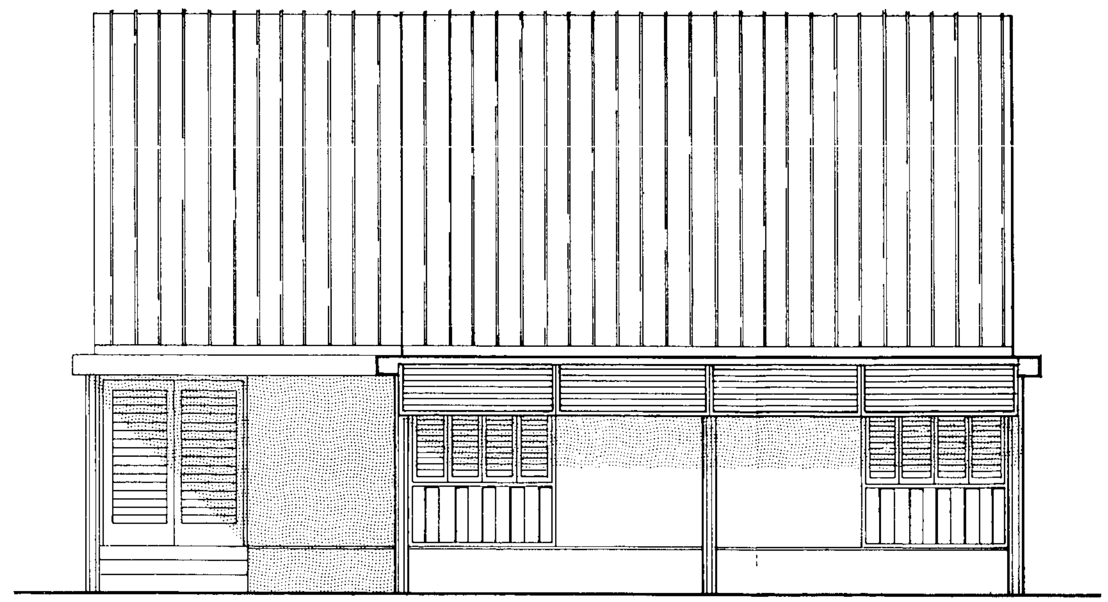



FLOOR PLAN

gross area 1300SF
enclosed area
first floor 976SF



FRONT ELEVATION



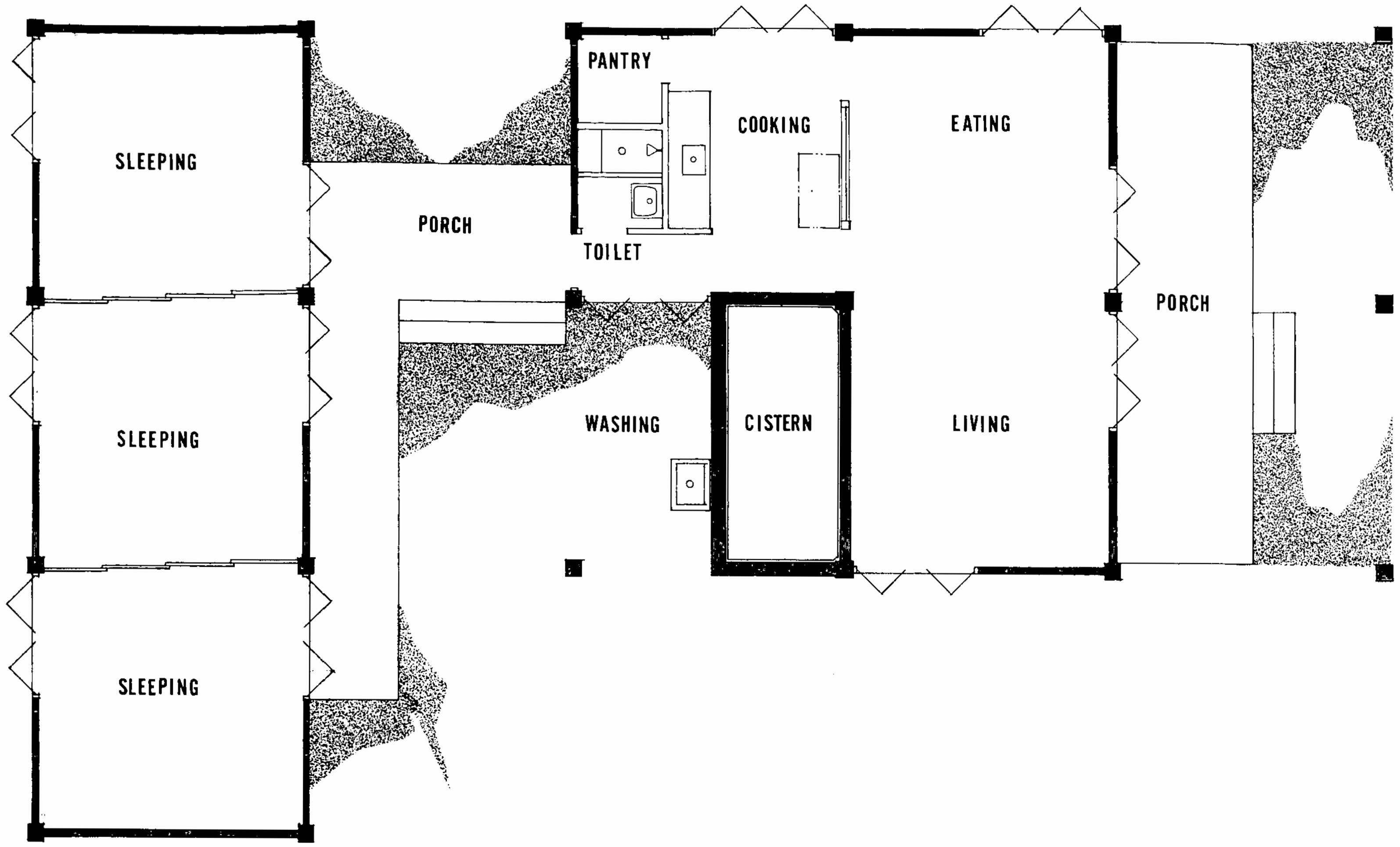
RIGHT SIDE ELEVATION

## MODEL E

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No. 29

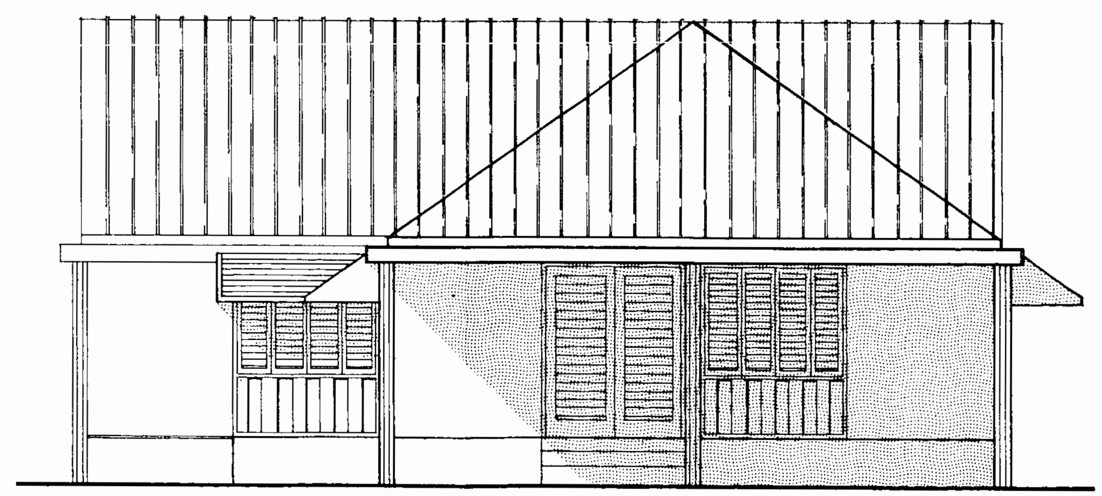
NOV. 1973




FLOOR PLAN

| | |
|---|---|
| gross area | 1138SF |
| enclosed area | |
| first floor | 976SF |

FRONT ELEVATION



RIGHT SIDE ELEVATION

**MODEL F**

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

Plate No. 30

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dividing walls between rooms are Shoji-type sliding panels 3 to 4 feet wide permitting these rooms, which are basically minimum size, to be enclosed or enlarged to suit the purpose. Typical space allocations are as follows:

- Parents' sleeping room - 144 square feet (12' x 12').
- Boys' sleeping room - 144 square feet (12' x 12').
- Girls' sleeping room - 144 square feet (12' x 12').
- Utility core - cooking - food storage - 144 square feet (12' x 12').
- Living - 144 square feet (12' x 12').
- Eating - 144 square feet (12' x 12').
- General purpose porch - 288 square feet (12' x 24').
- Cistern - 72 square feet (6' x 12').
- Stair - 72* square feet (6' x 12').
- Washing porch - 144* or 72 square feet (12' x 12' or 6' x 12').

The total square footage for a 1-story house is 1,296 square feet and for a 2-story house, 1,440 square feet. In each case there are 864 square feet of enclosed area, while porches, cistern, and stairs occupy the rest of the roofed area. The cooking area includes a counter top and sink for washing and a storage shelf underneath. A screened 4-foot by 4-foot pantry also is provided for food storage. A separate 144-square-foot work shed is provided with each house. (See Plate #31.)

4.3.2.2 Utilities. No electricity is provided for the residences in the initial stage. Kerosene will be used for lamps and stoves. Rainwater from the individual roofs will drain into a 3,780-gallon cistern. A supplemental 3,200-gallon cistern will be provided with each house to guarantee an

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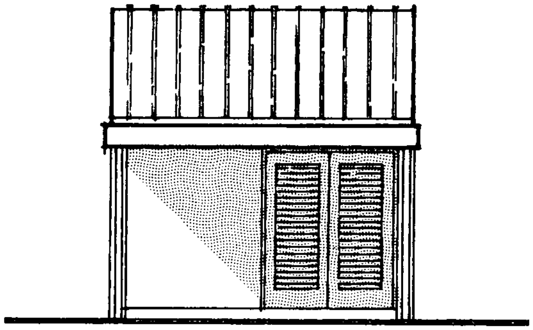
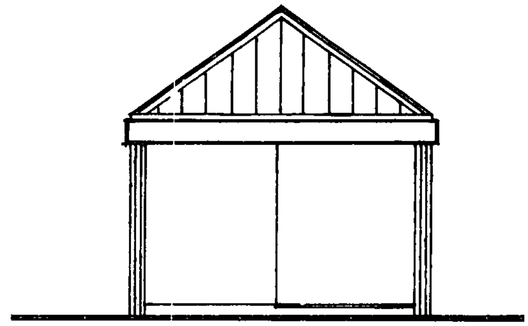
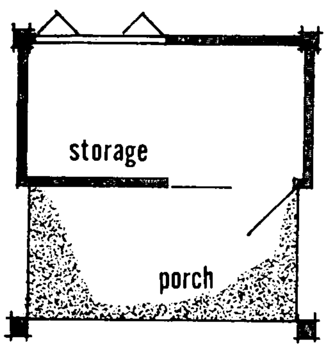
* On 2-story only.



FRONT ELEVATION

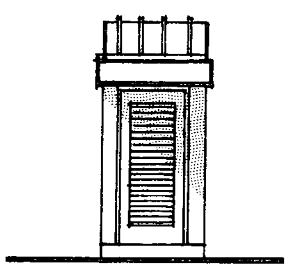


RIGHT SIDE ELEVATION

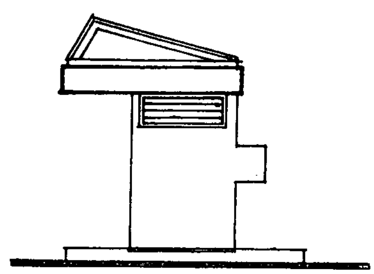



FLOOR PLAN

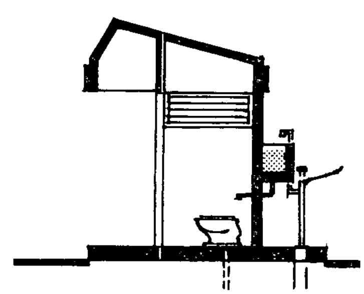
# WORK / STORAGE SHED



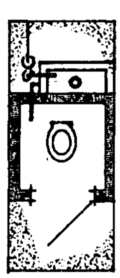
FRONT ELEVATION



RIGHT SIDE ELEVATION

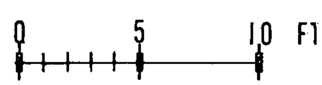


SECTION



FLOOR PLAN

# PRIVY




TRUST TERRITORY OF THE PACIFIC ISLANDS

ENEWETAK ATOLL MASTER PLAN

HOLMES & NARVER, INC.

| Plate No. |
|---|
| 31 |
| NOV. 1973 |

adequate water supply. A system for rationing water during dry spells consists of faucets located at three different levels on the cistern. As water level decreases, the user is made aware of the situation when the highest faucet goes dry. In this way, water consumption can be regulated and supplemented with well water when required. A common well serves each cluster (see Plate #23); and while the water may be too brackish for drinking, it would be adequate for washing clothes and dishes and for bathing. Plumbing fixtures in the house are limited to a sink in the kitchen, a lavatory and shower head for the shower room, and a utility sink on the washing porch. The shower floor is depressed 1 foot below finished floor permitting the installation of a shower head fed from the top of the cistern.

Toilets are provided in the form of privies (benjos) (see Plate #31), one for each house and located not more than 200 feet away. Toilet fixtures will be the sitdown type and a hand pump or a bucket will be provided for flushing and cleaning purposes. The outhouse effluents will be piped to central septic tanks with adequate drainfields to dissipate the effluents. Septic tanks will be located a minimum of 75 yards from any wells.

## 4.4 COMMUNITY CENTER DEVELOPMENT

Community centers are planned for Enjebi and Medren islands with an alternate arrangement for Enewetak Island. In most instances, existing metal buildings will be utilized to house the community functions, some in place and other relocated to suit the arrangements. However, churches and houses for ministers and teachers will be of new construction. Community center facilities include a four-classroom school; a two-bed dispensary and health aid quarters; an open-sided recreation building; a play field; a cooperative store; a council house containing the magistrate's office, radio transceiver equipment, weather office, and

meeting hall; an open nursery and storage sheds; and a berm enclosed POL yard. Rainwater storage and water wells will be located in these areas for community use.

Plate #32 shows the community center arrangement on Enjebi completely contained on the Tuwon Wāto. The Medren community facilities are shown on Plate #33. In this arrangement the existing concrete block computer building located on the Lomke Wāto is used as the council house, while the remainder of the facilities are on the Akadre Wāto. Portions of the old administration complex are used for the new recreation and school buildings; and existing slabs provide flooring for the church, cooperative store, and dispensary.

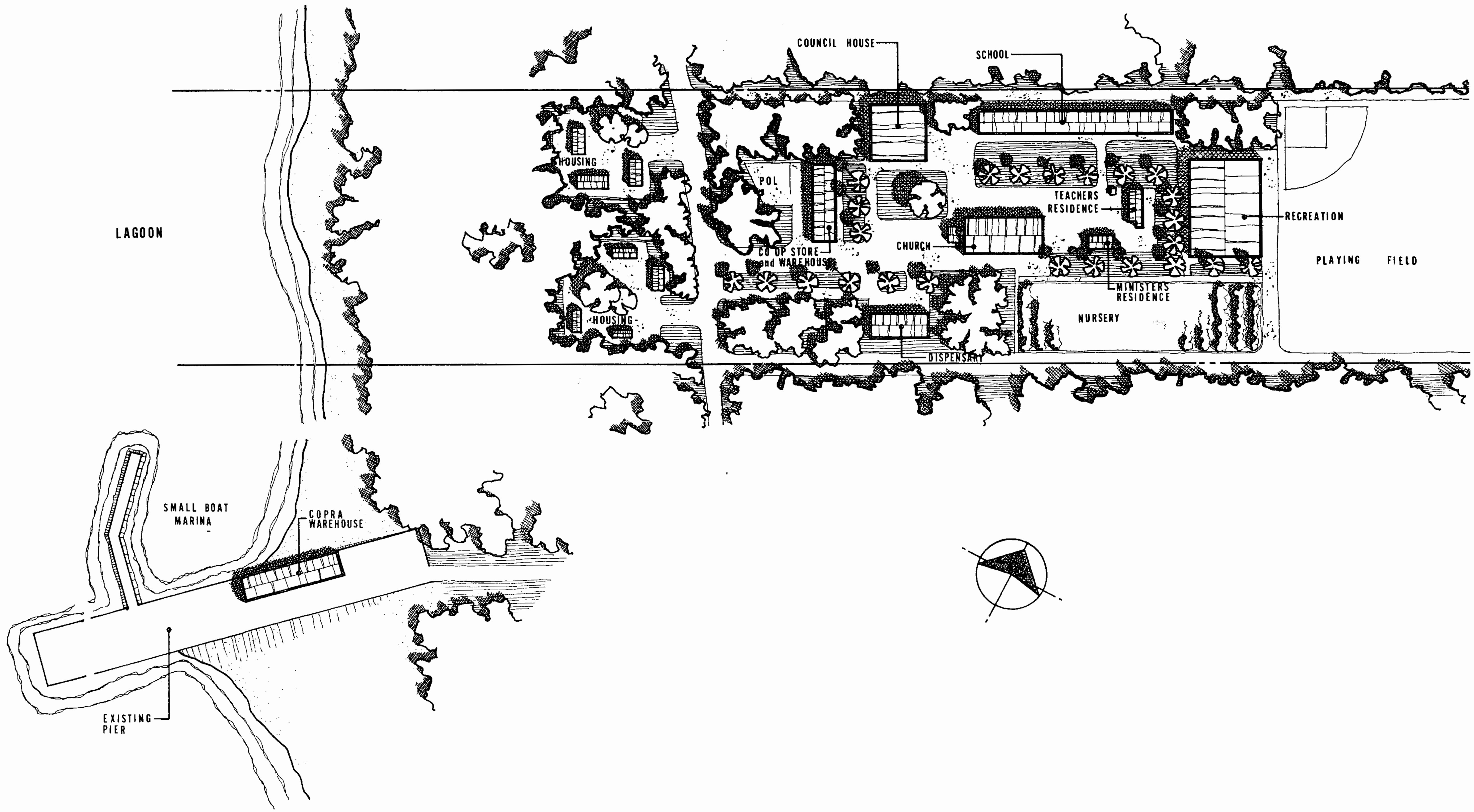
The community center in the alternate plan for Enewetak Island has been located on the Mwillimor Wāto since there is insufficient area in the Lositak Wāto where it had been previously located. All community buildings require new concrete slabs to suit the arrangement shown on Plate #34.

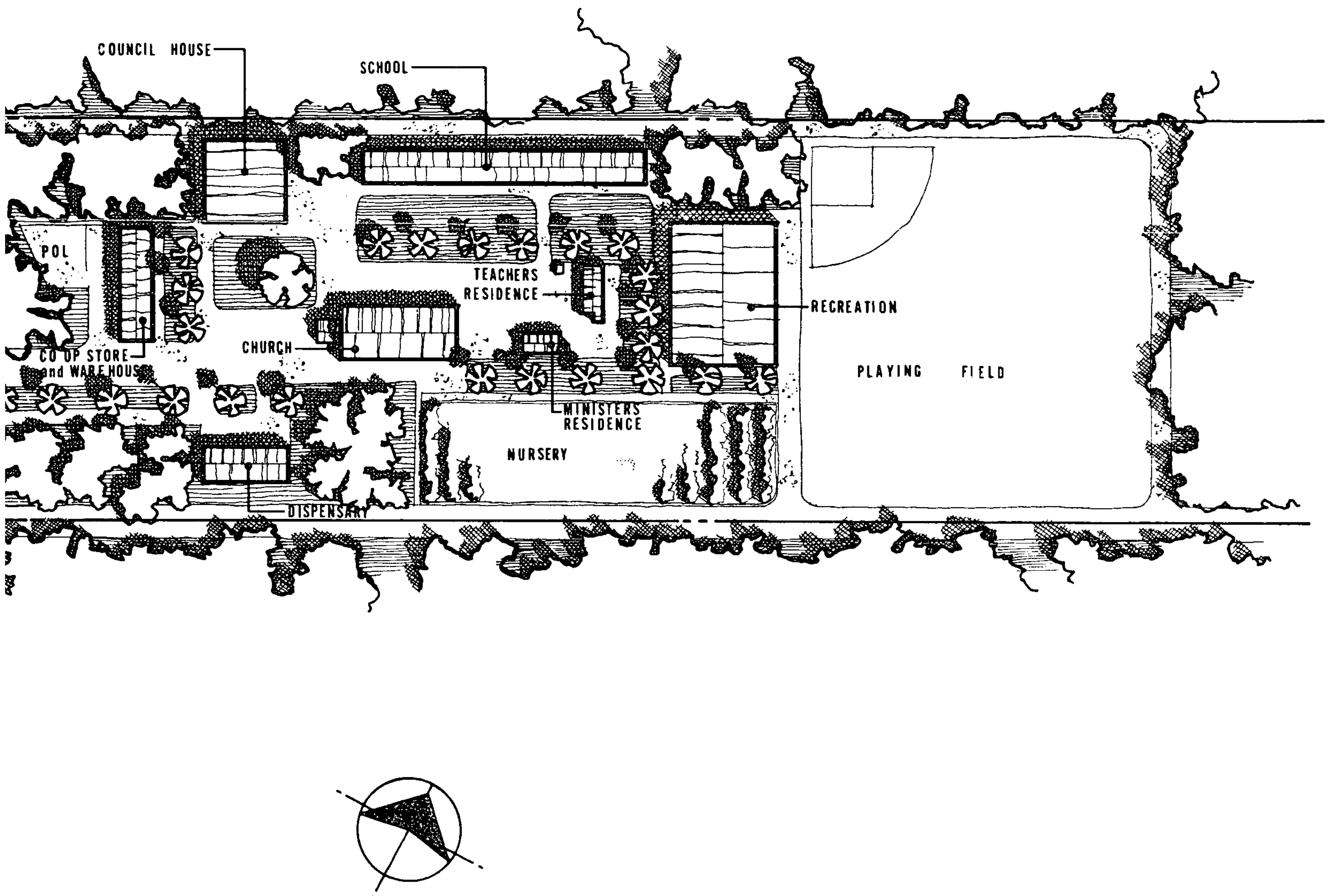
### 4.4.1 Schools

Each community is provided with a four-classroom school building totaling about 3,600 square feet. On Enjebi, the school is housed in a metal building relocated from Medren, while existing Building 1209 on Medren becomes the school. The school for Enewetak utilizes a relocated metal building.

### 4.4.2 Dispensaries

Small dispensaries are located on Enjebi, Medren, and if required, on Enewetak. Relocated metal buildings are used in each instance to provide a two-room, two-bed facility with health aid quarters. The total area required for each facility is approximately 1,200 square feet.


LAGOON
COUNCIL HOUSE
SCHOOL
HOUSING
POL
TEACHERS RESIDENCE
RECREATION
CO OP STORE and WAREHOUSE
CHURCH
PLAYING FIELD
MINISTERS RESIDENCE
NURSERY
HOUSING
DISPENSARY
SMALL BOAT MARINA
COPRA WAREHOUSE
EXISTING PIER




# ENJEBI COMMUNITY CENTER

TRUST TERRITORY OF THE PACIFIC ISLANDS

## ENEWETAK ATOLL MASTER PLAN

HOLMES & NARVER, INC.

A RESOURCE SCIENCES COMPANY
TECHNOLOGY & CONSTRUCTION
ANAHEIM, CALIFORNIA

Plate No.
32

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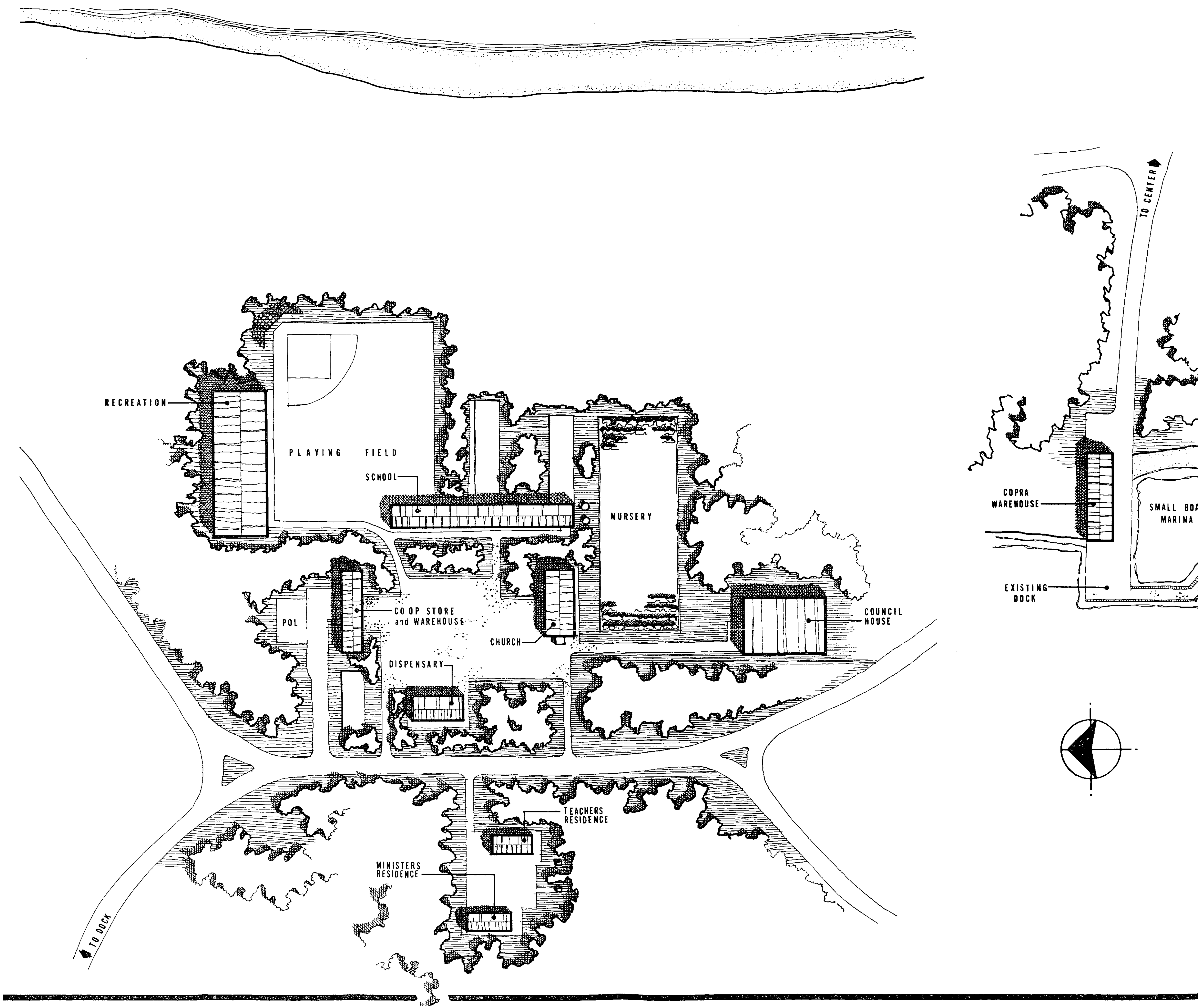
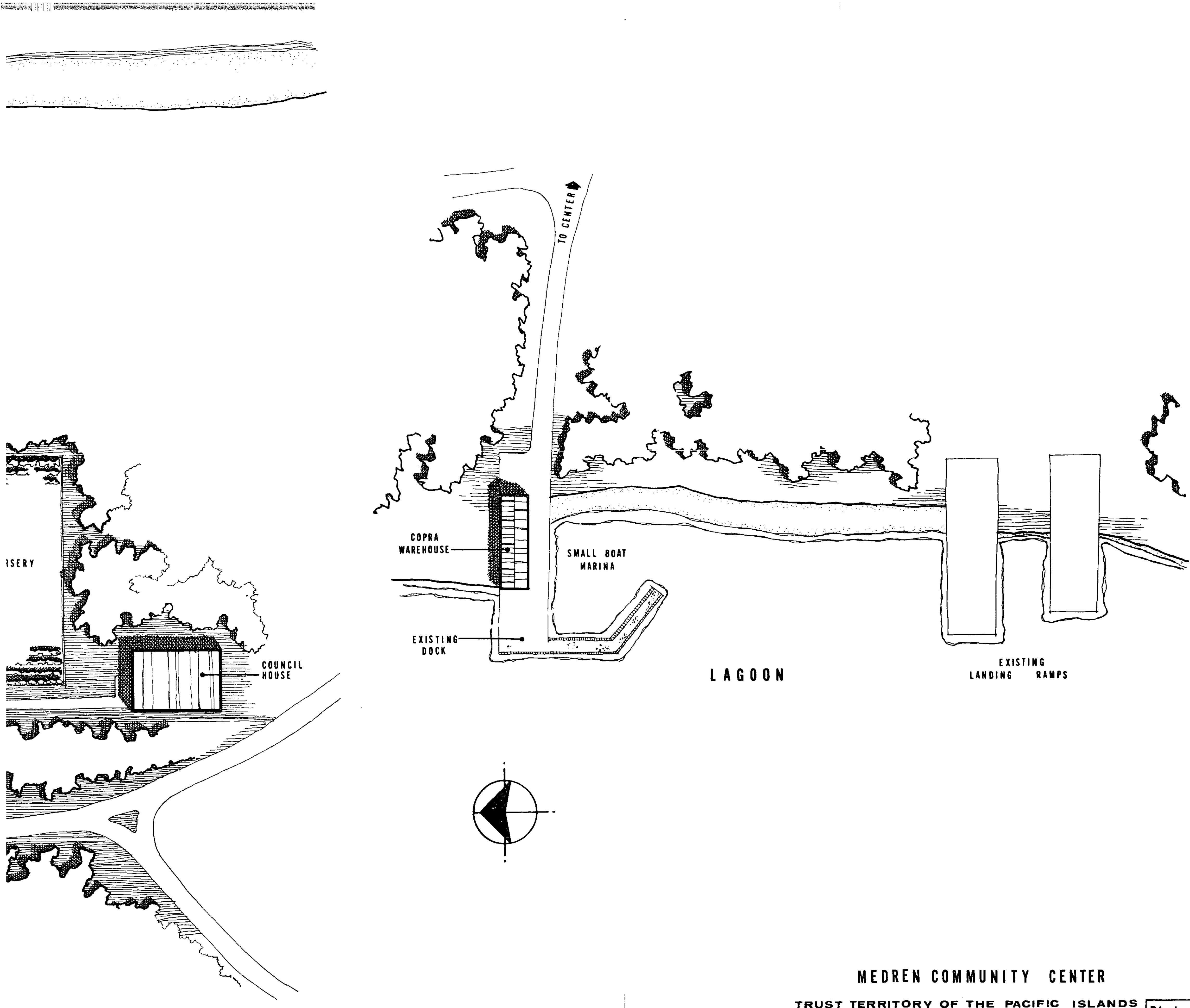

RECREATION
PLAYING FIELD
SCHOOL
NURSERY
POL
CO OP STORE and WAREHOUSE
CHURCH
COUNCIL HOUSE
DISPENSARY
TEACHERS RESIDENCE
MINISTERS RESIDENCE
TO DOCK
TO CENTER
COPRA WAREHOUSE
SMALL BOA
MARINA
EXISTING DOCK




## MEDREN COMMUNITY CENTER

TRUST TERRITORY OF THE PACIFIC ISLANDS

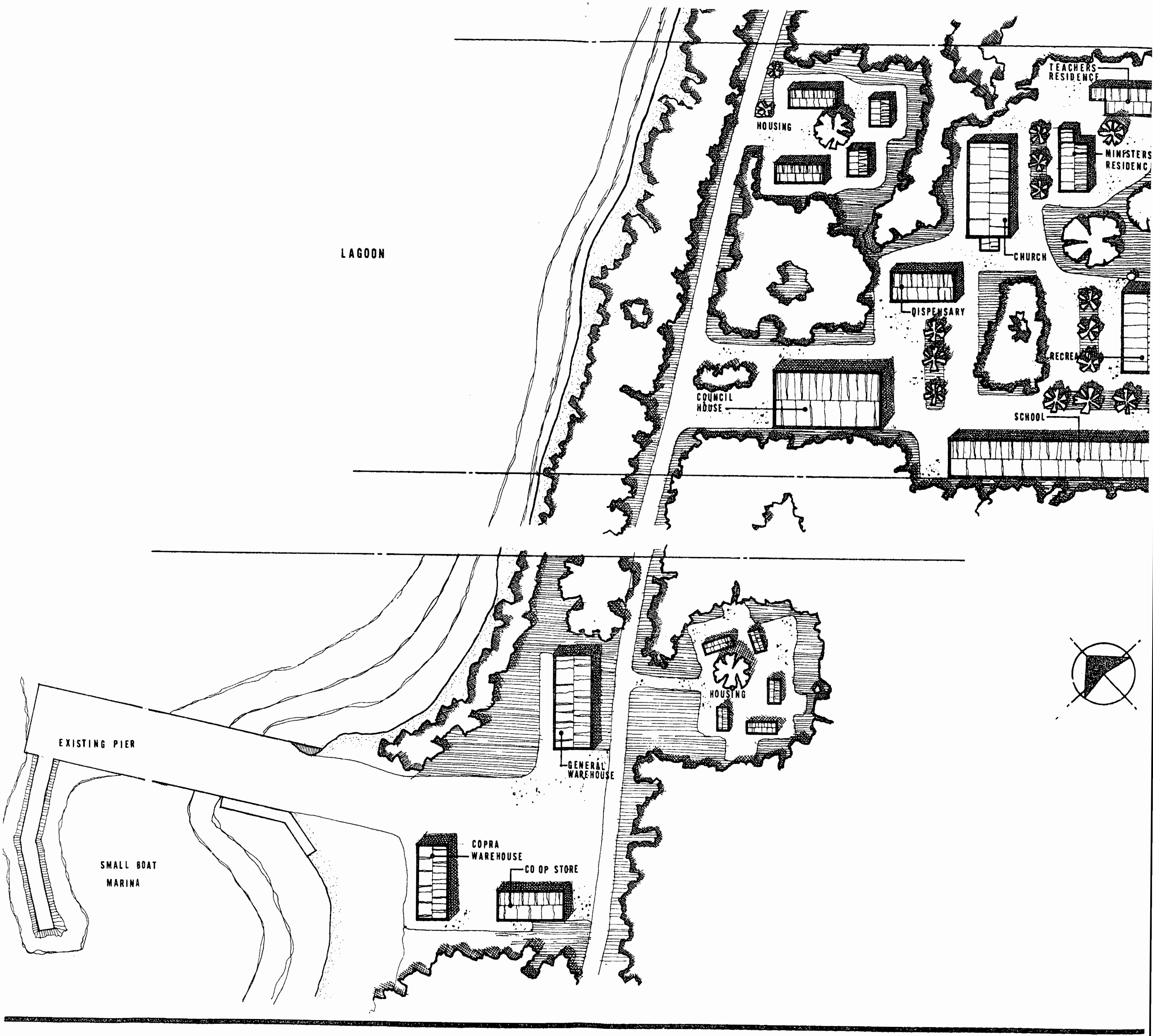
**ENEWETAK ATOLL MASTER PLAN**

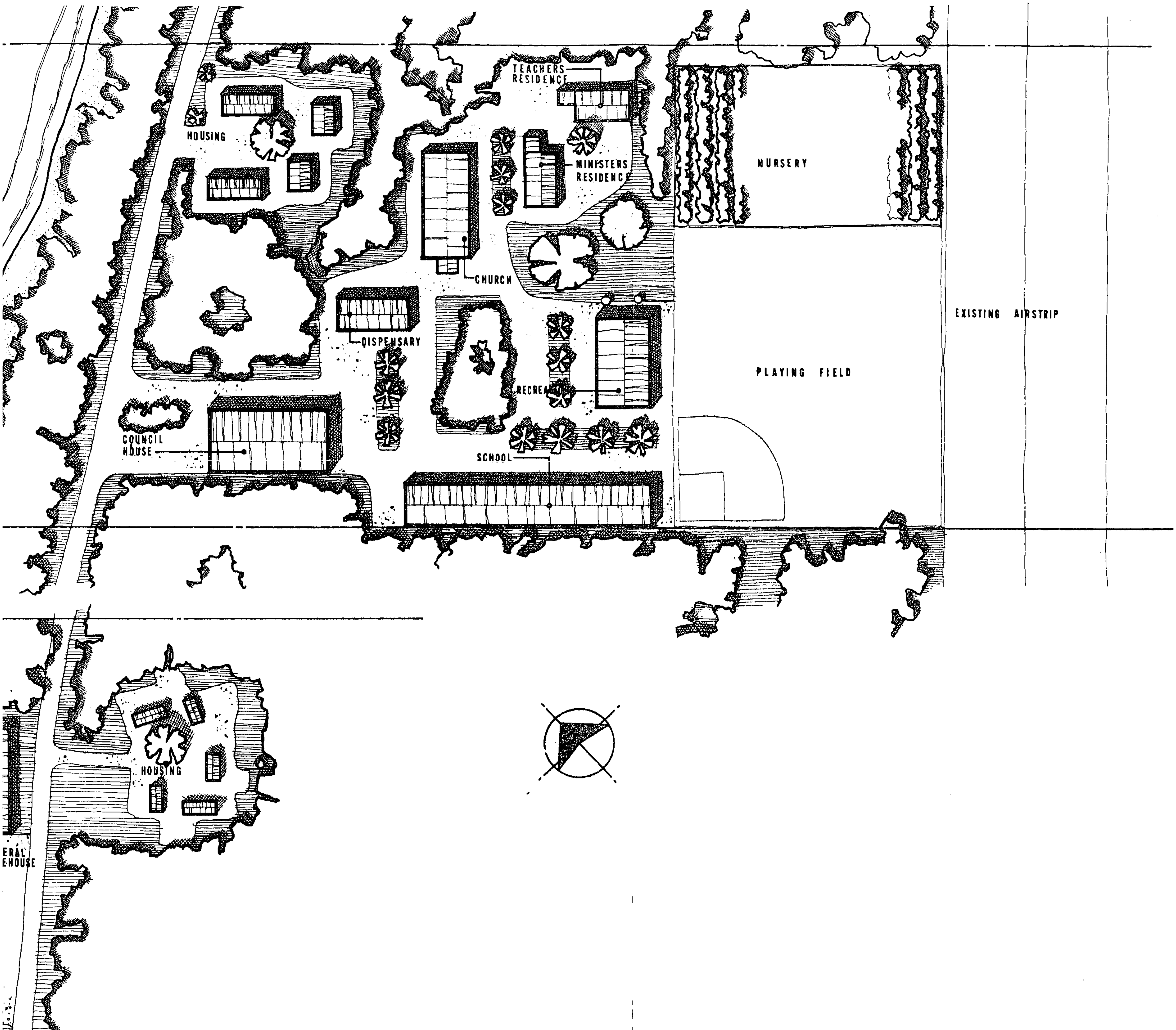
HOLMES & NARVER, INC.

A RESOURCE SCIENCES COMPANY
TECHNOLOGY & CONSTRUCTION

Plate No. 33

NOV. 1973


LAGOON
HOUSING
TEACHERS RESIDENCE
MINISTERS RESIDENCE
CHURCH
DISPENSARY
RECREATION
COUNCIL HOUSE
SCHOOL
EXISTING PIER
GENERAL WAREHOUSE
HOUSING
SMALL BOAT MARINA
COPRA WAREHOUSE
CO OP STORE




ENEWETAK COMMUNITY CENTER

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

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Plate No. 34

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4.4.3 Council Houses

The typical council house contains a meeting room, magistrate's office, radio and weather equipment, as well as necessary power-generating equipment. The council house on Enjebi consists of two metal buildings placed side by side. On Medren, the existing masonry block computer building (No. 1453) is to be modified to suit the functions. One necessary modification provides windows in the blank walls for ventilation and light. The council building on Enewetak is a relocated metal building similar to the one for Enjebi.

4.4.4 Cooperatives

There are two cooperatives which will handle the copra trading, one on Enjebi and the other on Medren. These functions are housed in relocated metal buildings. A small 2,200-square-foot warehouse consisting of a metal building located adjacent to the pier provides storage space for copra. The cooperative on Medren occupies an existing concrete slab, while the one on Enjebi requires a new slab as would the cooperative on Enewetak.

4.4.5 Churches

The churches on Enjebi and Medren will be of new construction, functionally designed and built to resist extremes in the weather. They will be located in the community centers and will be of sufficient size to accommodate the present congregations, as well as the projected increase in the near future. Should Enewetak Island become a community island, it is doubtful that the existing church would be used due to its remote location. Therefore, a new church would be required there as well.

#### 4.4.6 Recreation

The community centers provide both indoor and outdoor recreational facilities. The outdoor facility consists of a playfield large enough for softball. Indoor facilities for games such as basketball include the modification of part of Building 1437 on Medren and the relocation of the remainder to Enjebi. The building modifications consist of removing the sidewall panels to provide ventilation and more light. If a similar facility is required for Enewetak, an existing building would either be designated or relocated to suit the arrangement.

#### 4.4.7 Cemeteries

Burial facilities will be in family plots on the respective Wātos. In accordance with the request of the Enewetak people there are no community cemeteries planned for either Enjebi or Medren.

#### 4.4.8 Agricultural Stations

A small agricultural station is planned for both Enjebi and Medren. These will probably be manned by a representative of the District Agricultural Department, alternating between the two locations. The station on Enjebi consists of a small metal building located near the community nursery. On Medren the station is housed in the council building.

### 4.5 UTILITIES PLAN

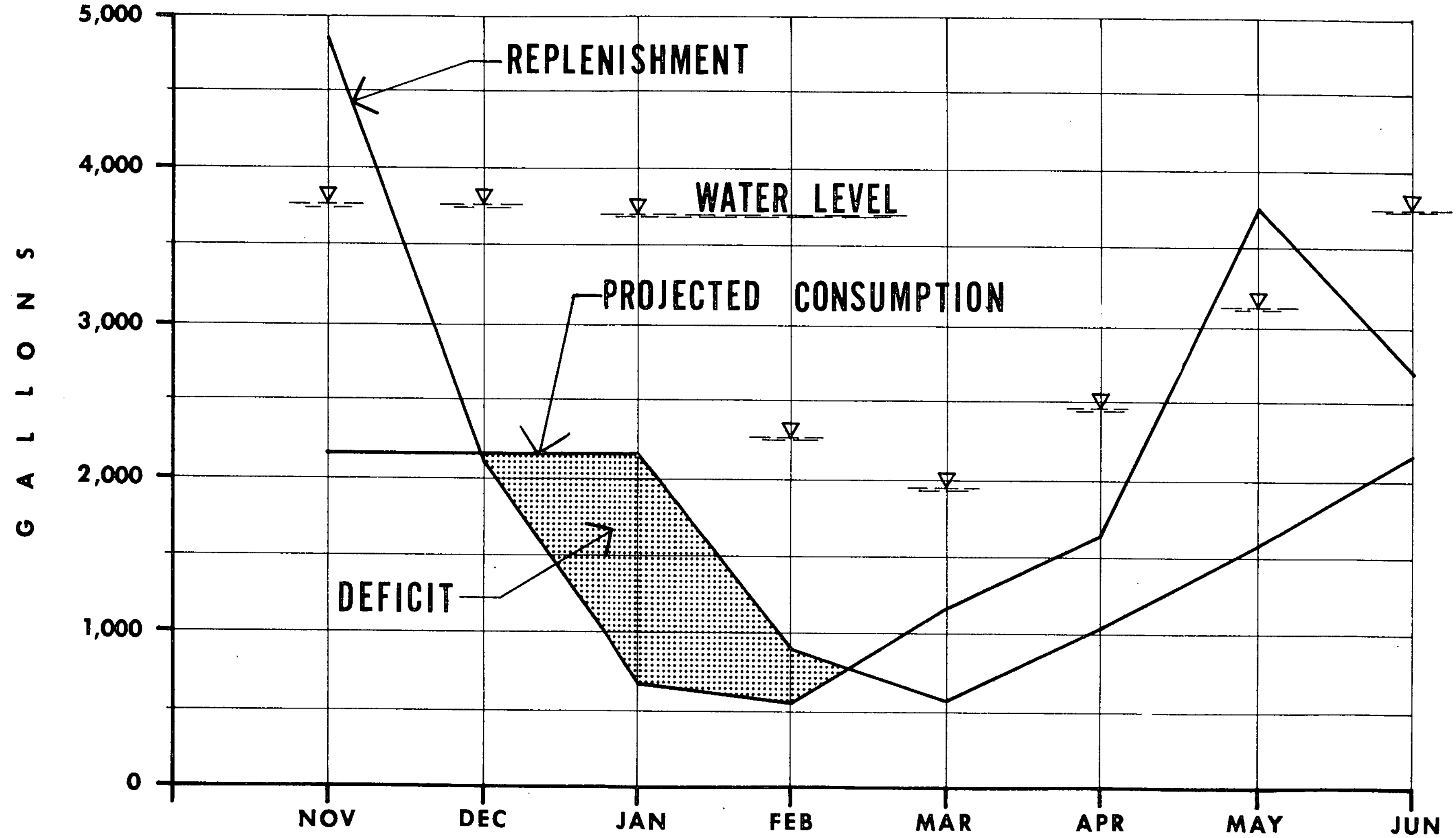
#### 4.5.1 Water Supply

The inhabitants of the atoll will have two sources of water from which to draw their daily requirements. Rainwater drained from roof catchment systems into cisterns for storage is considered the primary source. Brackish water wells located in the communities are expected to augment these supplies.

Each residence will be equipped with a primary cistern of approximately 3,800 gallons storage capacity. During dry periods, the types of rainwater usage would be curtailed commensurate with the receding water level, i.e., when the level reaches the lower third of the cistern, rainwater would be used only for drinking and cooking. Based on an initial daily requirement of 20 gallons per person, decreasing to 3 gallons per person as the supply diminished, a residential cistern would supply water to a family of 4 for 168 days without being replenished (see Plates #35 and #36). An additional 3,200-gallon capacity cistern will be provided for each house to augment the available water supply. Both cisterns will be positioned so as to more efficiently collect runoff from the entire roof area and will double the available supply of water indicated on Plates #35 and #36. Locations of the cisterns will be determined in the final design phase.

Rainwater from community building roof catchments will be stored in larger cisterns (≃ 10,000-gallon capacity). These will provide water to irrigate the plants in the community nursery and also will serve as a reserve water supply for the village. At the present time there is a 200,000-gallon capacity water storage tank located on Enewetak and a 100,000-gallon tank on Medren. These will provide additional reserve rainwater storage capacity for the atoll. Since Enjebi does not have a similar water storage facility, a rainwater catchment and storage system will be constructed on the island to provide a 100,000-gallon reserve storage capacity. Rainwater catchments and reservoirs are planned for Runit, Japtan, Lojun, Aomon, and other islands where agricultural development is planned.

Brackish water wells are planned to provide a supplementary source of water to the rainwater catchment systems. The wells will be




TYPICAL HOUSING CISTERN
CONSUMPTION VS. REPLENISHMENT

TRUST TERRITORY OF THE PACIFIC ISLANDS
ENEWETAK ATOLL MASTER PLAN
HOLMES & NARVER, INC.

Plate No.
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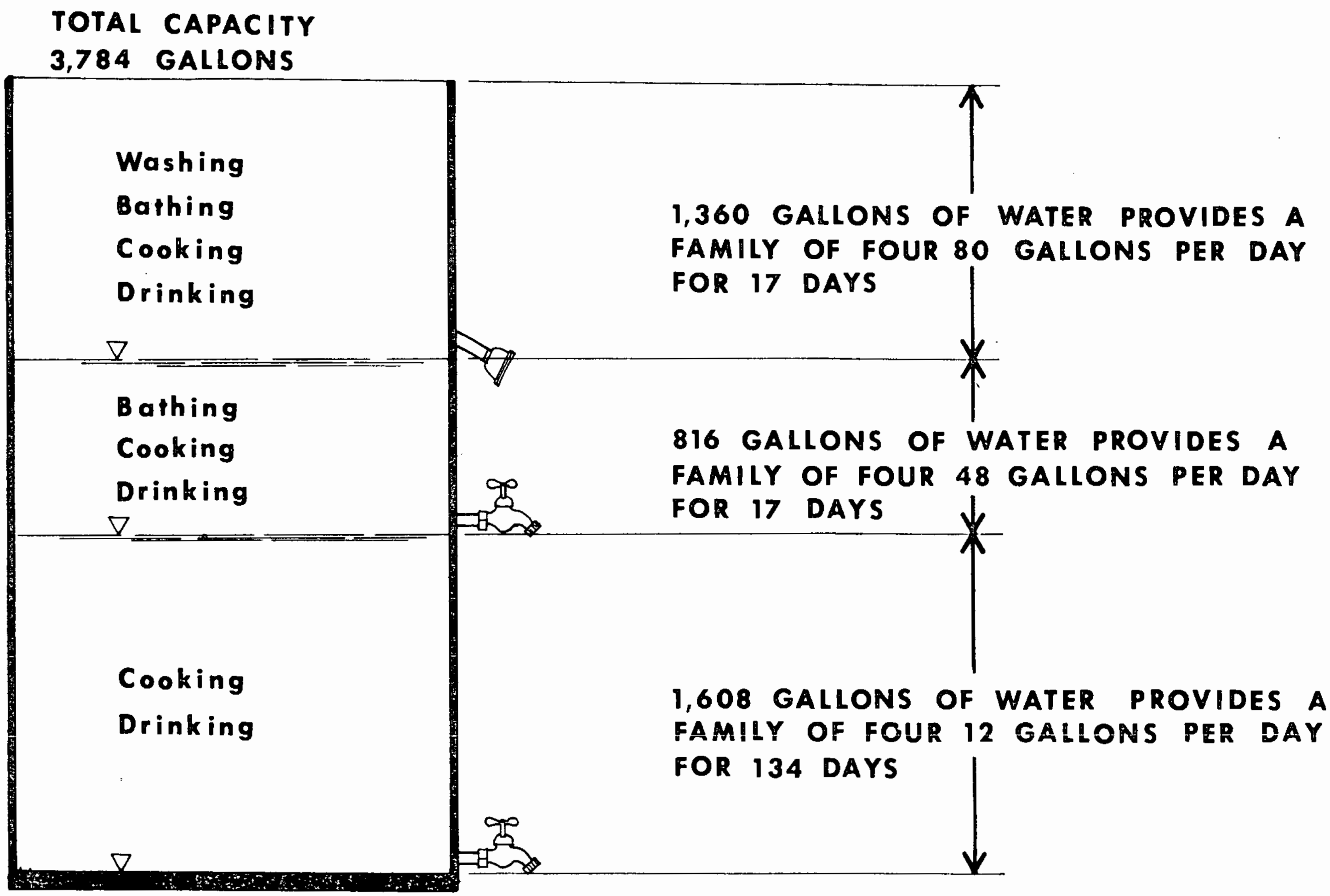



TYPICAL FAMILY WATER USAGE

located adjacent to the residential housing clusters and the community facilities, and normally would provide water for sanitary purposes. However, when rainwater supplies are low, well water can be used for washing and bathing and, if the situation requires it, for drinking and cooking. The community wells would supply additional water for agricultural use as required. The feasibility of windmill-driven mechanical pumps as a means of pumping water for agricultural irrigation should be studied. In addition, other pumping applications, such as conventional power-driven pumps, wave pumps, and wind-powered electric pumps will be studied.

4.5.2 Waste Disposal

Each residence has its own privy separately located to the rear of the house (see Plates #23 and #31). Each privy will be equipped with a water seal toilet, for which a bucket of brackish water or a hand pump drawing from a brackish water source can be used to maintain the water seal in the fixture. The water closets discharge into septic tanks behind the privies with as many as three closets interconnected to discharge into one tank. The septic tank leaching fields are located beyond the tanks. Privies and septic tanks also are planned for the community facilities for operation in the same manner as those in residential areas.

Other organic waste, such as garbage, will be disposed of by burial in pits located near the housing clusters. These pits can become a source of compost for agricultural use.

Nonbiodegradable waste, including glass, plastic, and metal cans, either will be collected periodically and dumped into a predesignated deep-water location or buried in pits. If the burial method is used, one pit would be required for each residential cluster and could be located near the housing area. A central disposal area is also planned for Enjebi and Mindren.

4.5.3 Energy

Electrical power requirements for the villages on Medren and Enjebi islands will be limited to the operation of a radio transceiver and a low level of lighting in the school, recreational building, and cooperative store. The dispensary, due to the possibility of emergency use, and the council house which contains the radio equipment and is used for community business, will require more lighting than the other buildings. The total power and lighting load for each island can be supplied with a 2 kw generator unit, powered with either a diesel or gasoline engine. Due to the distances between the generator location and the furthest community building (600 feet) on Medren, a 110-volt system should be planned. The community buildings on Enjebi are closer together and thus more suitable for a lower voltage system. However, in order to conserve on repair parts and maintenance, a 110-volt system should be planned for installation there as well.

Investigations will be made into the possibility of erecting wind-driven generator and battery systems to deliver power at 110 volts in both community locations. Equipment is presently available with capacities up to 2 kw and, if installed, could serve as the main power sources for the two islands. The engine-driven generators could be connected into the battery system through transfer switches and would then provide a back-up power source as well as a means of recharging the batteries during calm periods.

While present planning considers only the electrical requirements of community facilities, it is possible that future plans will include residential requirements. If wind-generator units are successfully operated and maintained as the main community power source, similar units might well be used in the future to provide lighting for the island residences.

#### 4.5.4 Existing Utilities on Enewetak Island

In the event that the island of Enewetak is leased to outside interests for commercial/industrial development, serious consideration must be given to utilities requirements. At the conclusion of the atoll cleanup program, all existing utilities systems on the island, including salt and fresh water, power generation, and distribution and sanitary sewer, will be left in operable condition. These systems will be available as required to serve the institutional, industrial, and way station areas indicated on Plate #38 (Section 5).

It is not expected that the entire power-generating capacity of 3,000 kva or the freshwater distillation capability of 43,200 gallons per day will be required to support these activities. However, it is probable that utilization of a portion of these capabilities would be advantageous. In addition, the saltwater systems used for fire protection, freshwater distillation, and sanitary purposes, as well as the hydropneumatic freshwater system would be valuable assets.

If the freshwater distillation process should prove to be economically infeasible, a rainwater catchment system utilizing the airport runway could be combined with the existing freshwater storage and distribution systems as the primary freshwater source. The distillation equipment then could be retained as back-up for use in emergencies.

The degree of performance required of the utilities will be determined by the manner in which the island is developed and the extent of development.

### 4.6 CIRCULATION PATTERNS

#### 4.6.1 Vehicular

Road systems linking residential clusters with community centers and commercial areas will be provided on Medren, Enjebi, and Japtan.

The alternate plan for Enewetak also includes a similar network. There will be approximately 12 miles of roads capable of sustaining light vehicular traffic on these four islands.

The 3.0 miles of roads on Enjebi will be new and generally follow the shore line, although located some distance inland. Plate #15 shows the main road which parallels the lagoon shore and connects the residential areas with the community center. A road passing in front of the community center connects the lagoon segment with the island loop on the east side.

On Medren some existing roads in the vicinity of the community center will be utilized, but the major portion of the planned 3.0 miles of roads will be new. Plate #16 shows the road network on Medren with the main access road running parallel to the lagoon shore line and separating the residential and commercial facility areas from the commercial agricultural areas. Two loop roads parallel the ocean shore and join together at the community center.

The alternate plan for Enewetak shown on Plate #17 provides for the use of the existing 4.7-mile road network. The majority of these roads are paved and will require a minimum effort to maintain them in a serviceable condition. If the island is utilized for commercial purposes rather than residential, it is expected that the existing road network would remain in service.

The existing road network on Japtan will be used during the period of the island's occupancy by the work force and upgraded as required. The network indicated in Plate #18 contains 1.6 miles of roads and links the living and commercial areas with the council house and the nursery.

### 4.6.2 Pedestrian

It is expected that paths for pedestrian traffic will be established by the inhabitants of all islands during the course of their daily routines. Undoubtedly, these will link the residential clusters with the community centers and with the agricultural areas. No attempt has been made to indicate footpaths on the island plates as the routings will depend largely upon the detailed plans for agricultural planting on each island.

## 4.7 TRANSPORTATION

### 4.7.1 Interatoll Shipping

Copra exported from Enewetak will be carried on Trust Territory supply ships (field ship vessels). These ships make scheduled stops at the atolls throughout the Marshalls, carrying staples to trade for copra, as well as carrying passengers. They perform a necessary economic function as trading vessels and also are the most popular method of interatoll travel. Over the years the island people have become dependent on the visits of the field trip ships for subsistence items as well as for luxury goods.

This dependency on outside transportation may decrease as it has been proposed that the Enewetak people obtain a vessel of their own. Tentative plans are centered around a 65-foot diesel-powered boat, rigged for an auxiliary set of sails. The vessel would be capable of voyages to Ujelang, Ponope, and other nearby atolls carrying copra directly to market. There also would be accommodations for a small number of passengers aboard in addition to the cargo space.

The field trip ships and the locally owned vessel comprise the entire interatoll marine traffice which can be expected to dock at Enewetak Atoll.

### 4.7.2 Docking Facilities

Presently there are not atoll docking facilities capable of accommodating field trip motor vessels. Existing pier locations on Enewetak, Medren, and Enjebi islands, where water depths are sufficient for shallow draft vessels or landing craft, are insufficient for vessels of deeper draft (field trip ships).

To accommodate Trust Territory vessels such as the Militobe and Truk Islander with a draft of 9 feet or the Yap Islander with a draft of 10 feet, it will be necessary to rebuild and/or extend existing piers at all three islands. Channel blasting or dredging is not considered feasible due to the constant requirement of maintaining the channel due to silting. A depth of 15 feet at low tide should be planned since it is known that some ships in field trip service draw as much as 12 feet of water.

The cargo pier at Enjebi is completely destroyed and will require rebuilding at the old location which is on the same Wāto as the community center. A 250-foot pier (mole) should be planned for this location to accommodate the field trip ships.

The cargo pier at Medren is partially damaged by erosion from wave action and requires rebuilding. A 200-foot extension is required to reach the depth of 15 feet of water at low tide.

Should it be decided to utilize the existing cargo pier at Enewetak for field trip ships, a 75-foot extension will be required to reach a depth of 15 feet of water at low tide.

The above pier extensions are estimated figures only, due to the absence of hydrographic information in those areas. Hydrography will be required to properly design these facilities.

4.7.3 Intraatoll Marine Traffic

Most of the intraatoll (or interisland) marine traffic will consist of small boats generally less than 20 feet in length. It is expected that the majority of these will be privately owned outboard motorboats used mainly for fishing and visiting other islands around the atoll. In addition to these craft, the two island communities will probably obtain small cargo boats for hauling copra. These are furnished to communities or island cooperatives through a Trust Territory Grant-In-Aid program, with a 30 percent cash contribution by the recipients. The boats are utilitarian in design, about 22 feet long, and powered by small inboard diesel engines. Distances between major islands of the atoll are shown on Plate #2, Section 2.

Marinas are planned for docking the small boats on each of the three islands. A small rip-rap breakwater will be constructed extending leeward from each cargo pier, running parallel to the shore line, thus forming a sheltered enclosure. The marinas also can serve as unloading points for the small copra boats whose cargo could be discharged directly onto the piers adjacent to the copra warehousing facilities.

4.7.4 Air Traffic

Air traffic at Enewetak is expected to be very light since the majority of the flights will be in support of either the U. S. Coast Guard or the EMBL and probably will not exceed a biweekly flight schedule. In the event that commercial activities are established at Enewetak, it is possible that flight frequency could increase to a weekly schedule.

Assuming that Enewetak Island is developed as the commercial center for the atoll, the present airport facilities would be available for use. The extent to which they will be utilized will depend largely upon the requirements. For example, if it is feasible to maintain and operate the control tower and air terminal, as well as the hangar for maintenance work, these facilities should be utilized to the extent required. However, if the island is not commercially developed and becomes the village site for the driEnewetak, the airport should be relegated to the status of an emergency landing strip. The airport buildings should be razed and most of the paved areas back of a 250-foot clearance line on either side of the runway center line removed and replaced with village facilities and agricultural planting as shown on Plate #17, Alternate Land Use Plan - Enewetak Island.

## 4.8 AGRICULTURAL DEVELOPMENT PLAN

The immediate purpose of agricultural rehabilitation is to provide for the subsistence and cash crop requirements of the Enewetak people returning from Ujelang. Coconut, breadfruit, and pandanus, the principal crops, all require from five to seven years to come into bearing after being planted. This time estimate can be significantly delayed by adverse weather conditions, inadequate care of the developing orchards, or poor selection of seed sources. The initial agricultural development, including land preparation and planting, is estimated to take from 16 months to 24 months for completion. In the interim, the population must subsist on existing subsistence crop plants which can be rehabilitated, suitable short term crops planted following their return, and on imported foods. Dependence on imported foods may be lessened and additional copra production encouraged if the Enewetak people following their return are provided with suitable ocean transportation and encouraged to return periodically to Ujelang to forage and harvest copra and other food crops for use by the population of Enewetak.

Future land use within Enewetak Atoll will be conditioned on the initial success with which the main inhabited islands can be rehabilitated and planted. Later the secondary or agricultural islands can be planted, thus providing additional sources of foods and copra for export (see Plate #40 in Section 5). Also, to be considered are factors such as real population growth (compared to current gross estimates) and the pressures this growth will place on available resources. In real terms, as additional population pressures are exerted on the limited resources, more and more of the resources will be consumed directly in support of the population and less will be available to generate income from outside the atoll. As more of the people have been exposed to education away from Enewetak and as they have developed strong tastes for imported foods and other luxuries, additional internal pressures may develop to turn the present situation more from a cash subsistence crop economy to a more total cash crop pattern, with the basic food requirements of the population being provided essentially with imported foodstuffs (which is the present situation at Ujelang).

A recent inquiry at Ujelang among the Enewetak people has indicated subsistence food intakes as shown in Table 4-2. These data must be used with caution inasmuch as there is little supportive data on record as to the exact dietary patterns of these people.

Analysis of the data in Table 4-2, together with information from other sources (published and unpublished), provide a means of estimating probable crop requirements to meet the basic subsistence requirements of the population on their return to the atoll and also to meet the anticipated population growth.

TABLE 4-2

APPROXIMATE FOOD INTAKE OF ENEWETAK PEOPLE

| Type of Food | | Estimated[(1)] Grams Per Day |
|---|---|---|
| Fish | | 600 |
| Local Meats (Pork and Chicken) | | 60 |
| Wild Birds | | 10 |
| Bird Eggs | | 5 |
| Coconut Crabs | | 0 to 5 |
| Clams | | 25 |
| Coconut (Copra)[(2)] | 1/2 Ripe Nut | 100 |
| Coconut Milk | 1-1/2 to 2 Green Nuts | 300 (0 to 1,500) |
| Coconut Cream | 1/2 Ripe Nut | 100 |
| Breadfruit[(3)] | | 200 |
| Pandanus Fruit | | 100 (200 to 400 for children) |
| Arrowroot | | 40 |
| Vegetables | | 200 |
| Imported Foods[(4)] | | 0 to 1,600 |
| | TOTAL ~ 1,900 | |

(1) Assuming little or no availability of imported foods.

(2) Equivalent to 4 to 5 coconuts for direct consumption.

(3) Seasonal from May to September.

(4) When available, imported foods such as rice, flour, tea, sugar, canned meats, and fish, etc., may reach 80 percent of total diet.

4.8.1 Types of Plants

Agricultural rehabilitation and development of the atoll must consider two basic elements: first, the basic subsistence requirements of the people returning to the atoll; and second, production of some type of cash crop which will generate income for the local economy. One crop, the coconut, is common to both these elements. Two other crops, the breadfruit and pandanus, are essential in the subsistence dietary, while other plant foods such as the banana, sweet potato, arrowroot, squash, vegetables, papaya, and lime are utilized when available.

4.8.1.1 Subsistence Crops. The coconut, *Cocos nucifera*, is the staff of life of many peoples of the world, and certainly of people within the Central Pacific areas. This palm not only provides one of the most important foods directly consumed in the economy, but also is utilized for timber, cordage, thatching, firewood, matting, fiber, handicrafts, and medicine. There is hardly an area of the native life which this ubiquitous plant does not touch.

The dwarf coconut, locally called *Ni Karu*, has also gained prominence in Marshallese communities. Due to its shortness in growth, it is grown essentially for drinking and cooking and also for the making of coconut toddy called "jakaru." This variety also provides a decent landscaping material aside from its other uses and is thus recommended for this purpose and not as a plantation material.

The breadfruit, *Artocarpus incisa*, of which there are numerous varieties within the Pacific Islands, is utilized in the Marshall Islands as a major source of carbohydrate foodstuffs. Most varieties are cooked prior to eating, and one or two of the varieties are preserved as "bwiro." Breadfruit is seasonal in production, which would limit its utilization but for the fact that methods of preservation and storage of the ripe fruit are known and utilized by the Enewetakese people.

The pandanus, Pandanus tectorius, is grown for its edible fruit, which provides sugars and starches in the dietary, and also is a good source of vitamin C. There are a number of varieties used for this purpose within the Marshall Islands, and a suitable selection should be made of planting material to ensure the variability that the Enewetakese people may require. Pandanus leaves also are utilized for thatching materials, weaving sleeping mats, and other articles. Nonbearing varieties can be utilized in plantation windbreaks.

The arrowroot, Tacca leontopetalioides (L), var., was once used as a major source of starch for food in the Pacific Islands and is still so utilized in many atoll areas. However, it is a food item that requires some effort to prepare for human consumption. Often it is utilized in times of food storage resulting from storm damage and during periods of extended drought. Although it may not be utilized regularly in the modern Enewetakese dietary, it should be planted widely as a regular as well as emergency source of food. It spreads rapidly and requires very little care.

4.8.1.2 Commercial Crops. The commercial or cash crops of choice, and of necessity, is the coconut; also it is the subsistence base of the people. The produce of commerce is the dried meat of the mature coconut, known in the trade as copra. Copra is the major source of coconut oil, one of the important world sources of edible oils; and also is a source of oil for soap manufacture. World production of copra entering the marketplace exceeds a million tons per year. Local consumption in the form of edible oils and other products probably equals this production. The U. S. Trust Territories are reported to have approximately 76,000 acres devoted to copra production and this is one of the major exports of the Trust Territories. Production from Enewetak Atoll will be handled through the normal commercial channels in the Marshall Islands.

Copra, or coconut production, is extremely difficult to predict because of two basic variables: one is the anticipated yield of coconuts per palm at full bearing which depends on soil capability, weather conditions, and the genetic quality of the seed sources, all of which affect both the quantity of nuts produced per tree and the number of coconuts required to produce a ton of copra. The second variable is the quantity of coconuts required to meet the subsistence requirements of the inhabitants of the atoll which come from the same general plantation resource. Table 4-3 represents an effort to indicate the absolute range of potential copra production from the atoll as a whole. The analysis assumes a total of approximately 60,000 coconut palms bearing within all islands of the atoll. The range of nut production per tree is from 10 to 100, with the most probable yield range from 40 to 60. One level of subsistence consumption is shown, the equivalent of 10,000 palms. The probable range of production of copra for the entire atoll is between 333 tons and 600 tons per year, with the highest probability at about 450 tons. The range of income to the atoll for copra production is between $30,000 and $54,000 with a high probability of a return of about $40,000 per year from this source.

4.8.1.3 Medicinal Plants. A number of endemic and introduced plants are utilized for medicinal purposes. Prominent among these are the Morinda citrifolia, or "nen;" Scaevola taccada (sericea), or "kunat;" Messerschmidia agentea, or "kirin;" Guettarda speciosa, or "wüttlomar;" Dodder or Cuscuta sanwhichiana; Triumfetta; Allophylus; and the papaya

TABLE 4-3

TREE YIELD AS BASIS FOR COPRA PRODUCTION

| No. of Nuts Per Tree Average | No. of Nuts Per Acre Average | 50,000 Trees | | 60,000 Trees | |
|---|---|---|---|---|---|
| | | Copra(1) Potential Tons | Income(2) Total | Copra Potential Tons | Income Potential |
| 10 | 700 | 83 | $ 7,470 | 100 | $ 9,000 |
| 20 | 1,400 | 167 | 15,030 | 200 | 18,000 |
| 30 | 2,100 | 250 | 22,500 | 300 | 27,000 |
| 40 | 2,800 | 333 | 29,970 | 400 | 36,000 |
| 50 | 3,500 | 417 | 37,530 | 500 | 45,000 |
| 60 | 4,200 | 500 | 45,000 | 600 | 54,000 |
| 70 | 4,900 | 583 | 42,470 | 700 | 63,000 |
| 80 | 5,600 | 667 | 60,030 | 800 | 72,000 |
| 90 | 6,300 | 750 | 67,500 | 900 | 81,000 |
| 100 | 7,000 | 833 | 74,970 | 1,000 | 90,000 |

(1) Based on average of 6,000 coconuts per ton of copra.

(2) Based on current copra prices Enewetak of $90.00 per ton.

Carica papaya. Other plants also are used within the native pharmacopaea, but due to the secretive nature of such use and treatment of illness, little is known of this element.

4.8.1.4 Exotic Plants. The Enewetak people at Ujelang have apparently become acquainted with and indicate a desire to utilize a number of exotic or introduced plant species within their dietary. These include such plants as papaya, banana, citrus (lime), squash, and other vegetables. The regular or even occasional use of these foods would enhance and add balance to the normal dietary of this area. It should be noted, however, that soils and climate are likely to be marginal for production of these plants without irrigation and intensive horticultural care. Inputs of labor and limited water resources may not justify planting of these crops unless individuals or families wish to do so independently.

4.8.1.5 Aesthetic Plants. Other plants which are considered of aesthetic value and cultural significance should not be left out of the planting program. These plants, some of which are utilized as local medicines and some of which are maintained for their landscaping and social values, are as follows: Morinda or "nen" (Morinda citrifolia), Guettarda or "wut" (Guettarda speciosa), bird's nest fern or "kartep" (Asplenium nidus), ground fern or "kino" (Microsorium scolopendria), syn. P. phymatodes, P. scolopendria (Burm), spider lily or "Kiōb" (Crinum asiaticum), False Kamani or "kodal" (Terminalia catappa), Kamani or "lwuiweji" (Calophyllum inophyllum). Most of these plants could be located growing in virgin areas especially, although some may have to be introduced from other sources. Messerschmidia, Scaevola, and Vigna also are important cultural plants, although these are found in practically all areas of the atoll.

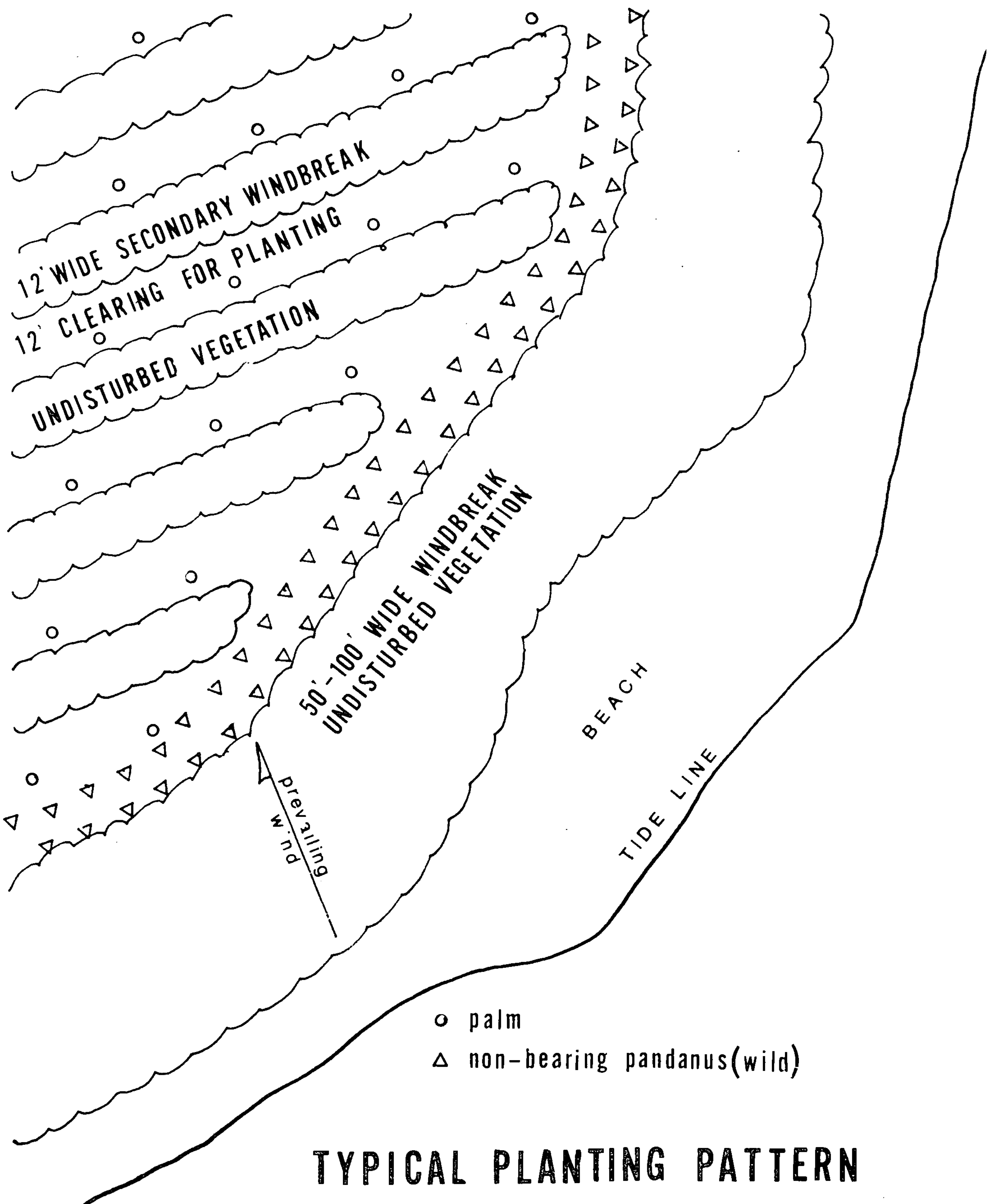
4.8.2 Land Clearing and Preparation

4.8.2.1 Removal of Undesirable Facilities. Undesirable buildings, structures considered dangerous to the returning people, broken concrete slabs, and other debris will be removed from all islands within the atoll during the major cleanup operation and will contribute to making full use of all agriculturally useful lands. Land clearing in preparation for agricultural development will consist primarily of removal of existing concrete slabs and buildings remaining after cleanup operations, trees, brush and shrubs, and ground cover which would prevent or substantially reduce optimum land use. Much of this work will be carried out with medium bulldozers preferably equipped with rake blades rather than straight blades. Every effort must be made to minimize damage to the soil profile and all organic material must be conserved for incorporation in the soil.

All organic material of suitable size will be shredded or chopped into compost for incorporation in planting holes and for general spreading over the ground surface. The land to be planted will be selectively cleared with great care taken to retain valuable trees and food plants and to retain existing windbreak areas. A typical planting pattern with windbreak area is shown on Plate #37.

Land leveling or grading will be required only in those areas where initial clearing operations have left the land in a rough condition, to level old sand and gravel stockpiles, and to fill old borrow pits. Some minor leveling can be carried out during the brush removal phases.

4.8.2.2 Soil Replenishing and Field Mulching. Agricultural rehabilitation of the islands, and particularly those islands where heavy construction and movement of heavy vehicles has destroyed or disturbed the normal soil profile, absolutely will require replenishment of the organic




# TYPICAL PLANTING PATTERN

TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
HOLMES & NARVER, INC.

Plate No. 37
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(humic) content of the soil. The soils in these low atolls are essentially coral sands and coraline soils. Inherent soil fertility is low at best and is held almost entirely within the organic fraction of the top few inches of the soil which is subject to very rapid breakdown when exposed.

Organic replenishment of the soils could be carried out through natural means, e.g., by allowing a slow accumulation of material through the natural growth and spread of trees and shrubs. However, this process is extremely slow, involving many years, and any crop yields during this period would be marginal at best.

Trees, branches, shrubs, and all available plant material can be shredded, chopped, or disintegrated by rakes and shredders, and stockpiled for incorporation into the planting holes. In fact, this process is advocated for the three or four residential/agricultural islands, and also for those islands intended for intensive agricultural use. However, it is doubtful that sufficient plant cover to adequately replenish the needed organic material for all potential agricultural areas presently exists on all islands (or even on all areas of each island). Therefore, it is recommended that serious consideration be given to importation from other areas, possibly the Pacific Northwest, of large quantities of organic matter (bark, wood chips, sawdust, etc.) for incorporation into deficient soil areas.

4.8.3 Planting Plan

4.8.3.1 Plant Selection and Sources. The major seed requirement will be approximately 100,000 selected seed coconuts. This estimate is based on the anticipation that failure or slow germination and culling of seedlings in the plant nurseries will eliminate up to 40 percent of the total nuts obtained. Other plant material requirements will include approximately 2,300 rooted breadfruit plants and 3,450 pandanus cuttings. Other materials such as lime plants, banana suckers, papaya seeds, and similar materials will also be required but in lesser quantities. Utmost care should be taken in selecting the sources of these seed requirements since poor seed will produce plants of inherently poor yields.

Table 4-3, which analyzes the potential copra yields of the atoll, also indicates the extreme importance of careful seed selection. Soil and climatic factors establish the potential productivity of any area, but only plants derived from high yielding parentage will achieve the highest potential yields within the environment. Table 4-3 shows how the number of nuts produced by coconut trees will control the ultimate copra production of the atoll.

High yielding coconuts and other selected plants such as breadfruit and pandanus have been introduced into the Marshall Islands and other areas of the Trust Territories. Seed coconuts of the desirable "Tifu" and "Nugget" varieties could be obtained from both Jaluit and Namorik atolls in sufficient quantities. Rooted cuttings of breadfruit, on the other hand, should be purchased primarily from Lae and Ujae atolls. Due to incidence of the so-called "Pingelap" disease in the southern atolls (Namorik, Kili, Jaluit, Mili, Ebon, and possibly Majuro), no breadfruit propagative materials should be purchased from these areas. Pandanus, commonly propagated by cuttings (from branches which have formed aerial roots), could also be purchased from both Lae and Ujae.

Should high quality seed stocks of sufficient quantity not be available from relatively close sources, no hesitation should be made at going further. Seed stocks obtained outside of the Marshall Islands will be subject to strict quarantine surveillance. Similarly, great efforts are justified in obtaining the highest quality and best yielding breadfruit and pandanus cuttings and rooted plants, since the long term yields will justify considerable additional cost of obtaining and transporting the best available seed.

Strict control should be imposed and quarantine measures taken for all planting material (and organic material of all kinds) brought into Enewetak. Propagative materials apparently infested with insects should be disinfected accordingly or properly discarded. A close watch should be kept for possible introduction of the scale insect (Cocus elongatus) and others of the family Coccidae. These insects are pests in many atolls and attack pandanus, breadfruit, banana, and many other plants.

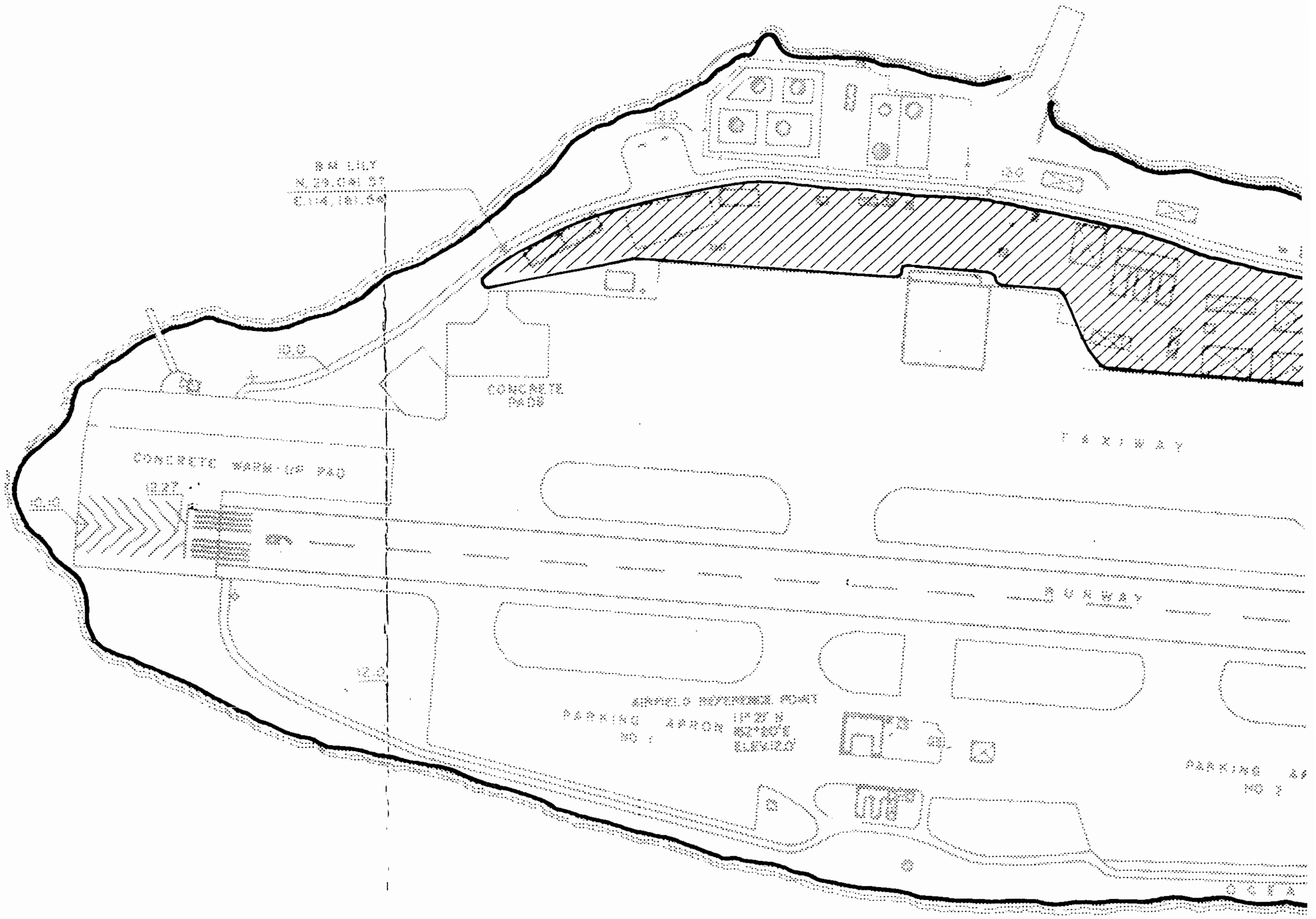
4.8.3.2 Nursery Care. Plant nurseries will be established on all four of the major islands, e.g., Enjebi, Japtan, Medren, and Enewetak, which are intended for residential/agricultural utilization, where seeds and developing plants can be given good care and where supplemental irrigation is good. These nurseries will accommodate coconuts, breadfruit, and pandanus; and they also will maintain sources of banana, citrus, papaya, and other introduced plants for use by individuals as may be desired. Ornamentals also may be maintained in the nurseries to meet the desires of the people.

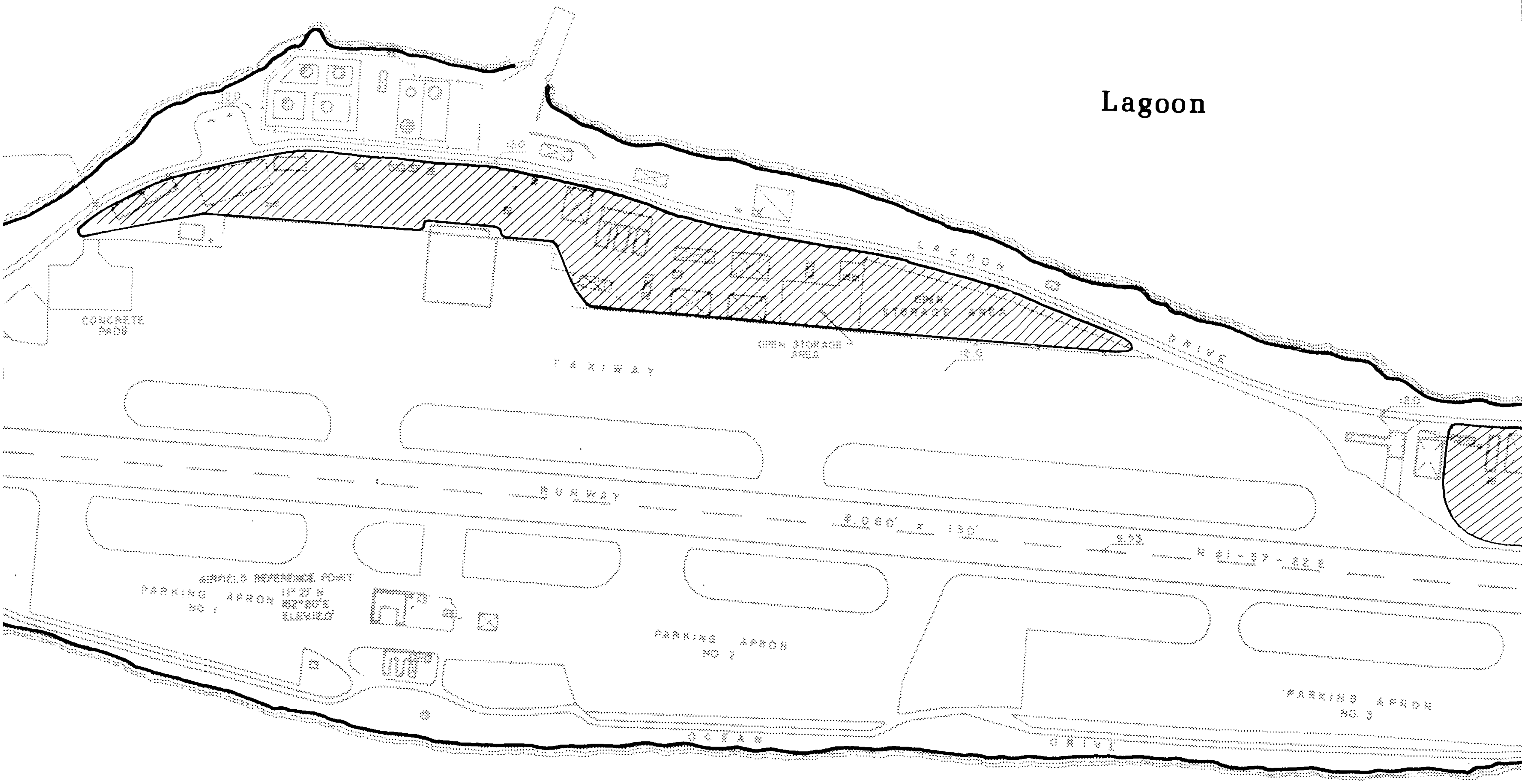
Nurseries will not require large areas of land since an acre will accommodate up to 40,000 seed coconuts. Japtan, for example, would require little more than one-third of an acre for this purpose. Each nursery should be adequately fenced to protect growing plants from pigs and poultry. A source of water should be available to provide supplemental irrigation of the nurseries during dry periods without adequate rain. Nursery areas should be kept free of weeds and carefully mulched to conserve water and for protection of the plants from excessive heat and drying out. Breadfruit seedlings should be provided with partial shade for protection from excessive heat and sunlight. The nurseries should be established approximately 6 months prior to the planned planting date to ensure plants of the proper size and vigor at time of final planting. Final planting operations must be scheduled to conform with the periods of adequate rain as shown in Plate #38.

4.8.3.3 Planting and Mulching of Plants. Planting plans must be prepared in detail for all islands and should indicate all phases of the development program:

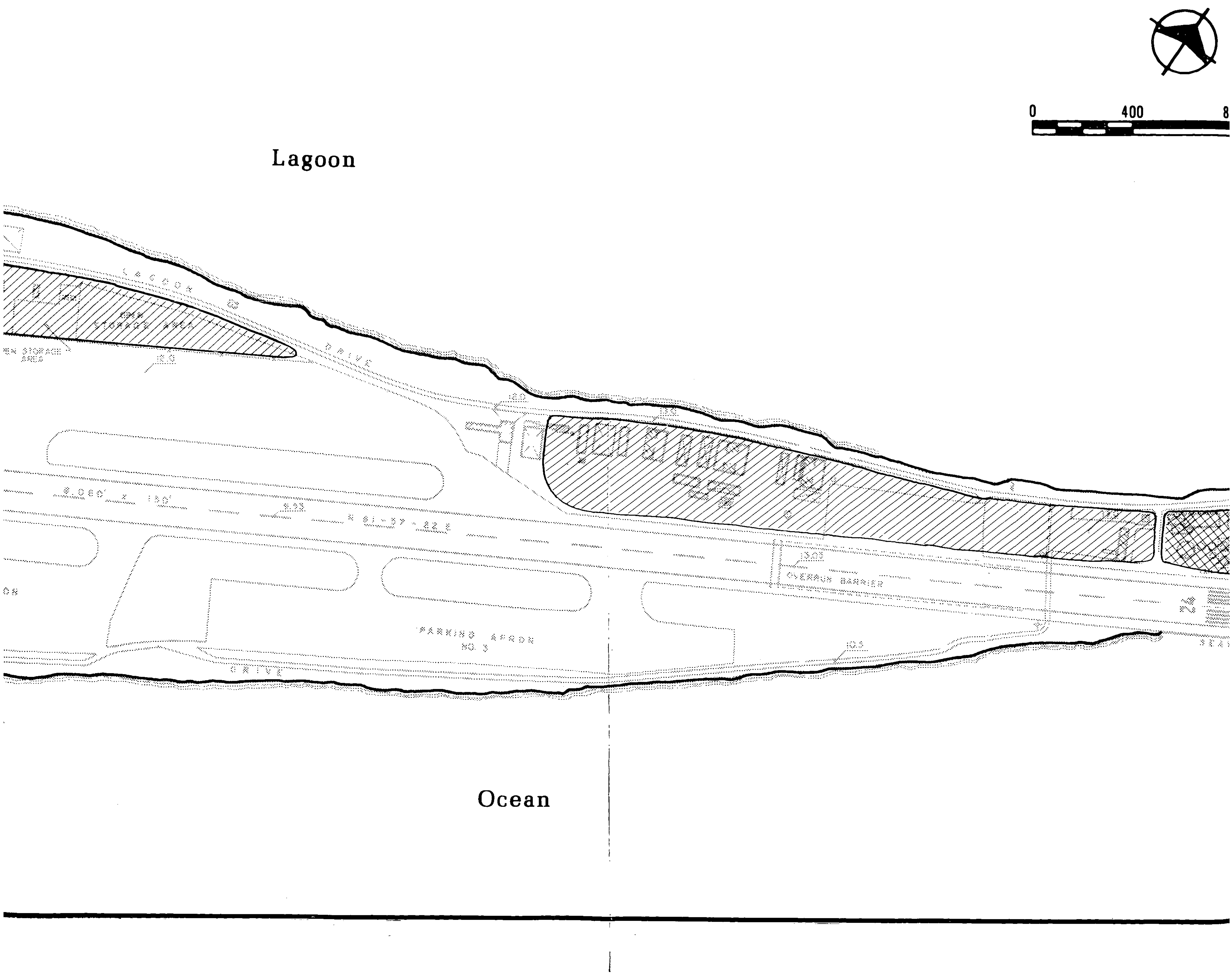
- Clearing.
- Grading and leveling.
- Survey and layout of planting areas (including both subsistence crop areas and copra areas).
- Preparation of planting holes (including placement of plastic liner and replenishment of organic matter).
- Lifting, transporting, and planting of seedlings.
- Watering in.
- Mulching of newly planted seedlings.

4.8.3.4 Planting. The planting of coconut involves essentially the placing of the seedling in the prepared hole and burying it with sand to about the base of the growing portion of the plant. Where wind is prevalent, a wooden stake is required to secure the young seedlings. The planting of breadfruit requires overhead shade to protect the growing plant from direct sunlight. The whole box should be planted along with the breadfruit plant as transplanting (from box to hole) would damage delicate root hairs necessary for growth. A wooden stake is also required for securing the breadfruit plant against heavy winds. Pandanus plants are hardier than breadfruit and should be planted in the same manner as coconut seedlings. The use of a wooden stake is normally not required.


CONCRETE PADS
CONCRETE WARM-UP PAD
TAXIWAY
RUNWAY
AIRFIELD REFERENCE POINT
PARKING APRON NO 1
PARKING



Lagoon
CONCRETE PADS
OPEN STORAGE AREA
OPEN STORAGE AREA
LAGOON DRIVE
TAXIWAY
RUNWAY
AIRFIELD REFERENCE POINT
PARKING APRON NO 1
PARKING APRON NO 2
PARKING APRON NO 3
OCEAN DRIVE
Ocean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Lagoon
LAGOON
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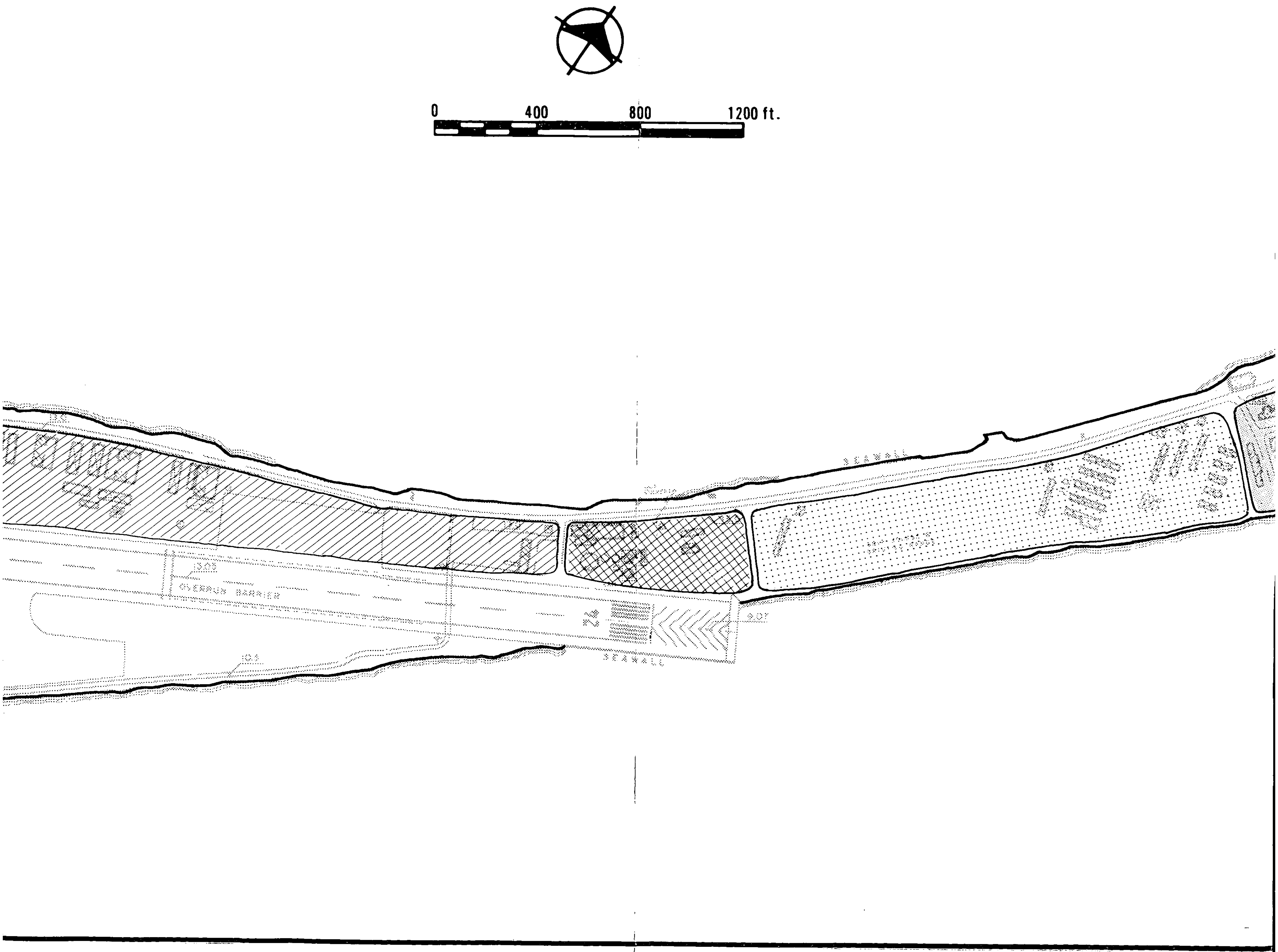
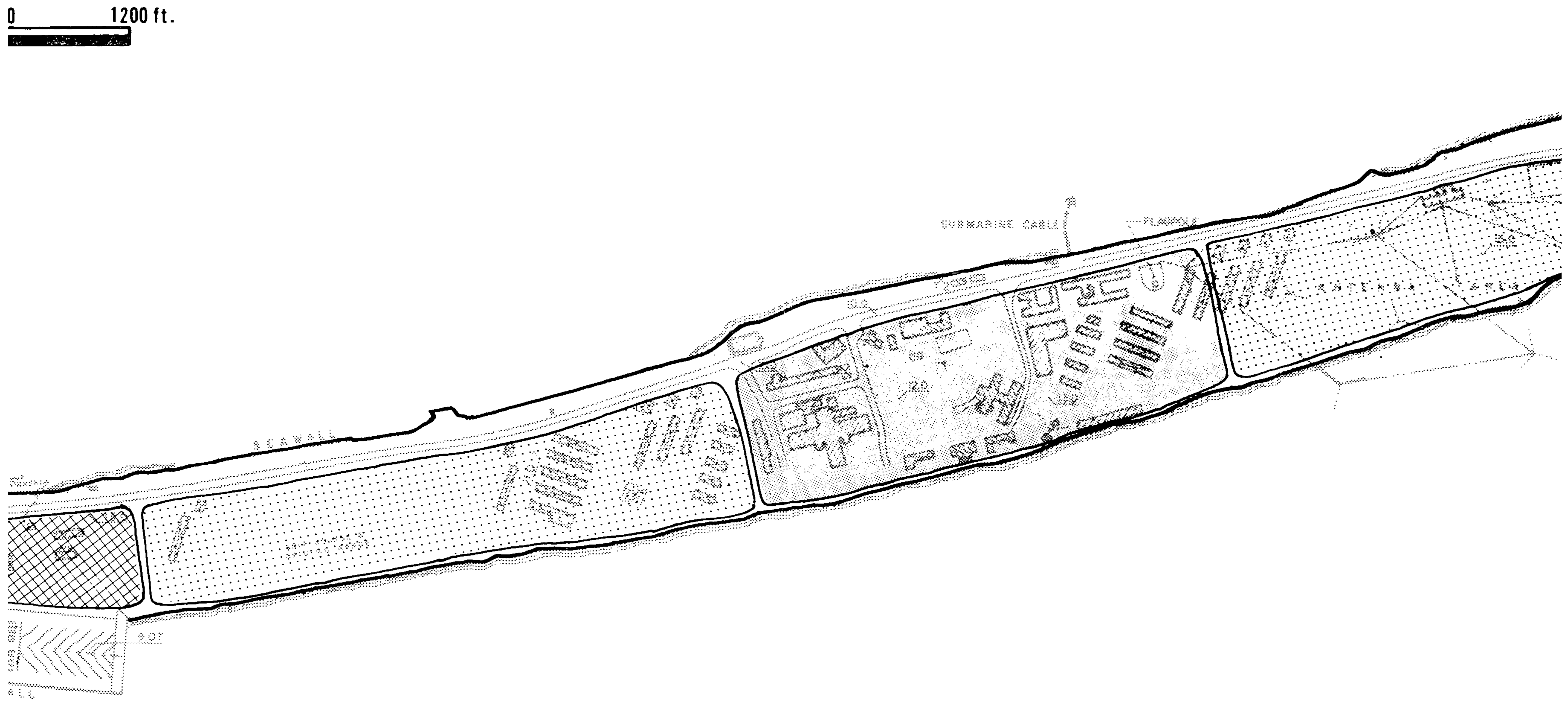
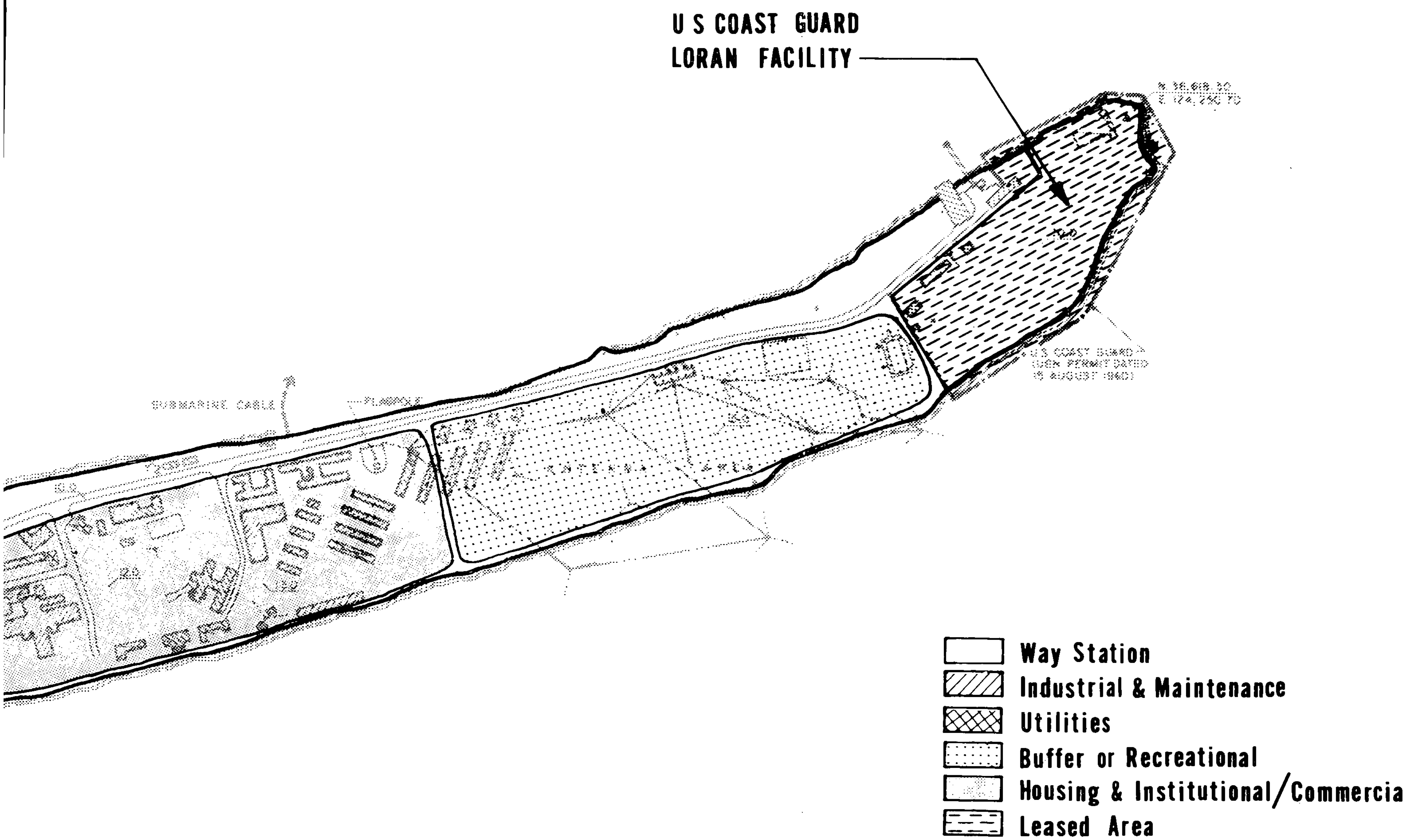
NO. 3
DRIVE
Ocean



0
400
800
1200 ft.
SEAWALL
OVERRUN BARRIER
SEAWALL

**U S COAST**
**LORAN FAC**






# BASIC LAND USE PLAN - ENEWETAK ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS
**ENEWETAK ATOLL MASTER PLAN**
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4.8.3.5 Mulching. The mulching of individual plants after they are placed in the ground is suggested here as a means of ground moisture conservation and weed control. A utilization of polyethylene clear plastic spread 2-1/2 to 3 feet in diameter around each plant is suggested. This method should be used primarily on breadfruit and coconut plants and as deemed necessary on pandanus.

4.8.3.6 Planting of Ground Cover. The planting of ground cover utilizing *Vigna marina*, a leguminous vine, in the coconut groves is recommended. Growth of *Vigna marina* should be encouraged in the field and in areas where it does not interfere with the growing food plants. This plant functions not only as a moisture conservation agent (ground cover), but also enriches soil fertility and therefore is considered an extremely valuable plant in atoll agriculture.

### 4.8.4 Maintenance Plan

The proper maintenance of the growing plants is considered the most important aspect of the planting program. Although initial planting would commence during the wet season (midMay to December), irrigation of the growing plants at least for the first year after initial planting, and especially during the dry season, would be required. The spot or direct irrigation method is recommended as opposed to an overhead sprinkler system.

As no hydrological study of Enewetak is available at this writing, it is recommended that rainwater be utilized as the sole source of irrigation water. Construction of water reservoirs with a minimum capacity of 50,000 gallons in areas where planting is to take place is suggested. Judicious use of irrigation water is very important and should be constantly borne in mind.

4.8.4.1 Fertilization. There is a definite need for the use of commercial fertilizers. The selection of commercial fertilizers should be made only after the fertilization requirements of the soils have been determined. It is possible that some of the results obtained from experiments and fertilization studies on coconut seedlings and palms conducted by the Philippine Coconut Research Center may be applied to the planting on Enewetak. (See "Fertilization Studies on Coconuts at the Philippine Coconut Research Institute," by A. M. R. Mendoza and R. L. Prudente, 1972.) Addition of trace elements in the chelate form, especially magnesium and iron chelates, also is suggested.

4.8.4.2 Grove Maintenance. Adequate maintenance of the coconut, breadfruit, and pandanus plantings is mandatory to avoid competition of weeds with the growing plants. At least a monthly cutting down of weeds and other unwanted vegetation in the coconut groves is recommended.

The use of herbicide or weedicide for weed control also is suggested but with limitations. The herbicide 2, 4-D is suggested for use in the control of broad leaf weeds only around coconut and pandanus plantings, but should never be used around breadfruit plantings as they are highly susceptible to the chemical. Hand weeding or brushing of crawling weeds should be done around breadfruit plantings as required. The use of the chemical 2, 4-D should be carried out only by personnel familiar with the chemical, and the manufacturer's instructions should always be followed.

The polyethylene mulch on individual plants should be properly maintained.

4.8.4.3 Rat Control. An effective rat control program should be initiated and continued throughout the development and mature phase of the agricultural plan. Adequate information on successful methods for rat eradication can be obtained elsewhere in the Marshalls.

4.8.5 Planting Locations

4.8.5.1 Populated Islands. In view of the limited resources available within the atoll for residential and community needs, for subsistence and for the production of cash crops, it is essential that maximum use be made of the land. However, there also is a need to provide for the psychological and cultural requirements of the people, and this must modify the purely agricultural or economic solutions to the major problem.

Four of the major islands of the atoll will be utilized for residential/agricultural use, with emphasis being placed on the development of Enjebi and Medren as centers of population. Initially Japtan will be developed and utilized as a temporary base for the Enewetak people who have requested participation in the rehabilitation effort. Following completion of the initial phases of the development of the four major islands and agricultural development of the remaining twelve islands, Japtan may revert to utilization principally as an agricultural resource with minimal residential use. Alternatively, Enewetak Island may be utilized as a residential/agricultural site in place of Medren.

Agricultural development must be carried on in close relationship with the village and community plans, with the residential clusters of the Wāto as the focus of the plan. The residential cluster will be placed inland from the lagoon beach, and will be protected from exposure by plantings of pandanus, breadfruit, and coconuts, which will provide windbreaks, storm shelter, shade, food, and firewood. There may also be planted, dependent on individual desire and inclination, bananas, lime, and vegetable gardens, and ornamental plants such as spider lily, eroton, hibiscus, and plumeria. In effect the village areas are wholly or partially surrounded with subsistence crops. The commercial plantings, solely of coconuts, will be placed to the interior of the island and toward the ocean. There should be no clear-cut and permanent boundary delineating the residential clusters, village centers, subsistence crops, and commercial crops; but instead, these areas will blend almost imperceptably from one area of emphasis to another.

4.8.5.1.1 Enjebi (see Plate #15). Enjebi Island is the second largest island in the atoll and falls in the driEnjebi area of the Enewetak Atoll political land division. The island encompasses a total land mass of 291 acres, 210 acres of which are considered suitable for agricultural development.

The topography of the island has been severely altered and with the exception of several pits and depressions, the island is practically level. Many wild shrubs, primarily Messerschmidia argentia, Scaevola frutescens, Guettarda speciosa, weeds, and ground cover (Impomea pescaprea), are found growing throughout the island. A narrow coral airstrip running southwesterly across the island is also covered by wild vegetation. A good deal of ground breaking will be required in preparation for planting in this area.

The island traditionally consists of 15 Wātos, and the area considered suitable for agricultural plantings could accommodate approximately 14,000 to 15,000 new coconut plantings. A minimum of 10 breadfruit trees, 15 pandanus trees of the edible species, and 15 coconuts of the dwarf variety per Wāto is recommended. Pandanus of the textile variety will be planted in the windbreak areas.

The bulk of work anticipated for Enjebi would involve massive land clearing and compost making. Existing vegetation (with the exception of vegetation to be reserved as windbreak) will be utilized as compost material during the initial cleaning phase.

4.8.5.1.2 Medren (see Plate #16). Medren Island is the third largest island in the atoll with a total land area of 220 acres. Unlike Enjebi, Medren is longer than it is wide and tapers off at the south end of the island. The estimated suitable acreage for agricultural plantings is approximately 193 acres.

Medren has been changed from mass construction activities and the soil profile has been severely altered. The island is leveled off and dotted with concrete slabs and other construction remains. Although no extensive leveling work will be required, considerable work will be involved in brushing and cleanup of abandoned concrete slabs, buildings, and other construction debris. Future use of some existing buildings and possibly concrete slabs for copra drying should be considered prior to initial cleanup of the island.

The land area considered suitable for agricultural development will accommodate approximately 12,000 to 13,000 new coconut plantings. Coconut trees currently growing and in good condition should be left in place and properly cultivated and/or thinned where necessary. The island with its 12 Wātos would require a minimum of 120 breadfruit and 180 pandanus trees of the recommended varieties and at least 180 plantings of the dwarf coconut variety.

4.8.5.1.3 Enewetak Island (see Plate #17). Enewetak Island is the largest single island in the atoll and possibly the least important of the four main islands in terms of potential agricultural usage (from a cost standpoint). The island has a total land area of approximately 322 acres (a little over half a square mile), of which approximately 193 acres could be of some agricultural value. This area would accommodate approximately 10,000 new coconut trees. The island with its 30 Wātos would require approximately 300 breadfruit and 450 pandanus trees and at least 180 plantings of the dwarf coconut variety.

The 193 acres of agriculturally usable land on Enewetak Island can be obtained only by extensive removal of existing paved taxiways, aircraft parking areas, buildings, and concrete slabs. Results of planting in an area under those conditions are unknown with the possible exception of the coconut plantation along the old runway at Majuro which was planted with poor results in 1959.

The Enewetak people should be encouraged to inhabit Medren in lieu of Enewetak which could be developed for some commercial use as indicated in Section 5. However, the island should have an agricultural economy regardless of the outcome of its use for commercial purposes. The runway in its entirety will be retained along with the usable buildings and facilities in the main camp area near the north end of the island.

4.8.5.1.4 Japtan (see Plate #18). Japtan Island with a total land area of 79 acres is the fifth largest island in the atoll. Approximately 63 acres are considered suitable for agricultural planting. Unlike most of the larger islands in the atoll, Japtan did not incur extensive damage from occupation. A portion of the western section of the island is still in its natural state, hosting a variety of indigenous plants such as Guettarda speciosa ("wut"), Morinda citrifolia ("nen"), and Pisonia grandis ("kangae"), aside from the common shrubs Messerschmidia ("kirin"), and Scaevola ("kunat"). A considerable portion of the eastern part of the island, however, has been leveled off and the soil much disturbed from construction activities.

Japtan will be a staging center for the Enewetak workers. The island hosts a good number of bearing coconut trees, making it a desirable site for a staging camp. The land area considered suitable for agriculture would accommodate 3,700 to 3,800 new coconut plantings. The existing coconut trees should be encouraged, thinned out where needed, and maintained. A minimum of 100 breadfruit, 300 pandanus, and 300 dwarf coconut trees is recommended for additional planting.

Some leveling work on the island would be required, especially on the western portion of the island. A few stands of Guettarda speciosa and Morinda citrifolia, plants of cultural significance, should be preserved and used as possible future propagative sources for islands lacking them. Other vegetation should be converted to compost during the initial clearing. The construction of a water reservoir for irrigation purposes is recommended.

4.8.5.2 Nonpopulated Agricultural Islands. (See Plate #14.) Certain islands in the atoll, listed as Group II in Table 4-1, were traditionally utilized on an exclusive agricultural basis in support of the major islands of Enjebi, Medren, and Enewetak. The Enewetak people have expressed a strong desire to have these islands rehabilitated and again utilized for agricultural uses in support of the inhabited islands. Further, there is a definite requirement to develop these islands to support the future population growth, which is projected to be approximately 300 persons on Enjebi and 450 persons on Medren or Enewetak by the year 1983, as indicated in Plate #5. These islands and their estimated usable acreage are listed in Table 4-4. The total usable land area of 328 acres contained in these islands will support approximately 16,700 coconut seednuts, 480 breadfruit plants, and 1,150 pandanus cuttings.

Work should be initiated on the remaining islands during the second planting phase. Runit Island was extensively altered due to past

TABLE 4-4

ISLAND SUMMARY - PLANTING REQUIREMENTS

| Island | Usable Acreage | Coconut | Dwarf Coconut | Breadfruit | Pandanus |
|---|---|---|---|---|---|
| Enjebi | 216.58 | 14,735 | 210 | 140 | 210 |
| Medren | 192.70 | 12,824 | 180 | 120 | 180 |
| Enewetak | 165.96 | 10,110 | 450 | 300 | 450 |
| Japtan | 62.93 | 3,755 | 300 | 100 | 300 |
| Subtotal | 638.17 | 41,424 | 1,140 | 660 | 1,140 |
| Runit | 41.43 | 2,517 | ----- | 86 | 213 |
| Alembel | 22.75 | 1,394 | ----- | 45 | 112 |
| Aomon | 126.39 | 4,014 | ----- | 110 | 264 |
| Bijile | 34.09 | 2,138 | ----- | 59 | 114 |
| Lojwa | 25.17 | 1,776 | ----- | 49 | 117 |
| Lujor | 37.50 | 2,331 | ----- | 67 | 167 |
| Aej | 27.50 | 1,736 | ----- | 45 | 112 |
| Ananij | 13.13 | 819 | ----- | 23 | 158 |
| Subtotal | 327.96 | 16,725 | ----- | 484 | 1,157 |
| Kidrinen | 13.07 | 941 | ----- | ----- | ----- |
| Mijikadrek | 12.06 | 868 | ----- | ----- | ----- |
| Bokenelab | 6.07 | 436 | ----- | ----- | ----- |
| Elle | 5.31 | 382 | ----- | ----- | ----- |
| Subtotal | 36.51 | 2,627 | ----- | ----- | ----- |
| TOTAL | 1002.64 | 60,776 | 1,140 | 1,144 | 2,297 |

operations which will require considerable cleanup and rehabilitation prior to agricultural development.

4.8.5.3 Food Gathering and Picnic Islands. (See Plate #14.) The remaining inhabited islands in the atoll will be used primarily for gathering birds and eggs, turtles and eggs, coconut crabs, pandanus, iu, copra, firewood, fishing, and family picnicking. The islands include the following:

- Biken, Kiddrenen, Ribewon, Boken, Mut, Ikuren, Louj, Kirunu, Bokombako, Bokoluo, and others. Most of these islands presently serve as bird sanctuaries and are fairly remote from areas chosen as population centers. With the exception of two islands which are believed to be of significant agricultural importance, the rest of the islands should be preserved as principal areas for food gathering and family picnicking activities.
- The islands of Mut and Ikuren, neighboring islands located in close proximity to the south channel into the lagoon, are both fairly large in size (about 40 acres each) and should sustain substantial agricultural plantings. An estimated 64 usable acres could support a minimum of 4,500 new coconut plantings. Both islands are currently hosting coconut palms of the endemic species which should be encouraged and properly cultivated. The two islands also can accommodate approximately 130 breadfruit trees and 320 pandanus plantings. As they are located a short distance across the south channel from Enewetak Island, it is possible that these islands could be utilized as small residential islands should Enewetak Island be subsequently

leased out and Medren become overcrowded in future years.

#### 4.8.6 Agricultural Summary

The total land area considered suitable for agricultural development on both populated and nonpopulated islands is approximately 960 acres. The acreage available for agricultural development and the number and species of plantings for each island are listed in Table 4-4. For planting purposes approximately 100,000 coconut seeds would be required for nursery care and selection for planting in the plantations. A minimum of 2,300 breadfruit plants, 3,450 pandanus cuttings, and 2,300 dwarf coconut seeds also would be required. The estimated quantities are based on the anticipation that failure, slow germination, growth deformities, and possibly unhealthy trees will eliminate up to 40 percent of the total nuts purchased. The mortality rate of breadfruit plants is considered to be 50 percent and pandanus cuttings are estimated to have a 70 percent survival rate or higher.

As stated by both Messrs. Manuel A. Tenorio and David H. Butchart, agricultural consultants, hydrological surveys must be conducted on all islands selected for planting to determine the extent, capacity, salinity, and alkalinity of the freshwater lens. The results of the surveys will assist in the final assessment of the lens as potential sources of irrigation. A rat eradication program for all islands is recommended and should be developed during the detailed agricultural planning phase of the program.

# 5. REVIEW OF POTENTIALS FOR ECONOMIC DEVELOPMENT

# 5. REVIEW OF POTENTIALS FOR ECONOMIC DEVELOPMENT

The people of Enewetak prior to and during their sojourn on Ujelang, have developed a liking for products from the outside world such as outboard motors, rice, canned meat, and other imported goods. To support these tastes into the future, the people must develop an economy on Enewetak Atoll which will contribute something to the outside world in return. Indeed, the atoll has considerable promise in this respect. In this chapter, potentials for economic development are surveyed, areas of greatest opportunities pointed out, and outlines sketched of a legal/business structure which could bring these potentials into actuality while safeguarding all interests of the Enewetak people.

## 5.1 OVERVIEW

This discussion will begin by summarizing the assets and liabilities of the atoll as an economic resource. On the negative side, the atoll consists of a tiny bit of dry land, 2.75 square miles, spread among 39 islands situated in the middle of a vast ocean. The atoll is 2,100 miles from Japan, 2,500 miles from Honolulu, 1,100 miles from Guam, and 360 miles from Kwajalein. The land is sandy and relatively infertile, rainfall is sparse, and markets and sources of skilled manpower are at great distances.

On the other hand, the atoll contains a lagoon of striking beauty, occupying 388 square miles and teeming with marine life. The main island of Enewetak was previously a busy military base and as such contains many facilities which suit it ideally as a commercial/ industrial center. Among these facilities are a modern jet airport with an 8,000-foot runway, a petroleum storage facility, repair shops, warehouses, cold storage lockers, piers, mess halls, dormitory buildings, swimming pool, etc.

From the standpoint of basic geography, those economic activities requiring large amounts of land, fresh water or, because of distance, shipment of bulk commodities, are not feasible. Thus, large scale agricultural and manufacturing activities can be ruled out. On a smaller scale however, there will be copra production, handicrafts (shells and corals), and possibly there could be small amounts of fruit, vegetables and meat produced for markets in nearby islands such as Kwajalein (Ebeye). Initially, the most interesting export item will be salvage materials. Subsequently, the most interesting export items are fishery products. Even here, because of long shipping distances and limited labor resources, emphasis must be on high profit per pound items. Thus the focus initially must be on smoked fish and other gourmet and delicacy items, such as lobster tail, shell fish, and shark fin, rather than bulk fish catches.

One other possibility of major interest for the atoll is "way station service" by which the airport could serve passing aircraft as a refueling stop. The existing port facilities similarly could serve ship traffic and fishing vessels operating in the vicinity as a resupply and rest point.

The atoll has distinct promise for "institutional use". It already contains the Eniwetok Marine Biological Laboratory, operated by the University of Hawaii under the auspices of the AEC. Discussions have been held concerning the enlargement of this laboratory into a research center specializing in atoll and fisheries research. Similarly, the possibility has been discussed of establishing a "Community College of The Marshall Islands." Such an institution would complement the EMBL and would be clearly a great asset to the economy of the atoll.

Finally, there is the possibility of tourism. Here, there is vast difference of opinion, ranging from those who ask "with all the islands in the Pacific, why would a tourist go there?", to those who point out the unusual beauty of the lagoon, sport fishing potential, and historical interest.

It is believed that while the tourism potential in this atoll might not impress a Las Vegas operator, viewed on a scale with the population of the islands the tourist trade, properly promoted, could make a very significant contribution to the economy of the atoll.

The potential for economic development is there. The degree of success will depend on the imagination and industry of the people who undertake the development. To develop this potential an inflow of outside expertise and capital will be required. The final section of this chapter presents a plan for acquiring this inflow while protecting the interests of the Enewetakese. The intervening sections discuss the various development possibilities individually.

## 5.2 EXISTING SALVAGEABLE ASSETS

There is an abundance of salvageable material on Enewetak Atoll left over from the Nuclear Testing Operations which represents a possible source of income for the Enewetakese. The holdings of the people could be expanded to include such salvageable items as submarine and land cable with copper conductors and iron and steel scrap. The people could subcontract the salvage rights to a reputable company for a percentage of the gross profits.

There are several hundred miles of armored submarine cable in the lagoon, all with copper conductors as well as a large quantity of wire and cable on land. With the current price of copper scrap at $.60 per pound, a salvage operation might prove to be profitable.

There could be as much as 20,000 tons of steel scrap on Enewetak and Medren which could be relatively easy to salvage. It is composed mostly of shore line debris and derelict landing craft on the lagoon beaches. Due to the location of these islands, there would be no danger of radiologically contaminated scrap being mixed in with noncontaminated metal debris. However, the current price of ferrous metal scrap at the time of salvage would be the governing factor in determining the economic feasibility of this operation.

A large number of metal buildings will become excess after the cleanup operation. Although some will be used for permanent community center facilities on Medren and Enjebi and parts will be retained for repair, there appears to be no use for the remainder. It appears feasible that these excess buildings could be sold to the TTPI or others for use on other atolls rather than salvaged for scrap.

It is suggested that if an agreement is reached between the people and a salvage contractor, the agreement include a provision to employ as many Enewetakese in the salvage operation as may be practicable.

## 5.3 AGRICULTURE

### 5.3.1 Copra

Copra has been the traditional "cash crop" of the Marshall Islanders. Although a market for copra exists in the Marshall Islands through the United Micronesia Development Association (UMDA), prices fluctuate, but of late have been quite depressed and the overall return in dollars per labor hour is low. The existing coconut palm trees at Enewetak Atoll are not in sufficient numbers to produce marketable quantities of copra. New trees which will be planted during the rehabilitation program will take 7-10 years to mature and start producing nuts. After maturity it is estimated, using today's prices, tha copra could bring the people approximately $40,000 in income per year.

### 5.3.2 Breadfruit, Pandanus, Banana, and Papaya

These plants are low in salt tolerance and consequently must be limited to the central and leeward areas of the larger islands. The establishment of these plants is very desirable to provide needed staples and variety in the diet of the Enewetak people. However, even when established, the total production from these plants will be small. Quantities of produce sufficient for export are not foreseen.

### 5.3.3 Vegetables

Vegetables such as tomatoes, Chinese cabbage, etc., have been grown on the islands in the past, and if reestablished could supplement the subsistence foods of the Enewetak people. Central nurseries could be established on the home islands. Plants could be transplanted from these nurseries to the Wātos where they would be cared for and harvested by individual family groups. The production of vegetables in this manner is expected to be mainly for internal consumption rather than for export. However, it is understood that there is a market for produce as well as for fresh meat and fish in other parts of the Marshalls, especially Kwajalein (Ebeye). It is recommended that a study be conducted to determine the feasibility of developing a vegetable export business.

### 5.3.4 Hydroponics

Hydroponic gardening techniques are being developed in several parts of the world as methods for production of large quantities of good quality vegetables. However, difficulties are involved which would have to be overcome. Facilities would have to be constructed to house a hydroponics operation. Personnel would require considerable training in hydroponics techniques, including procurement of chemicals, preparation and application of nutrient solutions, combat of plant diseases, etc. The existence of scholarships in this area should be explored. The hydroponic approach is a long range possibility for Enewetak but is not viewed as a significant business prospect in the near term.

### 5.3.5 Farm Animals

Chickens and pigs are found throughout Micronesia and are two important food sources for the Enewetak people. Commercial feed for these animals, however, is not readily available. As a result these animals are raised only for local consumption and not in sufficient numbers for sale to outsiders. There is little possibility that hog and poultry raising for commercial purposes could be established on Enewetak. However, if future development of Enewetak produces sufficient quantities of garbage it may be feasible to raise hogs commercially.

## 5.4 INSTITUTIONAL USE

The U. S. Atomic Energy Commission (AEC) has indicated that the Eniwetok Marine Biological Laboratory (EMBL) will continue to operate in a limited fashion under AEC sponsorship as it has in the past. This laboratory could become the basis for a major scientific center serving Micronesia and particularly the Marshalls. The work of the EMBL would focus on the study of atolls, lagoons, and the oceanography of that part of the Pacific. The impact of the laboratory and its potential for obtaining support would be most excellent if its work had a strong practical "applied science" approach. Clearly, there is a need for this type of work. As an example, more definitive work needs to be done on the certification and location of commercially useful sea life. Bait fish need to be located. Methods for harvesting, processing, and shipping need to be developed. Research on fish poisoning (ciguatera) is needed. Life cycles and ecologies need to be studied so that optimum yields may be quantified and fisheries management policies established. Various mariculture ideas need to be applied to lagoon environments and developed to a practical stage.

Last, but not least, the laboratory could serve the economy of the region significantly by taking on responsibility for communicating practical scientific and economic know how to the local populace. It is in this connection that the possibility has been discussed of establishing a "Community College of The Marshall Islands" in conjunction with the EMBL. Together, the two institutions could offer formal classroom work, vocational style training, seminars, short courses, and demonstration projects. They could bring the benefits of western technology to the people while retaining the values and traditions of Marshallese culture.

The EMBL is presently located on Enewetak Island which contains several existing structures that could be adapted to institutional functions. The existing three-story dormitory could provide adequate student and faculty housing, while teaching and research could be conducted in other conveniently located buildings in the area. Thus, the capital investment required to start these institutions would be minimal.

It is also recommended that after rehabilitation of the atoll the temporary housing facilities on Japtan be considered for use in a small educational/tourist type subcenter tied to the commercial development of Enewetak Island.

## 5.5 FISHERIES

### 5.5.1 Sharks

The abundance of sharks in Enewetak waters is legendary. These animals represent a valuable resource. There is on the one hand a great demand for shark products in various parts of the world. On the other hand it is clearly desirable to reduce the shark population, especially in the lagoon. Thus a menace could sharply be reduced and at the same time a profit made by harvesting these animals.

The most saleable parts of the shark are the pectoral, dorsal, and lower lobe of the caudal fins. These parts are used in shark fin soup, an oriental delicacy. Correspondence with merchants in Hong Kong and elsewhere indicates that they will take as many shark fins as they can get at prices ranging around $4 per pound.

Shark meat and shark skins are also marketable products. For many species it is necessary to soak the meat before it becomes edible, but this is a fairly simple process. Treated this way, shark fillets are reported to be delicious, comparable to swordfish steaks. Shark skins make very tough high quality leather. For shipment, shark skins are dried and placed in stacks which are rolled into tight bundles. The skins of large sharks have the greatest value and bring $0.50 to $1.00 per pound.

Sharks in general have enormous livers. Shark liver oil at one time was a major source of vitamin A. However, the demand for this oil disappeared after it became possible to produce vitamin A synthetically. Now, the pendulum is swinging back. With the current interest in "natural" vitamin products, shark liver oil can again be found on the shelves of health food stores. Thus there may well be a market for the livers of Enewetak sharks.

Finally, with the islands inhabited, with talk of tourism, scuba parties, etc. it is clearly desirable to reduce the population of sharks in the lagoon. Thus the initiation of a shark fishing activity soon after the return of the people could at the same time minimize an obstacle to tourism, produce initial revenue, and establish the working contacts and shipping/packaging procedures required for further fishery development.

### 5.5.2 Tuna

Several species of commercial tuna are known to exist in the waters near Enewetak Atoll. There has been discussion of a tuna cannery to be located elsewhere in the Marshalls. However, the availability of the required bait fish appears to be in question as is the fresh water required for cannery operations. Tuna fishing is a large volume, low profit business. If a cannery were established, it is possible that the Enewetakese might consider commercial tuna fishing. Without a cannery, emphasis would be better placed on low volume, high priced, gourmet type seafood products.

### 5.5.3 Rabbitfish

Siganids, or rabbitfish as they are sometimes called, are considered to be one of the tastiest reef fish. These fish are in demand by the inhabitants and hotels of the Trust Territory and could be marketed in the area, providing dependable transportation to market is available.

5.5.4 Other Fish

Some 700 species of fish are reported in the Enewetak area (Shutte, et al., 1953). Many of these could be of commercial importance. However, harvesting and marketing them in commercial quantities is a major problem. While there are long range possibilities for a major fishery industry, it is believed the best course for the Enewetakese for the present is to avoid any thought of high volume fishing and concentrate on gourmet items for which the price per pound is sufficient to justify freezing and shipping to market by air.

Many of these species can be smoked, salted, or sun-dried using local techniques and, in addition, improved techniques as detailed in literature provided by the South Pacific Commission and the Food and Agricultural Organization of the United Nations. Smoke driers such as the type used on Jaluit are both practical and feasible. Fish processed by these methods are in great demand in the Marshalls indicating a ready market for export by the Enewetakese.

5.5.5 Sea Cucumbers

Sea cucumbers are marine animals belonging to the Class Holotruoidea of the Phylum Echinodermata. Certain species of these animals are used to produce the marine food product known as Beche-de-mer (France), Trepang (Malay), Haisim (Singaporean-Chinese) and other names in different countries. This product is considered a delicacy and aphrodisiac by the Chinese people and is in great demand. It is also consumed in large quantities in Mongolia, eastern U.S.S.R., Korea, Japan, China (mainland), Hong Kong, Viet Nam, Cambodia, Laos, Thailand, Burma, Malaysia, Indonesia, Philippines, and the countries in the South Pacific Islands. It is estimated that there are over 50 different species of sea cucumbers in the Trust Territories of which about a dozen are suitable for producing Beche-de-mer. The species found at Enewetak are Actinopygia mauritiana, Holothuria atra, and H. leucorpilota; species were most abundant along the windward ocean side of the reef, especially off the east end of Enewetak Island. However, the Actinopygia species were not abundant at any of the sites surveyed. (V. A. Nelson, University of Washington, private correspondence, 1973.) These two species are used in the making of Trepang. Processing of these animals is a fairly simple procedure and could be readily handled by the Enewetakese. Traders in Singapore paid up to $2.50 per pound for Beche-de-mer in 1970.

### 5.5.6 Clams

Tridacna gigas commonly called the giant or killer clam is known to occur at Enewetak. The meat of these animals is considered a delicacy and shells of large specimens have been sold for as much as $500 each. This animal has been eradicated in some areas by over-fishing and poaching. Studies are required to determine optimum sustainable yield. A small export volume could yield significant income without depleting the population. Ready markets exist at both Ebeye and Majuro.

### 5.5.7 Lobster

Spiny lobsters (Panulirus spp.) are found throughout the Marshall Islands and are known to occur at Enewetak. These, too, are a high price per pound item of the type preferred for export. Little is known about the life history of these animals, but it appears that a lack of suitable sheltered habitats is the most important factor limiting abundance. Studies of these animals and experiments with artificial shelters should be conducted to determine the feasibility of increasing the sustainable lobster yield of the atoll.

### 5.5.8 Turtles

Sea turtles occur naturally in Enewetak and are another delicacy item that could be exported in low volume. At the present time there is much interest in turtle culture. Commercial feeds and farming techniques recently developed in the Caribbean and Torres Straits have demonstrated the feasibility of commercial farming of sea turtles. Thus may be a future possibility for Enewetak.

The establishment of "turtle rookeries" and farms on the smaller islets could prove to be a profitable venture. Turtles are in demand throughout the world and every part except the head has a market value.

### 5.5.9 Oysters

Oysters are presently being successfully cultured in several countries and a good market exists. A survey of the local species at Enewetak should be conducted to determine eating quality, abundance and rare or unique pearl production, e.g. the black pearl. If desirable types of oysters are found, studies should be conducted to develop appropriate high density culturing techniques for Enewetak. The feasibility of importing commercially desirable species for local culturing also should be determined. A worldwide demand exists for good quality oysters of specific types and any sizeable production could be readily marketed. Guam and Japan are presently very good markets.

### 5.5.10 Fish Waste Products

Unsaleable portions of fish can be utilized for supplementary animal feed and fertilization of plants. Its high protein content could be a valuable contribution to the raising of animals commercially. Fish waste products are also valuable when used as compost or fertilizer.

### 5.5.11 Ciguatera

One of the question marks surrounding any discussion of fisheries in the Marshalls is the question of Ciguatera, or fish poisoning. Occasionally, fish from this area have been found to contain a deadly poison, apparently from eating a certain type of algae. The outbreaks of this poison are rare, but unpredictable. Therefore, sampling programs will need to be established to ensure that no poison fish are ever sent to market.

## 5.6 BUSINESS STRUCTURE AND INITIATION PLAN

Enewetak Atoll has considerable economic potential and also many obstacles to the development of that potential. Whether or not this development is successfully accomplished will depend basically on the initiative, imagination, and sound planning of the people who undertake the job. Clearly, outside capital and know how will be required.

Historically, the problem with outside capital investment has been that control of the resources involved tends to pass to the outside investors. What is needed is a business structure which will be sufficiently attractive to bring in outside investment and skills while still protecting the interests of the Enewetakese. An example of such a structure might be as described in the succeeding sections.

### 5.6.1 Enewetak Peoples Inc.

In view of the facilities already present on the main island of Enewetak it makes most sense to set aside this island as the commercial center for the atoll. The remaining islands would be utilized for residential and agricultural purposes. In this way the Enewetakese could have the best of both worlds: a modern, developed commercial center on a single island, and a traditional South Seas atmosphere on the remaining islands.

Currently the land on Enewetak is divided into Wātos, owned by individual families. A typical Wāto cuts across the island from ocean to lagoon and might include for example, some beach, a piece of airport runway, part of a building, and an oil tank. Clearly a more workable arrangement is needed if there is to be economic development of this island.

Therefore, it is suggested that a legal entity be established, possibly called the Enewetak Peoples Inc., which would hold ownership of the island of Enewetak in common for all the Enewetak people. The percentage ownership of this company, by family, and trade-offs of land elsewhere in the atoll would be worked out by the people among themselves.

### 5.6.2 Enewetak Island Development Co.

Next, it is recommended that an Enewetak Island Development Company be established, partly owned by Enewetak Peoples Inc. and partly by outside investors. Enewetak Peoples Inc. then would grant a long term lease for Enewetak Island to the Development Company. The outside investors would put up a sum of cash. This cash, along with the lease would constitute the starting assets of the Development Company. This company would then establish a plan and begin business and development activities. The charter of the Development Company would be to develop the economy in a manner which is both aggressive from a business point of view, yet at the same time minimizes the environmental impact, the cultural shock, and complements to the maximum the development plans of the Marshalls District and Micronesia in general.

All this can be accomplished with a good business instinct tempered by thoughtfulness, judgment, and concern for the social aspects of the enterprise. A suitable board of directors would be selected to provide mature guidance in this respect.

5.6.3 Initiation Plan

On the subject of getting an Enewetak economy started the first thing that needs to be said is the way not to do it. The way not to do it is to wait until the cleanup and resettlement are complete and then to begin getting an economy started. The time to work the bugs out of the initial economic activities is while the islands are full of construction workers, while the airplanes are landing regularly, while there are skilled people around who can help, advise, and teach.

Therefore, it is recommended that some of the Enewetak people be returned to the atoll at the start of cleanup operations. Most of these men will want to assist in cleanup operations, however, some should initiate pilot fishing, agriculture, and salvage programs. The presence of skilled personnel during these pilot programs would be of great help should it be necessary to make boat, engine, or other mechanical repairs. This friendly and understanding assistance would help in overcoming myriad problems, which though small could otherwise cause discouragement and possible collapse of the enterprise. It is during this period also that detailed procedures for processing products, freezing, and packaging should be worked out.

Therefore, emphasis must be placed on the establishment of the Development Company during, or even prior to, the resettlement of the Enewetak people. The Development Company should be in position to guide and coordinate these initial economic activities. It is important therefore that the Development Company be established as soon as possible.

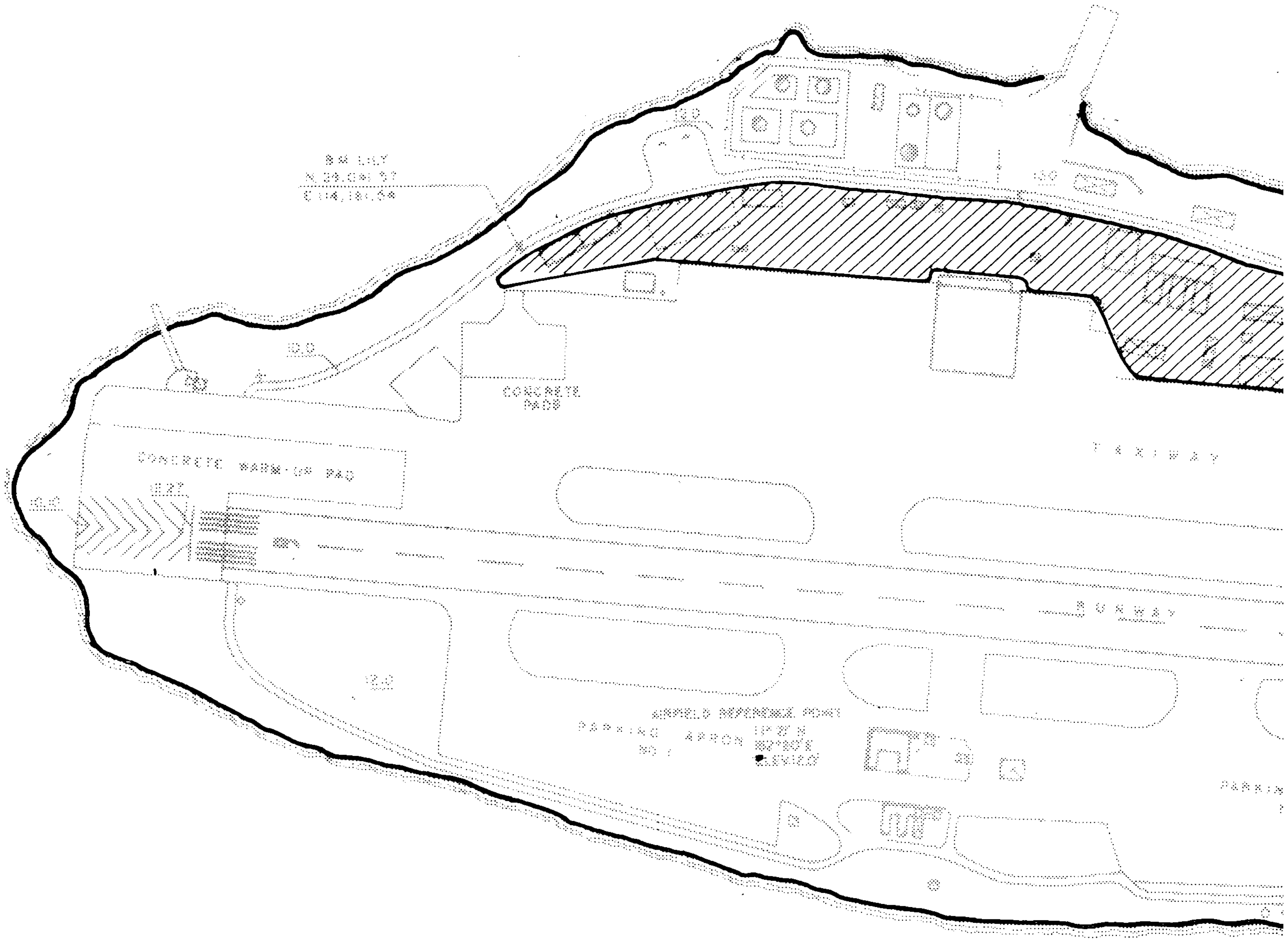
## 5.7 BASIC PLAN FOR ENEWETAK ISLAND

At the conclusion of the atoll cleanup program, all buildings and facilities used in support of the operation on Enewetak Island will be turned over to the Enewetakese. It is anticipated that the general state of repair of island facilities will reflect the use of good maintenance practices at the time of turnover. The intent of the basic plan for Enewetak is to utilize as many of the existing facilities as are compatible with the industrial and institutional development of the island.

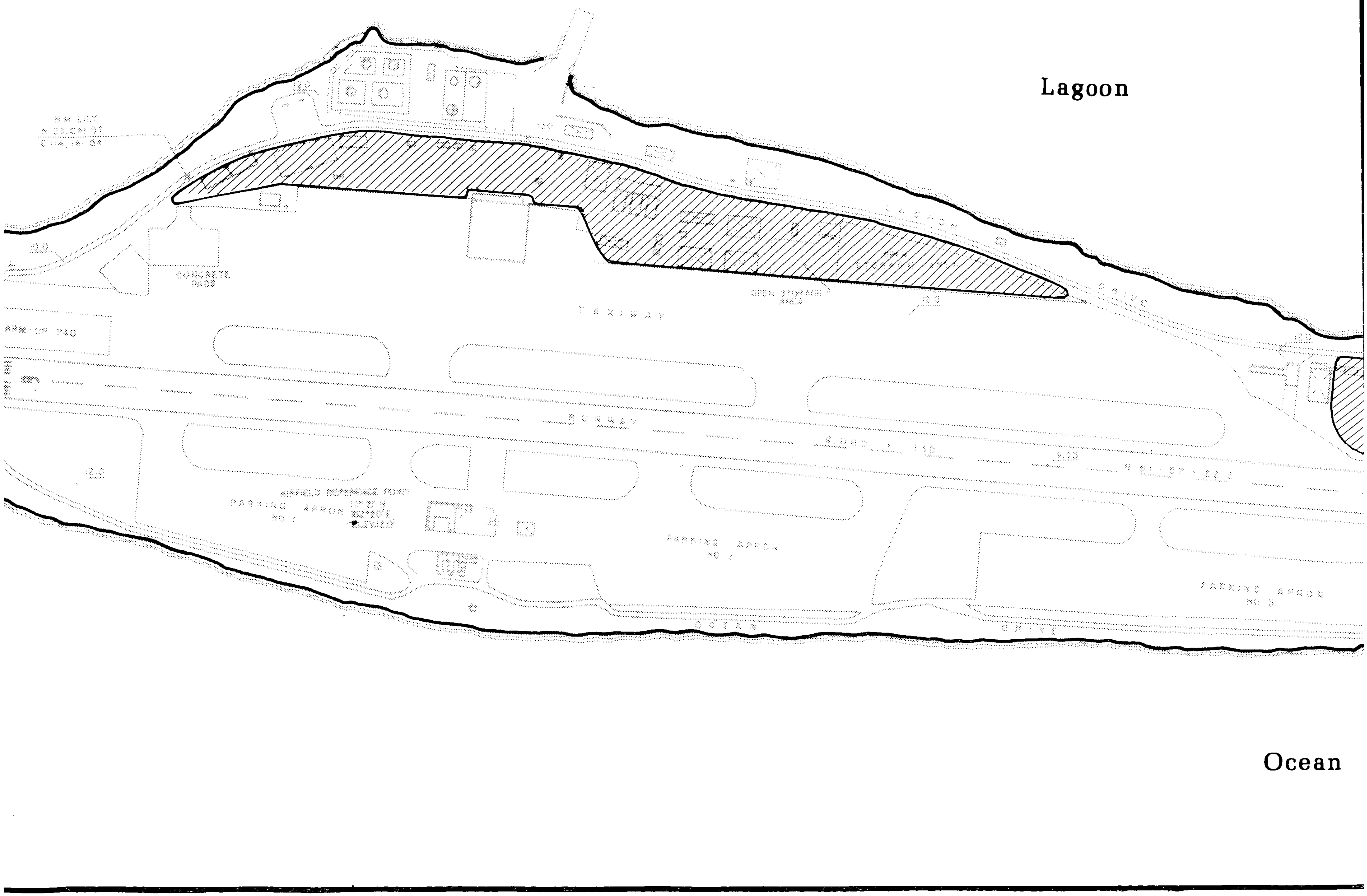
Plate #39 indicates tentative zoning for the various types of development previously discussed. The southwest end of the island containing airport facilities, POL storage, and the cargo pier are in the zone for industrial (marine products) and way station activities. Structures in this area include the hangar, airport terminal, and ancillary buildings, as well as warehouse and multipurpose buildings. There are approximately 26,000 square feet of space which could be devoted to a marine products industry. The hangar encloses a 50,000-square usable area and is ideally situated for servicing aircraft. POL storage facilities with a 56,000-barrel capacity in seven tanks are contained within bermed and fenced enclosures.

The major warehousing and maintenance facilities lie northeast of the airport. Eight buildings containing approximately 50,000 square feet of floor space are situated in this area. The ultimate usefulness of these structures as they would relate to planned development of the island remains to be determined.

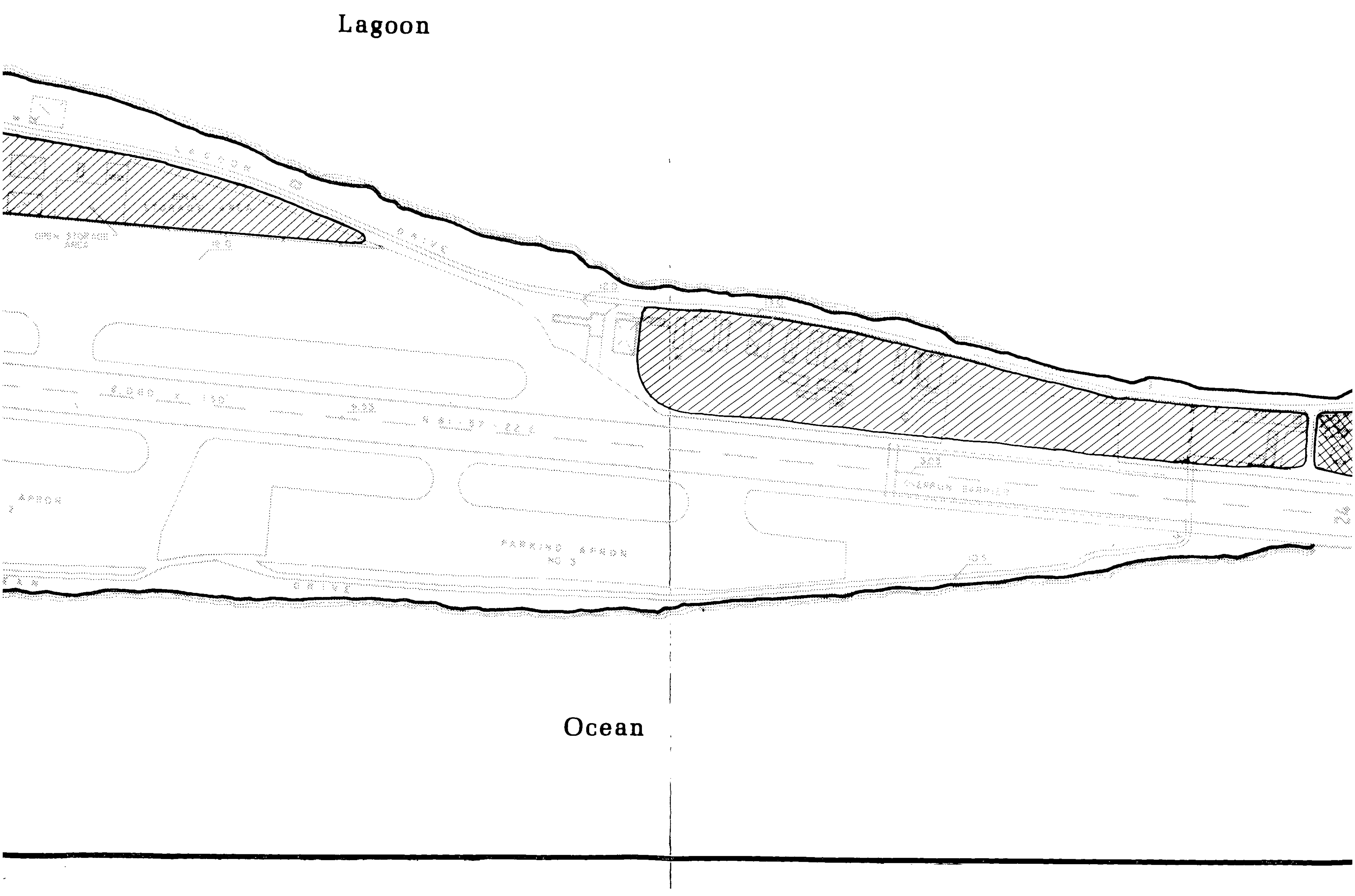
The island utilities, fresh water, salt water, and power are located adjacent to the northeast end of the runway. The distribution



CONCRETE PADS
CONCRETE WARM-UP PAD
TAXIWAY
RUNWAY
AIRFIELD REFERENCE POINT
PARKING APRON



Lagoon
Ocean
CONCRETE PADS
OPEN STORAGE AREA
TAXIWAY
RUNWAY
PARKING APRON NO 1
PARKING APRON NO 2
PARKING APRON NO 3
AIRFIELD REFERENCE POINT
LAGOON DRIVE
OCEAN DRIVE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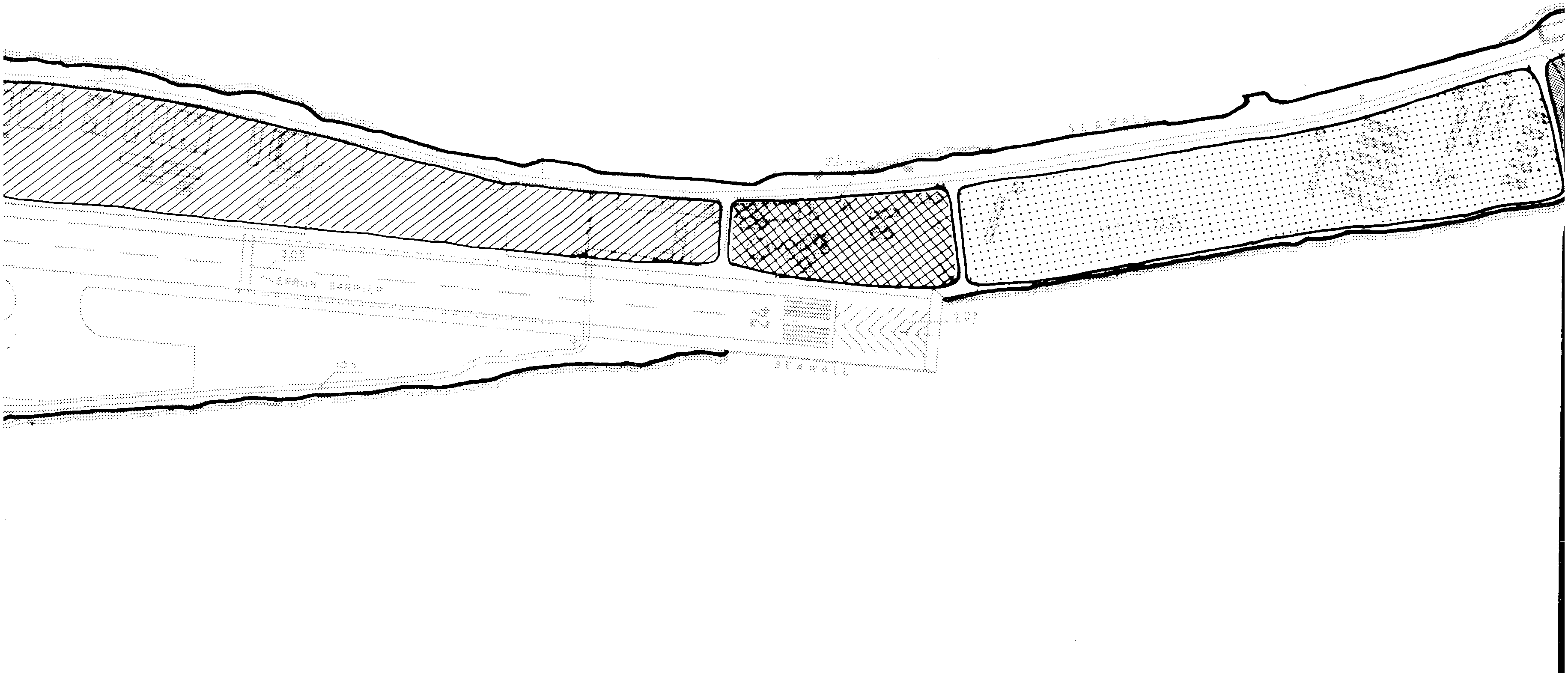
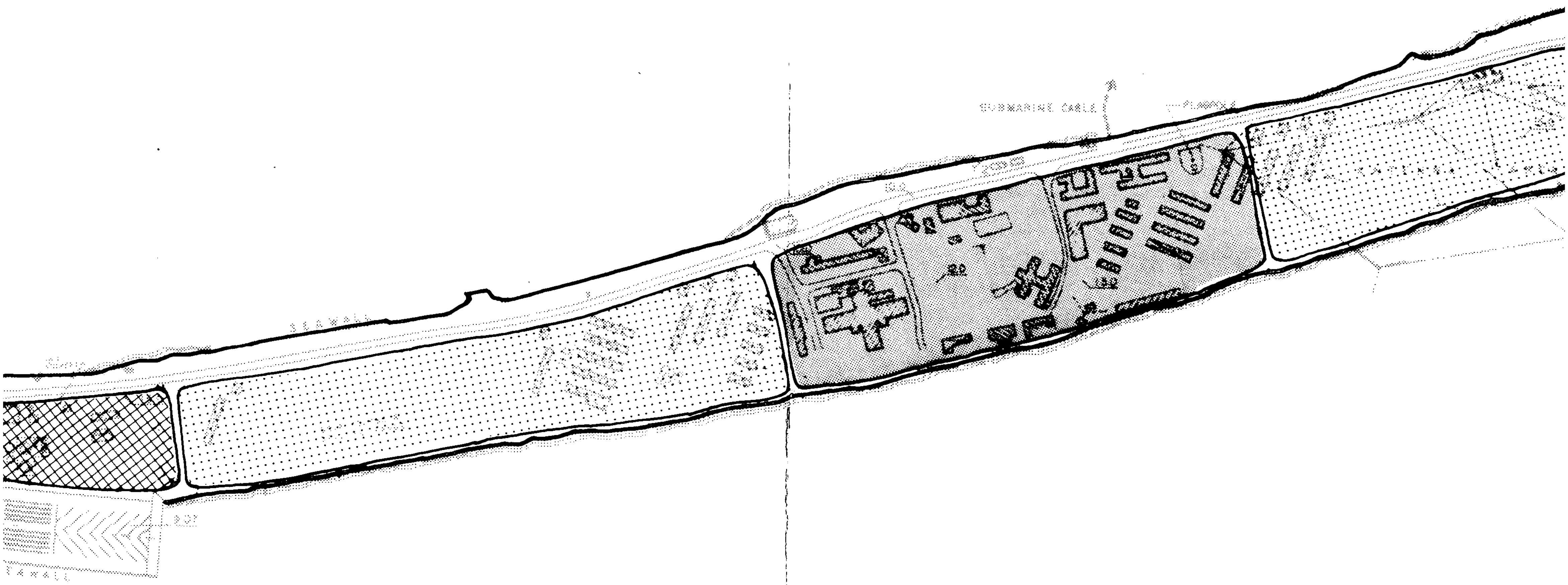
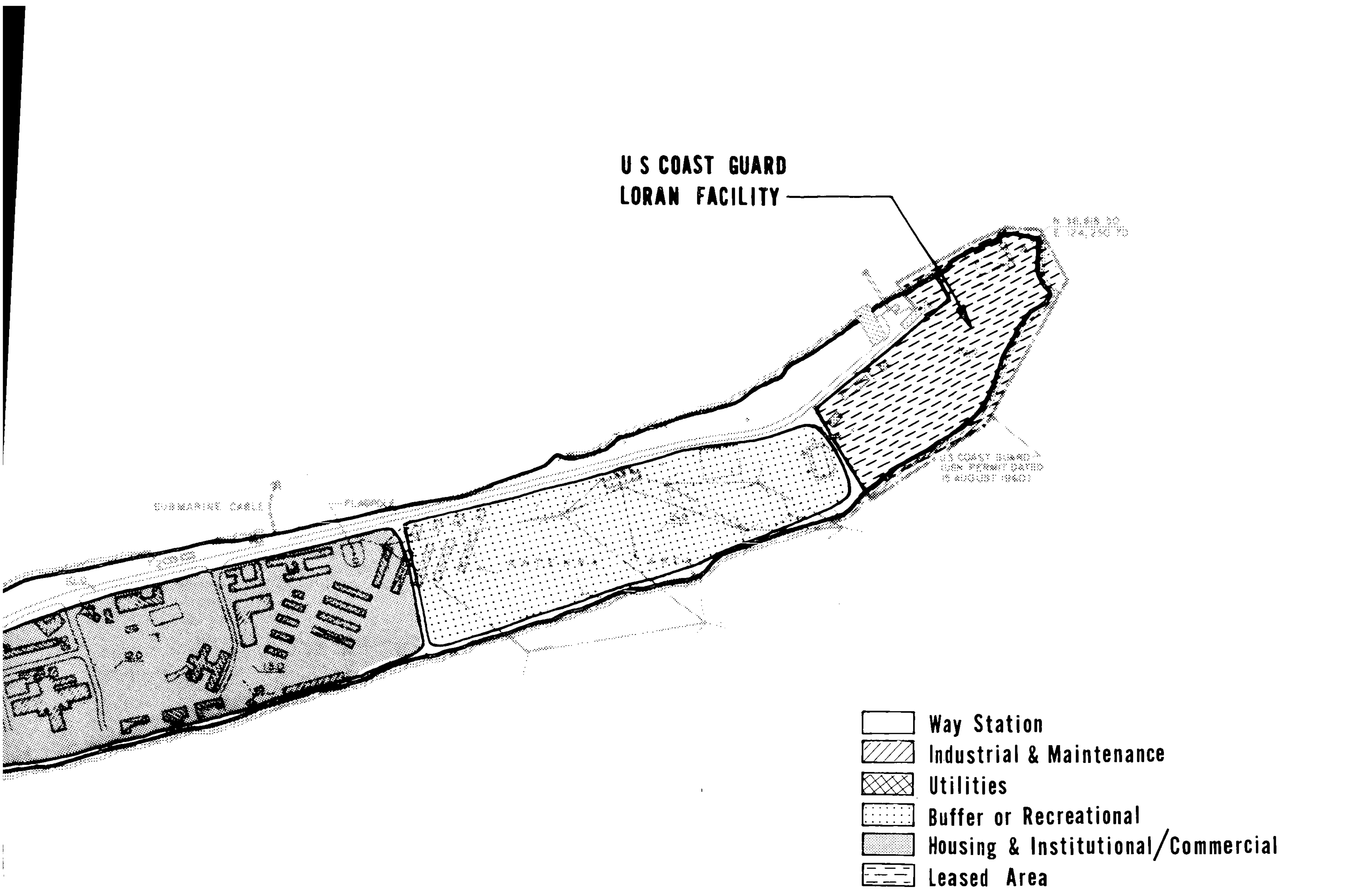


**U S COA**
**LORAN**






# BASIC LAND USE PLAN - ENEWETAK ISLAND

TRUST TERRITORY OF THE PACIFIC ISLANDS

**ENEWETAK ATOLL MASTER PLAN**

HOLMES & NARVER, INC.

Plate No. 39

NOV. 1973

systems run to both ends of the island from this central location. As discussed in Section 4.5, the extent of utilization of these facilities will be determined by the nature of the island's development.

The area to the northeast of the utility group is barren, with the exception of a personnel shelter and some concrete slabs. This can be utilized as a buffer zone between the industrial/commercial and utilities functions and the housing and institutional area above it. A golf driving range previously was located in this area and could be easily reinstalled.

The main camp area for the cleanup operation is located in the next zone. The buildings include living quarters (approximately 40,000 square feet available), mess hall, laundry, clubhouse, dispensary, chapel, and administrative offices. It is in this area that facilities for the EMBL and associated activities would be located. The three-story dormitory would be available for housing purposes while some of the remaining buildings situated nearby would provide space for the institutional functions.

A tennis court and swimming pool are located northeast of the camp area just below the U. S. Coast Guard enclave. It is anticipated that these facilities will be used for the same purposes as they were previously. Radio communications and marine operations also were situated in this area. The future function of these facilities is dependent upon the island development requirements.

A U. S. Coast Guard Loran Station is located on the north tip of the island. Living quarters, equipment, and maintenance facilities are contained within the enclave.

5.8 RESIDUAL RIGHTS

Certain residual rights on Enewetak Atoll have been requested by the U. S. Government agencies. Some will be terminated prior to the completion of the rehabilitation and resettlement program, while others will continue indefinitely. The Defense Nuclear Agency (DNA) requires the atoll cleanup rights and has requested rights to conduct the EXPOE program through mid1974. DNA probably will also be designated to hold the atoll for the TTPI when the turnover from the Air Force takes place. The U. S. Coast Guard has requested the right to continue operation of the Loran Station for an indefinite period. Also the Atomic Energy Commission intends to continue sponsorship of the EMBL on Enewetak Island for an indefinite period. The Coast Guard and EMBL functions are the only activities which are presently foreseen to be operational after the atoll is resettled.

# 6. MASTER PLAN IMPLEMENTATION

# 6. MASTER PLAN IMPLEMENTATION

## 6.1 RECOMMENDATIONS

Inasmuch as the primary elements of the Master Plan reflect the wishes and desires of the Enewetak People it is recommended that this plan be adopted. Further it is recommended that initiation of rehabilitation and resettlement activities commence without undue delay and in consonance with the Atoll Cleanup Program. It also is recommended that:

- The Enewetak People continue to be involved in the follow-on decision making which will be required.
- The Enewetak People be employed to the fullest extent possible in the rehabilitation and resettlement activities.
- The Enewetak Peoples Company be established as soon as is practicable so that plans for economic development may be initiated without delay.

## 6.2 CULTURAL CONSIDERATIONS

During the Enewetak Atoll cleanup and rehabilitation program, the Enewetak People who will participate will establish residence on Japtan Island. It is understood that these men desire to be accompanied by their families. To lessen the sociological impact on these people, it is planned to establish a community totally independent of outside influences. The presence of the families obviate any requirement for outside support and establishment of a cooperative store will minimize the need for off-island travel to obtain imported foods. Contact with these people will be kept to a minimum by restricting travel between the remaining islands and Japtan.

## 6.3 ON-THE-JOB TRAINING

In order to obtain maximum benefits from the close working relationships with skilled craftsmen it is planned to establish and maintain a continuing "on-the-job" training program for the Enewetakese during the cleanup and rehabilitation operations. The program will emphasize training in the skills which will be most beneficial after the islands have been returned to the people. Training in the areas of agriculture, carpentry, masonry and concrete construction, sheet metal work, gasoline and diesel engine maintenance and repair, and light equipment repair will constitute the primary objectives of this program. Instruction in other areas including administration will be given as required.

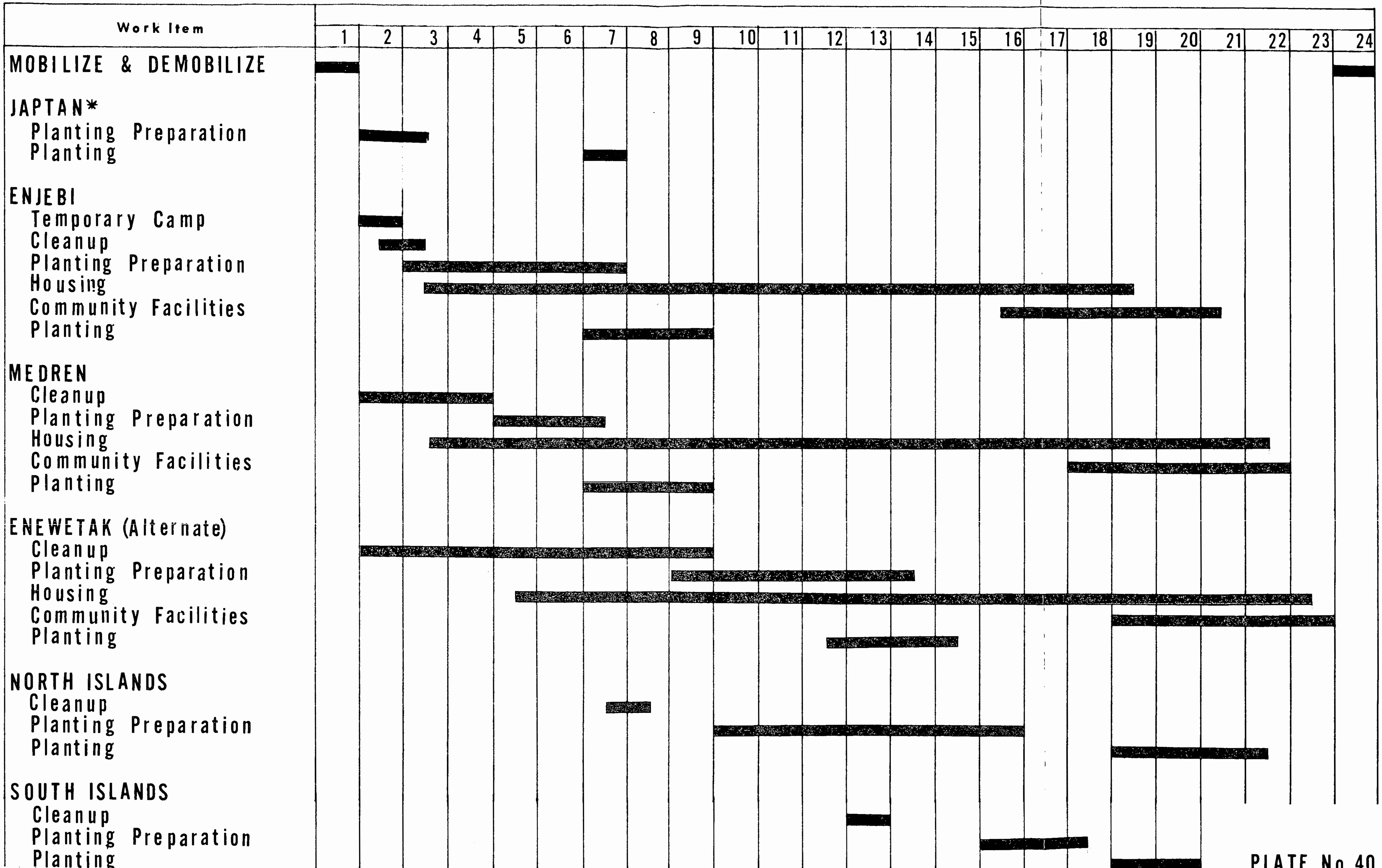
In consonance with the objectives of this training program talent will be provided capable of maintaining facilities which will remain in operation after resettlement is complete. It should be noted that maintenance of all facilities will be the responsibility of the Trust Territory and/or the Enewetak people.

## 6.4 CONSTRUCTION SCHEDULE RESETTLEMENT PROGRAM AND INTEGRATION WITH CLEANUP OPERATION

The construction schedule shown on Plate No. 40 reflects only the rehabilitation and resettlement requirements. It should be noted that temporary community facilities already exist on Japtan by virtue of the fact that they will have been prepared and used during the cleanup operation. Due to the magnitude of the tasks involved in the rehabilitation and resettlement work, it is presently planned to utilize two separate task forces over a 24-month period. Each task force will consist of approximately eighty men; half to be engaged in residential and community facility construction and the remainder in agricultural planting and associated activities.

# ENEWETAK ATOLL
## Rehabilitation Schedule

November 1973




*Temporary Camp Facilities Existing From Cleanup Program

PLATE No. 40

To expedite the work on Enjebi Island it is planned to establish a temporary camp on that island for the northern task force. Creation of this camp will eliminate weekday travel time between Enewetak/Japtan and Enjebi. Personnel of the northern task force will be returned each weekend to their respective base camps.

Rehabilitation and planting preparations can be initiated on Enjebi and Medren as soon as the cleanup of those islands is completed. Housing construction and agricultural planting on these islands will begin during the first year of rehabilitation. Agricultural planting on the remaining islands will be accomplished during the second year.

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## 7. BIBLIOGRAPHY

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# TRUST TERRITORY OF THE PACIFIC ISLANDS
# MARSHALL ISLANDS DISTRICT
# DISTRICT PLANNING OFFICE

March 19, 1974

Earl Gilmore
Holmes & Narver, Inc.
400 East Orangethorpe Avenue
Anaheim, California 92801

Dear Earl:

I reget the delay in replying to your letter of February 12, 1974 but have been off island to the Congress of Micronesia Budget Hearings.

The 14th. of March a meeting was held with the Ujlang Council and a number of important points decided as follows:

1. The two major residential islands will be Engibi and Eniwetok.

2. I agreed to the possibility of a few houses being constructed on Medren if insufficient land was available for a specific family on certain Eniwetok wetos.

3. No community facilities would be requested or built on Medren to support these houses.

4. The community center on Eniwetok will be on Mwillimor weto.

5. The council will submit a list of families wishing houses on Medren as soon as possible.

6. A resolution was adopted stating the council's full approval and support of Holmes & Narver to continue the project.

The council will be returning to Ujlang this week due to the death of one of the Iroij. Thus, I really see no great benefit from a trip by you to Majuro unless you have other item to discuss. I will keep you informed of future developments at this end.

Dennis P. McBreen
District Planner, Marshalls

cc: Distad
Legal Services
PAO