Appendix I

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RADIATION PROTECTION GUIDANCE FOR CONTROL OF EXPOSURES AT ENIWETOK ATOLL

INTRODUCTION

Standards for protecting man against exposures to ionizing radiation evolved from the use of radium and x-rays. They have been extended during the development of nuclear technology which has given us man-made radioactive elements. National and international groups of authorities have developed approaches for protection and established numerical standards which, in their view, provide an conservative and a degree of radiological safety at least as stringent as is achieved for other agents, such as chemicals, explosives and toxic substances.

Standards now exist for broad categories of exposure conditions. They are in daily use by governmental agencies and other bodies having responsibilities for health protection.

Standards are prepared so as to be easily understood and applied by the professionals. The use of judgement rather than rigid application is favored. There are benefits as well as risks associated with radiation usages, and situations will arise to which standards are not directly applicable. Such cases are handled on a case-by-case basis, with professional judgements made as to exposure levels that are justifiable under the circumstances.

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RADIATION PROTECTION STANDARDS RELEVANT TO ENIWETOK GUIDANCE

Within the United States essentially all radiation protection activity is based on issuances of the

Federal Radiation Council (FRC)

National Council on Radiation Protection and Measurements (NCRP)

International Commission on Radiological Protection (ICRP)

Standards adopted and published by these bodies are in regular, day-to-day use; they provide the bases for judgements and recommendations pertaining to radiation protection at Eniwetok Atoll in the years ahead as it relates to cleanup, rehabilitation and reoccupation of the islands by the Eniwetok Atoll People. The material which follows is based on the philosophy and numerical values contained in ~~ERC~~, NCRP and ~~ICRP~~ publications, with the most extensive use being made of the ~~first~~. Some details of ~~ERC~~, NCRP and ~~ICRP~~ guidance are provided in a concluding section. Readers are referred to the ~~bibliography~~ listed as references, ~~for the relevant publications~~ issued by the councils and commission.

RADIOLOGICAL CONSIDERATIONS FOR REOCCUPATION OF ENIWETOK ATOLL

~~ERC~~, NCRP and ~~ICRP~~ recommendations must be applied to Eniwetok in manner different from that used for a proposed nuclear facility or at a laboratory where radioisotopes or ionizing radiation generating machines are to be used. At Eniwetok radioactive contamination is distributed in the environment and the owners of the atoll are absent at a radiologically safe location. The problem is finding the procedure, assuming one exists, through which all or part of the atoll can be made safe as the permanent home for the Eniwetok

Atoll People, ~~as well as for visitors to the atoll~~.

The basic principles of radiation protection are applicable everywhere. ~~[At Eniwetok the potential risks are sufficiently low as to be offset by identifiable benefits]~~ In the case of Eniwetok, Fundamental decisions relate to ~~[are]~~ the exposure standards to be used in the evaluation of the radiological survey and the cleanup and rehabilitation options. Benefits for the returning people must be identified. The objectives, drawn from ICRP, are

a. to prevent acute radiation effects, and

b. to limit the risks of late effects to an acceptable level.

Implementation of the plans for recovery of Eniwetok Atoll will require for their success:

1. Periodic assessments of environmental radioactivity
2. Measurements of humans by dosimeters and whole body counter
3. Forthright attention to the procedures which will keep exposures as low as practicable.
4. The most critical element of the population receiving the highest exposure will be used in applying numerical criteria
5. Use of dynamic life style and diet adapted to radiological conditions during the lifetime of returnees and later generations
6. Data on total annual exposures for those receiving highest exposures

Risks and Benefits

Risks associated radiation exposures during a life at Eniwetok are assumed to be equal to others involving comparable quantities of

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radioactivity in conventional technological situations as treated by ~~FRC~~ ICRP, NCRP and ~~ICRP~~ FRC. Radionuclides in the land, lagoon and sea environment are predicted to pass through various pathways to man. To the extent that practical measures can reduce exposures, there is a degree of control available to inhabitants. ~~As an upper limit the risks inherent in FRC Radiation Protection Guides will be justifiable/acceptable at Eniwetok Atoll.~~

Benefits associated with the return ~~of the~~ to Eniwetok ~~people~~ Atoll ~~will~~ have ~~to be~~ been stated by the ~~P~~Eniwetok people. Recovery of property, use of land, lagoon and sea resources with minimal restrictions, obtaining new housing and community facilities, and acquiring structures, etc., left behind by the U.S.A. qualify as benefits from ~~one~~ their viewpoint. In this case, unlike some nuclear technology applications, risks and benefits apply to the same persons; nevertheless there may be some variation among Eniwetok families because of variations in conditions between the family owned land holdings.

Steps taken to reduce exposures may have undesirable consequences. Actions causing soil disturbance may reduce food crop production; inability to construct a permanent home on an island for a period of years would inconvenience the owners. The concept of net benefit must be kept in mind, ~~and evaluated~~.

Remedial measures

Engineering and advisory actions are the two categories of remedial measures.

1. Engineering actions taken during cleanup and rehabilitation operations provide a basis for measurement or other determination of effectiveness and adverse impact. Good initial assurance of satisfactory completion can be given.
2. Advisory actions cover those activites of the returning people and their professional counselors in response to instructions and technical advice on land use, housing sites, dietary usages, etc. Results will be achieved over a long period and depend on the conscientious use of advice and counsel and require continuing exchange of information between inhabitants and technical sources. Because of time, human factors, pressures and qualifications, less ~~that~~ than optimum effectiveness may be prudently expected, despite a strong will to cooperate at the outset.

Engineering actions are those upon which the U. S. parties to cleanup and rehabilitation should place the greatest reliance for assuring continuing "as low as practicable exposures." If the U. S. leaves the atoll in nominally safe condition, it can put the control in the hands of the people with a high degree of confidence that ~~Un-~~ predicted exposures will not be exceeded to any significant degree. ~~toward events will be at the minimum~~. Disposal of contaminated scrap, construction of permanent housing, selecting sites for any planting of delayed yielding food sources such as coconut and pandanus, and drilling and locating pumps at wells in uncontaminated ground water, are typical engineering actions. Decisions having the approval and cooperation of the Eniwetok People will be necessary for some of these.

Advisory actions should be considered as a bonus in the exposure reduction planning. Restrictions on visits to certain islands, restrictions on use of specific animal or vegetable foods, and ~~steps to be taken in the event of possible contamination~~ use of dietary supplements are advisory actions. ~~Between the two types of actions~~ Considering the exposure reduction achieved by engineering actions, it must be possible to maintain exposures of people below recommended levels; otherwise the U. S. parties must deliberate whether cleanup and rehabilitation of the atoll should be initiated now or at some later time. The application of the array of actions to the situation at Eniwetok Atoll as portrayed in the report of the radiological survey must lead to positive findings if the people are to be given clearance for safe return to their traditional home.

Recommended guides: ~~Radiation Protection Guides (RPG)~~ The Dose Limit issued by ~~FRC are~~ ICRP is recommended as the basic standards for control of exposures to individuals at Eniwetok, ~~as they are at Bikini Atoll and in the U. S.~~ ~~This should hold as long as the atoll is under the jurisdiction of a U. S. agency, TTPI.~~ ~~The use of RPG's~~ This is recommended with the proviso that not all the full amount of the numerical values should not be used for an allowable exposure from a single man-made source, in this case radioactivity from weapons tests. ~~The~~ This proviso is made so that the Eniwetok people will not be denied benefits of future nuclear technology because they are receiving exposure from man-made radiation to the level of acceptable standards.

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Survey, Cleanup and Rehabilitation Evaluation

It is recommended in this context that

1. A limit of 50% of ~~PRC RPG values~~ of the JCRP Dose Limits for individuals will be used. This assumes that the range of annual exposure levels for persons receiving the higher exposures will be known. The following values apply to the population.
2. ~~The~~ A limit ~~of~~ for gonadal exposure will be 5 rems in 30 years ~~base~~. This is based on the genetic dose coming primarily from ^{137}Cesium ~~($t_{\frac{1}{2}}$ = 30 years)~~, the radiological half-life of which is 30 years. ~~approximates the mean age for childbearing. (Note: Is this true for Eniwetok People?)~~

Table V summarizes the recommended exposure guides.

Gonads, red bone marrow	0.25 rem/yr
skin, bone, thyroid	1.50 rem/yr (0.75 rem/yr, children thyroid)
Hands and forearms; feet and ankles	3.75 rem/yr
Other single organs	0.75 rem/yr

TABLE V

TASK GROUP RECOMMENDATIONS

	Individual	Population Group
Whole body	0.25 rem/yr	-
Bone marrow	0.25 rem/yr	-
Bone	0.75 rem/yr	-
Gonads	-	5 rems/30 yrs

REVIEW AND SUMMARY OF STANDARDS

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A. THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP)

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

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

Exposure ~~from~~ to natural background radiation carries a probability of causing some somatic or hereditary injury. However, the Commission believes that the risk resulting from exposures received from natural background should not affect the justification of an additional risk from man-made exposures. Accordingly, any dose limitations recommended by the Commission refer only to exposure resulting from technical

practices that add to natural background radiation. These dose limitations exclude exposures received in the course of medical procedures. (These same qualifications with regard to natural background and medical procedures are applied to FRC and NCRP recommendations.)

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

For planned exposures of individuals and populations, the ICRP has recommended the term "dose limit."

It is not desirable to expose members of the public to doses as high as those considered to be acceptable for radiation workers because children are involved, members of the public do not make the choice to be exposed, and members of the public are not subject to selection, supervision and monitoring, and are exposed to the risks of their own occupations. For planning purposes, dose limits for members of the public are set a factor of ten below those for radiation workers. The dose limits for members of the public are a somewhat theoretical concept intended for planning purposes. It will seldom be possible to ensure that no single individual exceeds this dose limit. Even when individual exposures are sufficiently low so that the risk to the individual is acceptably small, the sum

of these risks may justify the effort required to achieve further limitation.

Where the source of exposure is subject to control, it is desirable and reasonable to set specific dose limitations. In this manner the associated risk is judged to be appropriately small in relation to the resulting benefits. The limitation must be set at a sufficiently low level so that any further reduction in risk would not justify the effort required to accomplish it. Such risks to members of the public from man-made sources of radiation should be less than or equal to other risks regularly accepted in everyday life. They should also be justifiable in terms of benefits that would not otherwise be received. ICRP has stated that when dose limits have been exceeded by a small amount, it is generally more significant that there has been a failure of control than that one or more individuals have slightly exceeded the limits.

"Dose limits" for members of the public are intended to provide standards for design and operation of radiation sources so that it is unlikely that individuals in the public will receive more than a specified dose. The effectiveness is appraised by assessments through sampling procedures in the environment, by statistical calculations, and by a control of the sources from which the exposure is expected to arise. Measurement of individual doses is not contemplated.

Actual doses received by individuals will vary according to age, size, metabolism, and customs, as well as variations in their environment. These variations are said to make it impossible to determine the maximum individual doses. In practice it is feasible to take account of these sources of variability by the selection of appropriate

critical groups within the population, provided the critical group is small enough to be homogeneous with respect to age, diet and those aspects of behavior that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose. ICRP believes that it will be reasonable to apply the appropriate dose limit for members of the public to the mean dose of this group.

The inate variability within an apparently homogeneous group means that some members of the critical group will receive doses somewhat higher than the dose limit. At the very low levels of risk implied, the health consequence is likely to be minor whether the dose limit is marginally or substantially exceeded.

Limitation of exposure of whole populations is achieved partly by limiting the individual doses and partly by limiting the number of persons exposed. It is of the utmost importance to avoid actions that may prove to be a serious hazard later, when correction may be impossible or costly.

The ICRP dose limits for individual members of the public are in Table I. No maximum "somatically significant" dose for a population is given. Using the linear dose-effect relationship and assuming no-threshold, the ICRP indicates that an annual exposure of active red marrow, averaged over each individual in the population, of 0.5 rem (corresponding to the annual dose limit for members of the public) might at equilibrium lead to an increased incidence of leukemia, at most, of about ten cases per year per million persons exposed.

The genetic dose to the population should be kept to the minimum amount consistent with necessity and should certainly not exceed 5

TABLE I

ICRP DOSE LIMITS [1]

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

1/ For conditions and qualifications see ICRP Publication 9.

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

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

rems in 30 years from all sources other than natural background and medical procedures. No single type of population exposure should take up a disproportionate share of the total of the recommended dose limit.

For exposures from uncontrolled sources, e.g., following an accident, ICRP identifies the term "action levels." The setting of action levels for particular circumstances is considered to be the responsibility of national authorities.

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B. NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS* (NCRP).

The NRCP was chartered by Congress in 1964 to collect, analyze, develop, and disseminate information and recommendations about protection against radiation, radiation protection measurements and units, and to provide a means for cooperation between organizations concerned with radiation protection.

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

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

To establish criteria, NCRP uses the concept of "acceptable risk" (where the risk is compensated by a demonstrable benefit) broken down to fit classes of individuals or population groups exposed for various purposes to different quantities of radiation. Numerical

*This was formely the National Committee on Radiation Protection and Measurements, ~~established in~~

recommendations for dose limits are necessarily arbitrary because of their mixed technical and value judgement foundation. The dose limits for individual members of the public and for the average population recommended by NCRP represent a level of risk considered to be so small compared with other hazards of life, and so well offset by perceptible benefits when used as intended, that public approbation will be achieved when the informed public review process is completed.

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

TABLE II

NCRP DOSE LIMITS [1]

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

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

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

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

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SUMMARY OF RADIATION STANDARDS

C. Federal Radiation Council (FRC). In 1959 by Executive Order the FRC was established to advise the President and to provide guidance for Federal agencies. The responsibility for establishing generally applicable environmental standards was assigned to the Environmental Protection Agency in 1970.

Basic FRC numerical standards and health protection philosophy are similar to those of the ICRP and NCRP. ~~International Commission on Radiological Protection (ICRP).~~ Numerical criteria and supporting material are provided in (1) Radiation Protection Guides (RPG) which deal with exposures of individuals and of population groups where actions are directed primarily at control of the source of radioactivity; and (2) Protective Action Guides (PAG) that deal with exposures of individuals and population groups to radioactivity from an unplanned release where action is taken in the production and use of foods.

RPG, Radiation Protection Guides, express the dose that should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. The RPG's are intended for use with normal peacetime operations, and there should be no man-made radiation exposure without expectation of benefits from such exposure. Considering such benefits, exposure at the level of the RPG is considered as an acceptable risk for a lifetime. The RPG's for the population are expressed in terms of annual exposure except for the gonads where the ICRP recommended value of 5 rems in 30 years is used. FRC states that the operational mechanism

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described for application of criteria to limit the whole body dose for individuals to 0.5 rem per year and to limit exposure of a siutable sample of the population to 0.17 rem per year is likely to assure that the gonadal exposure guide will not be exceeded.

Environmental radiation monitoring is a necessary part of complying with the RPG guidance. The intensity and frequency of measurements is to be determined by the need to be able to detect sharply rising trends and to provide prompt and reliable information on the effectiveness of control actions. Radioactive source control actions and monitoring efforts are to increase as predicted exposures move upward through a range of values and approach the numerical value of the RPG. A sharply rising trend approaching the RPG would suggest strong and prompt action. The magnitude of the actionshould be related to the degree of likelihood that the RPG would be exceeded.

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

The FRC primary numerical guides, expressed in rem, are provided in two reports, FRC Nos. 1 and 2, summarized in Table 1. Secondary numerical guides developed by FRC are expressed in terms of daily intake of specific radionuclides corresponding to the annual RPG's. Consideration is given to all radionuclides through all pathways to derive a

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TABLE III

FRC RADIATION PROTECTION GUIDES 1/

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

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

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

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

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total annual exposure for comparison with FRC guides. However, for many practical situations a relatively few radionuclides yield the major contribution to total exposure; by comparison, exposures from others are very small.

PAG: The term "Protective Action Guide" has been defined as the projected absorbed dose to individuals in the general population which warrants protective action following a contaminating event. In setting these numerical guides the FRC was concerned with a balance between the risk of radiation exposure and the impact on public well-being associated with alterations of the normal production, processing, distribution and use of food.

A protective action is described as an action or measure taken to avoid most of the exposure to radiation that would occur from future ingestion of foods contaminated with radioactive materials. An action is appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset undesirable features of the protective action. An event requiring protective action should not be expected to occur frequently.

The numerical guides are related to three types of actions, (1) altering production, processing, or distribution practices, (2) diverting affected products to other than human consumption, and (3) condemning affected foods. An additional category involves long-term, low level exposure for which numerical guides are not provided; the need for action is determined on a case-by-case basis.

The FRC identifies the critical segment of the population for which dose projections are to be made for comparison with the guides. For

instance, for ^{131}I in milk, the critical segment is children one year of age.

In cases where it is not practical to estimate individual doses, action will be based on average values of radiation exposure. Guides for both individuals and a suitable sample are provided. For ^{131}I in milk, the suitable sample is to consist of children approximately one year of age using milk from a reasonably homogeneous supply.

Numerical guidance for PAG's is provided in two reports, FRC Nos. 5 and 7 summarized in Table ~~II.~~ IV.

TABLE IV

FRC PROTECTIVE ACTION GUIDE (PAG) - INDIVIDUALS AND POPULATIONS[1]

Category	Environmental Pathway	Sensitive Member	Body Organ	Dose in Rads[2] Sr-89	Sr-90	Cs-137	I-131	Total	Recommended Actions
None (FRC #5)	pasture-cow-milk-man	children 1 year of age (2 gm thyroid)	dose to thyroid	---	---	---	30 (10)	---	1. Change cattle from pasture to stored feed. 2. Substitute unaffected fresh milk by altering processing or distribution practices.
I (FRC #7)	pasture-cow-milk-man	children ~1 year old	dose to bone marrow and whole body in first year	10 (3.3)	10 (3.3)	10 (3.3)	---	15[3] (5)	1. Change cattle from pasture to stored feed. 2. Substitute unaffected fresh milk. Divert or dispose of contaminated milk.
[4] (FRC #7)	other than Category I	local population consuming locally produced foods	dose to bone marrow and whole body in first year	5 (2)	5 (2)	5 (2)	---	---	1. Modification of animal feed, food processing, and marketing practices. 2. Diversion of crops from human food chain. 3. Destruction of crops or animal feeds.
III (FRC #7)	plant uptake from root mats and soil	suitable sample of population	long term chronic dose to bone marrow and whole body	PAG not provided for this category. If annual doses after first year exceed 0.5 rads to individual or 0.2 rads for suitable sample, situation to be appropriately evaluated.					Case by case determination of desirability of action. Action involves long term changes in farming practices such as crop selection, chemical and mechanical soil treatment, and land utilization.

1/ Values for populations are given in parenthesis. The proper description of a "suitable sample" of the population is contained in FRC reports.

2/ Guides for individual categories for Sr-89, Sr-90, and Cs-137 are sufficiently conservative; i.e., low, that it is unnecessary to provide additional limitations on combined doses. Since all three nuclides contribute to bone marrow dose, the sum of projected doses from each should be compared to the numerical value of the respective guide in the appropriate category when the need for protective action is considered.

3/ Assumes dose from Sr-89 and Cs-137 received in first year. Contribution to total dose from Sr-90 is estimated to be five times dose in first year.

4/ Action not usually required in this category if not required in Category I. No additional total dose criterion presented.