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REPORT BY

THE AEC TASK GROUP ON RECOMMENDATIONS FOR

CLEANUP AND REHABILITATION OF ENEWETAK ATOLL

~~APRIL 19~~ June 11, 1974

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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 judgments as to whether all or any part of the Atoll can safety be reinhabited and, if so, to describe cleanup actions to be taken and any constraints.

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 ~~in~~ 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 ~~participated in~~ attended Task Group meetings.

The job of the Task Group is to recommend 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. ~~and~~ 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.

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, sediment, water, and marine and land animals.

- The Survey report, plus the Master Plan for Rehabilitation and resettlement of Enewetak Atoll*, provide ~~an accurate, comprehensive, and up-to-date assessment of the likely~~ 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 eight 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 three week period in December 1972 on uninhabited northern islands, showed extremely low levels of airborne radioactivity. Com-

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*"Enewetak Atoll Master Plan for Island Rehabilitation and Resettlement," (3 Vols.), Holmes and Narver, Inc., Nov. 1973.

prehensive 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 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.
- A value of 50 percent of the Federal Radiation Council (FRC) Radiation Protection Guides (RPG's) for individuals is recommended for the criteria to be used in evaluating the various exposure reduction options considering that such exposures cannot now be precisely determined.

  The following values apply:

Whole body and bone marrow -	0.25 Rem/yr
Thyroid -	0.75 Rem/yr
Bone -	0.75 Rem/yr

- The guide for gonadal exposure of the population should be - 4 rems in 30 years.
- The guidance for ^{239}Pu in soil should be the following*:

  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.

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*These values are recommended for use in cleanup of Enewetak Atoll only.

**See Appendix III for additional guidance.

- The Federal Radiation Council (FRC) Radiation Protection Guides (RPG's) for individual and gonadal exposures are recommended as the criteria to be used in evaluating the various exposure radiation options. The numerical guidance therein should be reduced by the factors of 50% for individual exposure and 20% for gânadal 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

~~While~~ Since there is no adequate ~~of~~ 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. ~~The following is re~~ With this in mind, the Task Group recommends the following for use in making decisions concerning ~~plutonium~~ cleanup operations at Enewetak

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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:

- 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 population doses on the atoll in its current radiological condition for six living patterns ~~chosen~~ to be most representative of the Enewetak people's desired life-style after they return. 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.

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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 [illegible] who are [illegible] when they return and [illegible] children born after [illegible] parents to the atoll. [illegible] exposure is the highest are [illegible] provided. These estimates are not therefore average annual [illegible] applicable over a period [illegible] should [illegible] the [illegible] year. ~~[illegible]~~

P. [illegible]

in [illegible]

[illegible] [illegible] [illegible]

expected

of [illegible] peace. Though [illegible], the

[illegible] and

[illegible] do not constitute the [illegible]

[illegible] as [illegible] exposure.

~~[illegible] to the environment [illegible] thoroughly.~~

~~[illegible]~~

~~The most [illegible]~~

~~[illegible]~~ The conservative [illegible] expected [illegible]

exposures presented in Appendix I are considered by the Task Group

to be applicable to individuals in the Enewetak population.

~~[illegible]~~ There will be [illegible] persons in the population at any one time

~~[illegible]~~ who are fetuses, newborns, or infants, believed to be the most

sensitive members. Therefore, the preceding exposures

~~[illegible]~~ are judged suitable for comparison with FRC exposure

guides for individuals & members of an exposed population.

The estimates for 30 year whole body doses in the Survey Report are summarized in Table 1, and 30 year bone dose estimates are summarized in Table 2. Note that the option for "Gravel Village Area - Plow Village Island," achives 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 intergrals for genetic doses. 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 must be confirmed through analysis of test plantings.**

In its assessment of dose reductions that might be possible due to removal of contaminated soil, the Task Group posed the following questions: "Given the dose estimates of Tables 1-4, and the dose reductions that can be expected due to ~~modifications of the diet~~, 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

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*A detailed description of the calculations leading to the estimates in Tables 3 and 4 is given in Appendix IV.

**The Task Group does not favor soil removal as a dependable or feasible exposure reduction action. However, such action is reviewed in the Task Group Report in order to present a complete picture of the various possibilities considered.

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) ~~is expected to be a~~ residence and agricultural island. 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 i 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 t 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 (~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. ~~There is no experience to support these reduction levels.~~

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 D 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 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

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... The Group believes that subsistence crops should not be planted on an island if ... of the food ... in ... Measurements of ... of ... planting would be used to ... the effective ... 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 D-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.

The maximum dose reduction that can be achieved 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 D1 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. ~~Considering the time required for such studies and that the levels of radioactivity in soil are being reduced by radioactive decay and weathering, it may take about as long to return people to JANET using soil removal and confirmatory studies as would be needed without such actions.~~

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) = 1.3 ^{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 ~~radionuclide~~ ~~and is~~ always present in copra, ~~it seems reasonable~~ to judge the ~~marketability~~ of copra grown in Enewetak Islands 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, ~~and~~ one ~~might argue~~ that its marketability should be ~~un~~affected. 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 committment is made for planting of coconut trees in commercial quantities. ~~With additional study~~ it may be possible to predict ~~with confidence~~ the level of ^{137}Cs in coconut meat through analysis of stems and leaves of immature trees. This would save time.

DISPOSAL OF CONTAMINATED MATERIAL

For disposal of contaminated material, there appears 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 ~~recommended~~ removal of such soil 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 followup requirement to insure that this situation continues after disposal.

The Task Group view is that because of its ~~extreme~~ 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 ~~the higher levels of~~ plutonium contaminated soil and the pieces of plutonium metal, ~~and~~ 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 contaminated materials, soil and scrap, from the various islands including buried scrap ~~with placement in stockpiles as few in number as possible~~. The object is to get better control ~~of the materials~~ and to minimize spread of contamination.

YVONNE may be a suitable site for ~~such stockpiling with the quarantine continued~~ until proper disposal is accomplished. 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 appears to be ~~three~~ possibilities:

1. Disposal wherein there is an irrevocable committment of the contaiminant to the environment.
2. Disposal wherein, with some difficulty, a later decision could change the method of disposal.
3. An effort made to find a way to reduce the volume and amount of material requiring disposal ~~in either way (1 or 2) above.~~

The following ideas have been put forth ~~for~~ 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.

Any ocean disposal plans must be ~~coordinated with~~ the Environmental Protection Agency. ~~The Enewetak people should be informed of any plans~~

Any place for ~~land~~ 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 ~~in the time available. To the extent possible the Task Group~~ 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 ~~approach to~~ development of recommendations~~, and have led to numerous changes of a technical nature.~~ 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 costs ~~for cleanup actions are being~~ prepared by DNA; 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 recommendations are presented more effectively in narrative form.

There are three basic questions to be addressed: , "Is the radiation environment acceptable or can it be made acceptable for the Enewetak people to return to their atoll," "Is the radiation environment on Enjebi acceptable or can it be made acceptable for the people to return," and "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, Appendix II):

<u>Option I</u>

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 are well within acceptable standards.

<u>Option II</u>

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 ~~with~~ zero cost for radiological cleanup that results in population doses well below the guides (Row A of Tables 1-4). 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 ~~substance~~ 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. ~~Substance~~ 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 thirty years, the waiting period could be slightly more than one 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 ~~near~~ at or s~~lightly~~ above the criteria for annual exposures and also well above the general 30 year 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 area 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 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, would be hard to regulate, and would constitute an experiment involving the Enjebi people. In addition, use of clean soil for subsistence crops may have little affect 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 sixty 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 top soil sufficient to support subsistence and commercial agriculture. With any of these actions a period of time would be required ~~possibly as long as 8-10 years, or until test plantings of coconut, pandanus, and breadfruit are grown and analyzed for their radioactivity content, before~~ a decision could be made to settle people on JANET. An additional period ~~of~~ 8-~~10 years~~ 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 Options 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 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 on any island in in the atoll ~~without any remedial measures~~ 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.

h. Wells which are intended to provide lens water for human consumption or for agricultural use be drilled only on the southern islands. 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 three miles of the Mike event that had a total yield of about 10 Megatons. 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 ~~copra~~ 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 plutonium contamination on that island ~~is reduced to acceptable levels~~. 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. 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. 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 ~~and reduction of these to the lowest practicable value.~~

   b. A team of experts should be assembled who can make and interpret field radiation and radioactivity measurements, advise on cleanup actions, and provide necessary health physics support including protection of workers, decontamination of workers and equipment, and packaging and handling of collected ~~plutonium~~. The Envi

   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.

e. 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.

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

9. Test plantings of pandanus, breadfruit, coconut, and arrowroot should be made, as soon as growth can be assured, on each of the islands ~~on which these plants are to be grown.~~ 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.

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. ~~An~~ air sampling program should be conducted ~~during cleanup in support of cleanup operations and to add to the body of available~~ information on radioactivity levels in air.

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 collection of ~~additional~~ information on the chemical form and size distribution of ~~^{239}Pu~~ particles in the air.) 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. ~~At~~ To 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~~ these conducting the cleanup operation.

15. The planning and conduct of cleanup, including radiological support for cleanup, should [illegible] be similar to [illegible] cleanup of Bikini [illegible] in terms of experience. As Bikini people were given opportunity for employment in cleanup, an equal opportunity should be given Enewetak people if they desire.

Tape Changes

1. P19, line 4, add ref to map E-106, ...options (see Fig. 106, Appendix I)......
2. P... ... & ... II & II
3. Page 7, line 4. agencies
line 6. have to import..t....
line 8. integral
4. Page 20, line 11. ..... islands do not.....
5 Page 16, item 3 Cement
6. Delete ... at top of ...
7. Delete ... sentence, line 14, page 11
8. Add ... line 14, profile, page 11.
9. Line 19, maximum, page 11.
10. Page 15, line 10. ..... its extreme long.....
11. Page 15, line 12 .... activity.
12. Page 15, line 12 ..... its deliberations,
13. Page 15, line 15. Delete the word in.
14. Page 15, line 16. Delete s on word follows.
15. Page ..., ...
... from ... ...
... line 11, ... a wait of about
50 years ...
17. Page 27, line 26, profile.
18. Page 28, line 1, 400 pCi/g ... .
... note all ...
19. Page 28 line 4..... recovery of contaminated.....

20. Page 28, line 9.... no pieces <u>or</u> hot.....