be conducted such that radiological exposure to cleanup personnel will be in accordance with applicable regulations.

(d) The composition of the actual cleanup work force will consist of DoD personnel, ERDA contractor-provided personnel, and local labor (except for the handling, collecting or removal of contaminated material).

(e) The use of certain equipment and other assets currently available to the DoD has been determined by the U.S. Congress to be in the best interest of the U.S. Government. These assets, to the extent possible, will be utilized for the Cleanup Phase.

(3) The engineering study prepared for DNA (Ref b) was an island-by-island survey which located and identified man-made structures and debris. In addition, it provided instructions concerning disposition of each of these items which were determined to constitute a health or safety hazard, or to interfere with the reasonable use of the Atoll. These dispositions were subsequently modified as reflected in the FCDNA Enewetak Cleanup Master Index dated 7 April 1977.

(4) An Environmental Impact Statement (Ref c) was published which examined five specific alternatives. Case 3 was determined to be the most practicable and is the basis for this plan. In Case 3, non-contaminated material is stockpiled or disposed of in accordance with appropriate procedures and contaminated material is placed in a crater(s) on Runit (Yvonne) Island.

c. An advisory team of experts called the Radiation Control Committee (see Tab C, para. 4.a(6) will be established at Enewetak Atoll to advise on cleanup actions and monitor the implementation of the radiological protection program. Radiological cleanup decisions will be made by the Commander, FCDNA or his designee considering the advice of the Radiation Control Committee, cultural and socio-economic impact, as well as cost, logistics and technical factors.

d. When all reasonable effort has been made to remove contaminated scrap and debris and when the process of survey, removal of plutonium contaminated soil and resurvey of an island progresses to the point where the Enewetak Radiological Support Project (ERSP) manager can agree that the extent of cleanup complies with the AEC/ERDA Task Group recommendations and the additional ERDA guidance in para 4, Tab E, App 2 to Annex C, then the ERSP Manager will provide the CGTJ certification that cleanup has been completed on that island.

(2) On 30 Nov 72, the Director, Defense Nuclear Agency, was designated as the Department of Defense Project Manager for matters concerning the Cleanup of Enewetak Atoll (See reference d.) Specific guidance was as follows:

(a) The Cleanup Phase is limited to the removal of debris and structures or materials residual from the use of the Atoll by the DoD which could pose radiation or other hazards to inhabitants, interfere with their reasonable use of the Atoll, or preclude safe, continuous habitation.

(b) The ERDA, in coordination with other appropriate government agencies, will establish guidelines for the radiological cleanup and will provide technical support to the DoD Project Manager during the Cleanup Phase.

(c) The handling and removal of contaminated material will

DNA OPLAN

2. MISSION: Conduct a full Case 3 Environmental Impact Statement approved Cleanup to accomplish those cleanup actions listed in Reference c, para 5.5.3.2:

a. Physical hazards will be removed from all islands.

b. Obstructions to development of habitation and agriculture will be removed.

c. Unsalvageable radioactive material will be disposed of in accordance with appropriate procedures.

d. In general, the ERDA guidelines provide for removal of concentrations of plutonium in soil exceeding 400 pico curies per gram (pCi/g), for selective removal in the range of 40 to 400 pCi/g and for no mandatory action below 40 pCi/g.

guidelines, however, are not sufficiently specific to facilitate detailed operational planning. ERDA has agreed to provide more specific guidance on the application of the basic Task Group recommendations and to provide greater specificity and operating criteria (see Tab E).

b. The "Case 3 Cleanup" as described in Reference a conforms with the Task Group Recommendations. Thus, Cleanup is dependent upon radiologically monitoring all scrap and debris which conceivably might be contaminated, and the classification of soil according to its Pu concentration as either (1) greater than 400 pCi/g (mandatory cleanup), (2) less than 40 pCi/g (no cleanup required), or (3) in the range of 40 pCi/g to 400 pCi/g (individual case cleanup).

unmodified conditions the percentage is far less than these. The concentrations of radionuclides in fish muscle is higher in fish around the ALICE-to-IRENE complex, but even if the fishing were confined to these islands, a completely unrealistic fishing pattern, the resulting 30-yr, whole-body and bone doses would still be less significant than the other pathways and less than the 30 yr integral U. S. background dose.

Inhalation Pathway — The dose commitment via the inhalation pathway is due to the presence of plutonium throughout the soil in all of the northern islands. It is not generally localized sufficiently to consider "spot" cleanup. Anything short of removing the top layer of soil and replacing it with uncontaminated soil, or of simply covering existing soil with new soil, or of restricting living on northern islands will have little effect on the dose commitments via the inhalation pathway presented in this chapter. However, it should be noted that the plutonium concentrations on the southern islands are world-wide background levels, and the corresponding dose via the inhalation pathway is less than 1 mrem over 30 yr. This is the same level of exposure one would expect if new soil were brought in to the northern islands. The doses via inhalation on the northern islands is also insignificant relative to other pathways, where remedial action could be far more productive. (See Tables 204 and 206).

Summary of Remedial Action — In summary, the greatest reduction in dose commitment can be realized by developing carefully designed agricultural plan limiting the dose via the terrestrial chains. The next most effective sure would be directed at the external dose commitment by plowing the large island and graveling the village . Other remedial measures for cing the dose commitment via the rent pathways are possible but reduce potential dose commitment by far r amounts.

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.

AEC SURVEY (NVO 140)

Remedial Action

Terrestrial Food Chain—The doses estimated for the various living patterns indicate that careful assessment and design of an agricultural plan must be an integral part of the program plan for returning people to the Atoll. For example, the southern half of the Atoll has sufficient land area to supply pandanus, breadfruit, and coconut for the entire returning population; therefore, even if people were to live on Engebi, the dose commitment could be greatly reduced by confining agriculture to the southern half of the Atoll. This one restriction, especially for pandanus, breadfruit, and coconut would be the single most effective preventive measure for reducing the dose commitment. The combination of modifying the village island and living area and, confining the agriculture to the southern islands, both relatively easy to implement, have a very large impact on reducing the dose (compare Tables 204

There are, of course, other options for reducing the dose via the terrestrial pathway. One option would be to dig large area pits on all islands which would be filled with "clean" soil from another source; pandanus, breadfruit, coconut and other plants could then be grown and harvested from these "clean" soil areas throughout the Atoll. The subsequent reduction in dose would lead to doses from ^{90}Sr equivalent to or less than those predicted for the southern islands. Another option would include removing the surface layer of soil (0-20 cm) from the northern islands and replacing it with uncontaminated topsoil. This approach should also lead to doses equal to or less than those predicted for the southern islands. This form of remedial action would in the process reduce the dose via the inhalation pathway. This alternative, of course, requires the removal and disposition of an enormous amount of soil, and ocean dumping, which would provide the large reservoir needed and minimize the potential man-rem, would probably be the best and easiest method of disposal. This approach is certainly not one of the easier alternatives.

Efforts to maintain a high calcium diet could also be implemented to reduce the uptake of ^{90}Sr; however, remedial measures to reduce the uptake in the plants or food product would be more effective and desirable as the primary preventive measure.

Of course, the dose commitment would be largely eliminated if no pandanus, breadfruit, or coconut were planted on the Atoll for another 20 to 30 yr and if the diet were to consist of predominantly imported food. As was discussed in the chapter on dietary and living patterns, imported foods are very likely to form a significant fraction of the diet (possibly 85% or more) and, if so, a plan to control the production of pandanus and breadfruit, or at least the location of production, could essentially reduce dose commitments to levels near U. S. external background.

External Dose — The integral 30 yr external dose is reduced between 30 and 70% for living patterns III, IV, V, and VI as a result of plowing the village island and graveling the village area where people will spend a majority of their time. These procedures are fairly straightforward, relatively easy to implement, and lead to the largest percentage reduction in external dose. An additional reduction in external dose of approximately 16% could be attained if all islands were plowed; however, implementing such a program in order to achieve the additional slight reduction is certainly another order-of-magnitude problem. In any case, any plan to plow all islands would have to receive careful scrutiny to determine the possible effects upon the island and Atoll ecology.

Marine Food Chain — The marine food chain would appear to require no remedial action (see marine food chain chapter). The marine pathway contribution to the 30-yr integral dose for the modified case and for agriculture on southern islands (Table 210) is less than 4% for whole

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 2.2×10^{-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

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.

Differs from EIS and CRPA

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.

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.

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.

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.

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 physica 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 rehabilitation of the Atoll, the Task Group recommends the following:

(12)

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.

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.

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

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

RECOMMENDATIONS (AEC TASK GP)

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.

To what level may water in Alice c

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.

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.

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. /

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 occurring radioactivity in the product.

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.

of plutonium in the form of contaminated 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.

Recommendations 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.

AEC TASK GROUP REPORT

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 action 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.

Cs^{137} & Sr^{90}

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.

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.

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.

of the environmental radiation and radioactivity should be made in the first year of return and repeated, for example, every other year.

13. Methods of disposal of plutonium contaminated soil and scrap will have to be decided. Pending a decision, it is recommended that cleanup should accomplish the recovery of plutonium contaminated soil and scrap with storage on Runit (Yvonne). If disposal is deferred for further study, such study should be initiated promptly.

14. The cleanup, with particular attention to removal and disposal of contaminated scrap, debris, and soil, should be documented in detail in a final report by those responsible in the field.

15. Advantage would be taken of experience gained during cleanup of Bikini Atoll. No objection should be made to employment of Enewetak people during cleanup.

No attempt has been made to draw conclusions regarding the validity or the lack of validity of the proposed "Radiation Standards for Hot Particles" of Drs. Tamplin and Cochran or its application at Enewetak. The guidelines for conducting the cleanup of Enewetak Atoll were developed by the Atomic Energy Commission (now ERDA) after consultation with the Environmental Protection Agency based on standards established by the Federal Radiation Council. Since these guidelines are based on established standards set by competent authority, it is planned that the proposed cleanup be conducted on the basis of the recommended AEC guidelines.

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.

(2) Recovery of plutonium contaminated soil.

d. Recovery of plutonium in soil at concentrations greater than 400 pCi/g $^{239, 240}$Pu at any depth these levels are found. Also, recovery of contaminated soil sufficient to reduce surface levels to a value well below 40 pCi/g $^{239, 240}$Pu. After soil removal, all areas should be resurveyed to ensure no pieces or hot spots of plutonium remain.

8. Plutonium contaminated soil on Boken (Irene) should be handled as on Runit (Yvonne). Pieces of Pu metal are not expected to be found.

9. Test plantings of food crops may be conducted on each of the "no crops" islands as designated by the Enewetak people. As edible parts of these plants become available, concentrations of significant radionuclides should be measured and compared with the radiological survey predictions. These studies will indicate times at which planting of subsistence and commercial crops can be safely resumed.

10. Lens water sampling and analysis should be conducted, samples to be taken over a period of at least 12 calendar months. Bacterial content, salinity, and radionuclide content should be measured. Radioactivity information will contribute to an understanding of processes 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 Enjebi (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 to provide information on radioactivity levels in air. This program could be conducted coincident with and support cleanup.

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, and periodically thereafter. Resurveys

was the most heavily contaminated of the larger islands. The Task Group has been unable to determine a reliable, feasible way to bring exposures within the acceptable criteria and permit resettlement of Enjebi on the same schedule as southern islands. The island can be resettled sometime in the future when radionuclide ingestion is no longer a problem. To develop the facts, test plantings with and without soil removal may be made. Construction and agriculture would be deferred until produce from test plantings showed acceptably low levels of radioactivity. Test plantings without soil removal would have least adverse impact on the island environment.

4. Concurrent with the Enjebi work, radioactivity levels should be measured in coconut and other food crops grown on Lujor (Pearl), Kirumu (Clara), Bokoluo (Alice) and Bokombako (Belle). Produce from Runit (Yvonne) should be included after removal of plutonium contamination.

5. All radioactive scrap metal and contaminated debris now or later identified should be removed. This includes three locations on Aomon (Sally) and one on Medren (Elmer) where buried contaminated debris should be exhumed and removed.

6. Runit (Yvonne), quarantined by the USAF in 1972, should remain quarantined until plutonium contamination on that island has been cleaned up. An authority responsible for enforcement of the quarantine should be identified and in residence in the atoll if people return to the atoll before cleanup is completed.

7. Only general recommendations for cleanup of Pu on Runit (Yvonne) can be presented at this time. An accurate picture of this contamination should develop as the decontamination proceeds. The area observed to have small pieces of plutonium and the highest soil concentrations is about 30% of the island. A background for plans for the recovery of Pu will require:

   a. Assembly of a team of experts to interpret field radiation and radioactivity measurements, advise on cleanup actions and provide necessary health physics support. A Public Health Service group, now part of EPA, provided radiological assistance for cleanup of Bikini Atoll. Similar support should be sought from EPA for Enewetak.

   b. Decontamination of Runit (Yvonne) is seen as an iterative process. This amounts to a search for and removal of the higher plutonium levels in soil.

RECOMMENDATIONS

The Task Group reached the following conclusions:

1. Observing precautions, the people may safely return after certain actions are taken. Exposures will be somewhat above current levels in the U. S., but the small risk seems permissible in relation to the desire of the people to return.

2. To assure exposures that will be as low as practicable:

   a. Villages and residences to be located on Medren(Elmer), Enewetak (Fred), Japtan (David), or other southern islands, Jinedrol-Kidrenen (Alvin-Keith).

   b. Travel and visits may be unrestricted to all islands except Runit (Yvonne). When Pu contamination on Runit (Yvonne) is removed, the restriction of travel to that island may be lifted.

   c. Coconut excepted, growth of animal and vegetable subsistence crops to be limited to southern islands Jinedrol-Kidrenen (Alvin-Keith).

   d. Subsistence and commercial coconut may be grown without remedial measures except on Bokoluo, Bokombako, Kirunu, Louj, Boken, Enjebi and Runit (Alice, Belle, Clara, Daisy, Irene, Janet, and Yvonne).

   e. Fishing permitted anywhere.

   f. Wild birds and eggs may be collected anywhere.

   g. Coconut crabs may be collected only on the southern islands Jinedrol-Kidrenen (Alvin-Keith).

   h. Wells to provide lens water for human consumption or for agricultural use to be drilled only on the southern islands Jinedrol-Kidrenen (Alvin-Keith). Water from any well to be assayed for bacterial, salinity, and radioactivity content before approved for use.

3. Enjebi (Janet) is a special case, and the people have a strong desire to live there. Three ground zeroes were on Enjebi and high yield events were fired nearby, with the result that this

recommends that studies be conducted as follows:

- A test planting program on Enjebi to determine when exposure would be within acceptable criteria without the removal of soil. This program has been initiated.
- A program to determine radioactivity levels in coconut and other food crops produced on Lujor, Kirunu, Bokoluo, Bokombako, and Runit (after plutonium cleanup).
- As an alternate to the preceding program, soil removal on Enjebi, followed by a test planting series to determine whether exposure for Enjebi residents would be within acceptable criteria.
- The assembly of a team of experts to make and interpret field radiation and activity measurements, advise on cleanup actions involving plutonium and other radionuclides, and advise on necessary health physics support for protection of workers, decontamination of workers and equipment, and handling of collected contaminated materials.
- A comprehensive underground water lens sampling and analysis program for a minimum period of 1 year. Bacterial content, salinity, and radionuclide content would be measured every twelve months. However, the primary emphasis would be on the development of understanding those processes which are operating or 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. This program has been initiated.
- An air sampling program, conducted during cleanup, which would obtain samples representative of those that might be expected from the activities of the returned population.

THE BEST COMBINATION OF FEATURES IS FOUND IN CASE 3. IN THIS CASE CLEANUP IS PRACTICALLY COMPLETE; THE PROBLEMS OF CONTAMINATED PANDANUS AND BREADFRUIT ARE MINIMIZED; RESTRICTION ON POPULATION MOVEMENT IS MINIMAL, EXCEPT FOR THE RESTRICTION OF NO RESIDENCES OR AGRICULTURE ON ENJEBI; THE 30-YEAR DOSES ARE LOW; THE MAXIMUM ANNUAL DOSES FALL WITHIN AEC GUIDELINES; AND THE INCREASED RADIOLOGICAL RISK, EXPRESSED AS HEALTH EFFECTS, IS NO MORE THAN EQUAL TO THE RISK FROM BACKGROUND RADIATION.

Guidelines for safe exposures to radioactivity on the atoll are given in terms of the maximum annual dose received by an individual and are also evaluated in terms of long-term health effects. The main objective of radiological cleanup is to reduce the radioactivity of the Atoll to levels at which the population can be expected to have annual exposures below the value of these guidelines.

5.3.2.1 Long-Term Health Effects. Quantitative evaluation of low levels of absorbed radiation on human health continues to be a subject of medical research. Present knowledge is based on the response to high levels of radiation of research animals, of persons undergoing medical treatment with radioactivity, and of a few victims of radioactivity accidents. Direct determination of the human health response to low levels of radiation, such as are discussed in this report, is complicated by a number of factors such as:

- the requirement to study radiation effects on a large population for statistically meaningful results,
- the long time delay between radiation exposure and appearance of such effects as neoplasms,
- difficulty in distinguishing between effects attributable to radiation and those not related to radiation,
- the fact that such factors as cancer susceptibility are widely varying functions of age, sex, genetic constitution, diet, personal habits, socioeconomic factors, and other variables.

Because of the above factors, present risk estimates are based predominantly on conservative extrapolations from data obtained at high doses.

The recommendations are based on the conservative assumption of a nonthreshold linear relationship between radiological dose and the health effect. The assumption of no threshold means that any nonzero dose yields a nonzero effect detrimental to health. Evaluation of risks using this assumption probably results in overestimates of risks.

The methods examined for limiting radiological hazards on Enewetak Atoll are: (1) the control of the diet of the Enewetak people and, by implication, their agricultural and food gathering practices; (2) the control of residence of the population throughout the islands of the atoll; and (3) the cleanup of radioactive materials.

Case 3 is considered to be the most responsive to the established goals and is a balance of the human, physical, and cost parameters which must be considered. It is planned to conduct the proposed cleanup, resettlement, and rehabilitation project as outlined by Case 3. The estimated radiological dose is well below the radiation protection guides recommended by the AEC Task Group; all physical hazards resulting from past construction and testing will be removed and the cost is well below the mid point between other viable solutions.

5. Under the conditions of Case 3, the Enjebi People could not expect to return to their ancestral residence island of Enjebi at an early time. This would require both the Enjebi and the Enewetak People to live on land formerly owned and occupied by only the Enewetak People. Thus, until natural decay processes reduce the exposure rates on the northern islands, there would be less land available for agriculture and some supplement to the people's diet may be needed. The people will be subjected to acceptable low levels of ionizing radiation with a relatively low risk. Some contend that the residual plutonium levels should be established in accordance with the hot particle theory. Since this theory is controversial, not currently accepted by existing standard setting authorities, and results in very severe if not impossible residual limitations for transuranium radionuclides, it has not been applied.

The selection of Case 3, as presented in Section 5, as the preferred case is based on the premise that the safeguarding of the Enewetak people from harmful radioactivity is of prime importance. Acceptance of the AEC exposure criteria together with the above premise leaves no viable choices other than the AEC recommendations which are described as Case 3. These recommendations are designed to keep the population radiation dose safely within the guidelines set by the AEC. Deviations from the AEC recommendations regarding radiological standards are not considered to be acceptable.

The major drawback to Case 3 is that it would not permit scheduling of the planting of crops, the construction of family and community housing, and the resettlement of the people on Enjebi Island. It also quarantines the island of Runit for an indefinite period. The quarantine would be enforced by the TTPL. However, it would provide for the eventual return of the people to Enjebi when the test plantings and environmental monitoring program indicate that it is safe to do so.

28

E15

ENEWETAK ATOLL

CASE 3

Case Summary:

1. Pu Cleanup To AEC Guidelines On Boken, Lujor & Runit. Crypts On Aomon Removed.
2. No Restrictions On Fishing
3. All Radioactive Scrap To Be Cleaned Up From All Islands.
4. Physical Hazard & Obstructive Debris Cleanup On All Islands.
5. Live on Southern Islands, Jinedrol Through Kidrenen.
6. Subsistence Agriculture Limited To Southern Islands, Plus Mijikadrik Thru Billae, Except That Pandanus & Breadfruit Are Limited To The Southern Islands.
7. No Restrictions On Travel Except Runit, Pending Cleanup.

I

EIS

TABLE 5-13: SUMMARY OF CASE STUDIES

Item	Case 1	Case 2	Case 3	Case 4	Case 5
Residence Islands	No Restrictions	South Only	South Only	South plus Enjebi	No Restrictions
Interisland Visitation	No Restrictions	South Only	No Restrictions*	No Restrictions*	No Restrictions*
Sources of Pandanus and Breadfruit	No Restrictions	South Only	South Only	South and Farm plots on Enjebi	No Restrictions
Sources of Coconuts	No Restrictions	South Only	South and agriculture Islands in northeast	South and Enjebi through Billae	No Restrictions
Physical Cleanup	None	Hazardous and obstructive non-radioactive scrap	Hazardous and obstructive non-radioactive scrap. All radioactive scrap	Hazardous and obstructive non-radioactive scrap. All radioactive scrap	Hazardous, obstructive, and unsightly non-radioactive scrap. All radioactive scrap
Plutonium Cleanup	None	None	All concentrations ≥ 400 pCi/g and concentrations between 40 and 400 pCi/g as considerations warrant	All concentrations ≥ 400 pCi/g and concentrations between 40 and 400 pCi/g as considerations warrant	All concentrations ≥ 400 pCi/g and concentrations between 40 and 400 pCi/g as considerations warrant
D & Y Cleanup	None	Radioactive scrap	Radioactive scrap	Radioactive scrap, soil removal and replacement	Radioactive scrap, soil removal and replacement
Thirty Year Dose to Average Individual (rem)					
Whole Body	6	Background	1	3 (6 on Enjebi)	Background
Bone	60	Background	5	10 (20 on Enjebi)	Background
Lung	0.1	Background	Background	Background	Background
Number of Fatalities from Thirty Year Dose to Population of 1000	≤3	Background	≤0.3	≤0.8	Background
Maximum Annual Dose to Average Individual (rem)					
Whole Body	0.3	Background	0.05	0.1 (0.3 on Enjebi)	Background
Bone	2	Background	0.2	0.5 (1 on Enjebi)	Background
Lung	0.004	Background	Background	Background	Background
Ratio of Maximum Annual Dose to AEC Criteria					
Whole Body	1.2	≤Background	0.2	0.4 (1.2 on Enjebi)	≤Background
Bone	2.7	≤Background	0.3	0.7 (1.3 on Enjebi)	≤Background
Cleanup Cost (Millions of Dollars)	0	20.3	33.6	49.4	79.6
Disposal Cost (Millions of Dollars)	0	0	6.3	23.9	83.0

*Runit temporarily quarantined

(30)

CONCLUSIONS / RECOMMENDATIONS / SUMMARIES