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MEMORANDUM FOR: Raymond F. Fraley, Executive Director
Advisory Committee on Nuclear Waste

FROM: B. J. Youngblood, Director
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

SUBJECT: UPDATE TO DRAFT "UNCERTAINTIES" COMMISSION PAPER

During the March 22, 1991 Commission briefing by the Advisory Committee on Nuclear Waste (ACNW), the Commission raised questions about the format of the high-level waste (HLW) standards of the U.S. Environmental Protection Agency (EPA). Among these concerns, the Commission asked about the benefits of collective dose versus individual dose to determine the risks posed to public health and safety by a release from a repository, including the assumptions needed, the cut-off levels used, and the manner in which the doses might be truncated. The Commission also asked about the benefits of the individual dose limit approach compared to the release limit approach now used by EPA.

The draft "uncertainties" paper which I forwarded to you on March 20, 1991, dealt briefly with these topics, but in less detail than the Commission's questions of March 22. In order to more fully address the above concerns, the enclosed alternative wording is being considered for incorporation into the paper. The staff will be prepared to discuss this alternative wording with the ACNW during the April 24, 1991 briefing on the "uncertainties" paper.

/s/

B. J. Youngblood, Director
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure:
Alternative wording for
sections 1.1 and 1.2 of
draft "uncertainties" paper

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1.1 Release Limits

EPA's containment requirements are expressed in terms of allowable releases of radioactive materials from a repository. EPA's release limits were derived from a health-effects goal, using a generic biosphere model with world-average characteristics. An alternative format would explicitly limit the doses (or health risks) that might result from those releases. For example, the recommendations of ICRP Publication 46 include both application of ICRP's basic dose limits for expected releases and limits on projected health risks for releases that are not likely to occur.

The advantage of the release-limit format is that it provides a usable measure of repository performance while significantly simplifying demonstrations of compliance. Regardless of the form of the standards, a major part of an analysis of compliance will consist of evaluating the ability of the repository barriers to reduce releases of radioactive material to the environment. If the standards place limits on releases, the evaluation is complete at that point. If, however, the standards limit doses or health effects, an additional evaluation is needed to estimate the environmental transport and human uptake of the released material. Over the long time period of concern in repository licensing (10,000 years), the parameters involved in dose or health effects estimates can be highly uncertain. For example, the locations where people might live, their dietary habits, the amount of their food obtained locally, and even metabolic characteristics could change, as they have in the past. Elimination of such speculative parameters from a licensing review would be beneficial in terms of reacning a timely licensing decision that adequately protects public health and safety.

One disadvantage of the release limit format is that it is difficult to compare such a standard with other radiological impacts (e.g., background radiation) or with other radiation protection standards. Another disadvantage is that the actual number of health effects to be expected for a repository will probably vary from EPA's goal since few actual repository sites will conform to the world-average biosphere model used by EPA to derive the release limits.

A standard expressed directly in terms of doses or health effects would have the advantage of facilitating comparison with other radiological impacts and radiation protection standards. Another advantage is that such a standard would directly limit the potential doses or health risks of concern at a specific site. As noted above, a release limit standard might allow the actual public health risk from a repository to vary from EPA's goal if the characteristics of the biosphere surrounding the repository are significantly different from the generic biosphere used by EPA to derive its release limits.

An intermediate alternative would be to express the standards in terms of doses or health effects and to specify, by rule, the assumptions to be made in projecting the doses or health effects associated with releases of radioactive materials to the environment. For example, either EPA or the Commission could specify a "static biosphere," in which current population locations, lifestyles and metabolic characteristics would be assumed to remain unchanged for the indefinite future. However, such an approach would merely substitute an assumption that present site-specific biosphere conditions are representative of the future in place of the EPA assumption that current world-wide averages are an adequate representation. The staff is not convinced that such a specification would be any more accurate. Thus, the staff continues to favor retention of the release-limit format of EPA's standards.

The U.S. Nuclear Regulatory Commission (NRC) staff has long supported EPA's release-limit format for the standards, because it would eliminate many potentially contentious issues from a licensing review. The staff continues to believe that the implementation advantages of the release-limit format far outweigh the disadvantages. It should be noted that the staff has previously commented to EPA on the need for EPA to provide a better comparison of its standards with other risks and radiation protection standards, and the staff intends to continue to pursue this subject in its interactions with EPA.

1.2 Population Impacts Basis

EPA's standards emphasize protection of populations by imposing "containment requirements" that limit the cumulative amount of radioactive material released over 10,000 years. The cumulative release limits correspond to EPA's population impacts goal of 1,000 premature cancer deaths for a 100,000 metric tonne (MTHM) repository. Only limited protection of individuals is provided for "undisturbed performance" during the first 1,000 years. Thus, while the population is protected for most of the circumstances and time period of concern, radiation doses to individuals could be either very high or very low, depending on specific site characteristics. The alternative to EPA's cumulative release limits, as recommended in ICRP Publication 46, would be limits that emphasize protection of individuals rather than populations.

EPA's decision to base its standards on population impacts rather than on protection of individuals was EPA's most significant departure from the traditional concepts of radiation protection. EPA argued that limits corresponding to protection of individuals might be very difficult to meet and that cumulative release limits would be more practical to achieve. (See 50 FR 38077, dated September 19, 1985.) It was also noted that standards based on protection of individuals might encourage selection of disposal sites where any release of wastes would be substantially diluted, even if such sites offered less than optimal containment of wastes.

Recently, the Advisory Committee on Nuclear Waste commented on the population impacts basis underlying EPA's standards (see January 29, 1991 letter from Dade W. Moeller to Chairman Carr). The Advisory Committee stated, in part:

> The projection of collective dose estimates far into the future (as is necessary to comply with the high-level radioactive waste repository standards as proposed by EPA) is extremely difficult. Factors that complicate such estimates include errors in predictions of regional and global population demographics (size and location) and of potential radionuclide pathways (groundwater flow and agricultural practices). In contrast, long-range projections of the locations and living habits of individuals who may reside near a repository are relatively

straightforward, and estimates of their potential doses can be made with greater certainty.

The staff agrees that long-term projections of collective doses are extremely difficult. As discussed in section 1.1 above, a fundamental feature of EPA's standards is the use of limits on the amounts of radioactive material released to the environment. This feature of the standards eliminates the need for difficult dose calculations, and has long been supported by the staff. Nevertheless, the Committee's comment raises a valid question -- would EPA's derivation of the release limits have been more technically rigorous if those release limits had been based on protection of individuals rather than populations? The following discussion examines four measures of repository performance that could have been used by EPA in developing its standards.

1.2.1 Maximum Individual Dose

An estimate of the maximum individual dose begins with a projection of the location, timing, and rate of release of radioactive material to the human environment. For most releases, the concentration of released material must also be projected. Then, potential pathways of exposure (e.g., drinking water and food chains) must be defined. Finally, the usage rates (e.g., drinking water and food consumption) of the maximally exposed individual must be defined.

Estimation of the maximum individual dose is strongly dependent on the rate of release of radioactive material to the environment, since the rate of release will largely determine the concentrations of radioactive material ultimately reaching an individual. The relative timing of releases of different radionuclides will also be important, since simultaneous release of two or more radionuclides will cause higher doses than would sequential releases. Finally, the estimated doses will depend strongly on whether the location and characteristics of the exposed individual are taken to be projections of current demographics and lifestyles or are defined in a manner that maximizes the doses that reasonably could be hypothesized to occur in the future.

1.2.2 Average Critical Group Dose

ICRP Publication 46 recommends limits on the average dose within the "critical group," i.e., those who are expected to receive the greatest exposure. Application of the ICRP recommendation would require essentially the same information as the maximum individual dose standard discussed above. However, it would also be necessary to define the critical group in terms of size, location, and usage rates for the potential pathways of exposure, and to determine the average dose expected within this group.

1.2.3 Summation Collective Dose

The most obvious way to estimate the collective dose associated with a repository is to determine the individual dose anticipated for each person exposed to releases from the facility, and then to sum those individual doses. Estimation of the collective dose in this way requires fairly detailed demographic information about the population exposed to a release, including the number of individuals exposed, their locations, and the usage rates for each person for each pathway of exposure. As a practical matter, a truncation of the summation of individual doses may be necessary, either as a function of distance from the facility or at some de minimis or "negligible risk" individual dose rate. Some radiation protection experts extend the "negligible risk" concept to conclude that truncation is necessary, as a matter of principle, arguing that collective doses composed of very small individual doses are meaningless for regulatory purposes. For example, EPA's release limit for carbon-14 was based on a world-side collective dose estimate in which each individual dose is only a tiny fraction of natural background radiation levels. However, there is no consensus within the radiation protection community regarding truncation, as illustrated by the directly contradictory advise offered by radiation protection advisory organizations.

The National Council on Radiation Protection and Measurements (NCRP), in its 1987 recommendations (Report No. 91), recommends truncation of collective dose estimates for individual dose contributions below 1 mrem/yr, arguing that such dose rates represent a "negligible individual risk level." The NCRP describes this risk level as "trivial compared to the risk of fatality associated with ordinary, normal societal activities," and recommends that such risks "be dismissed from consideration." In contrast, the 1990 recommendations of the International Commission on Radiological Protection (ICRP) state that "the Commission does not recommend the use of this technique" (Publication 60, paragraph 293). Instead, the ICRP recommends truncation in only two situations: "when the subsequent [individual dose] contributions are common to all alternatives or it is no longer possible to distinguish between options" (Publication 55, papagraph 149). Perhaps the most practical course of action would be similar to that of NUREG-1150 where collective doses were estimated both within a 50 mile radius of a facility and to the entire regional site population. Differences in the two estimates generally were not substantial. As discussed below, the method used by EPA in deriving its standards did not involve any truncation of individual doses.

Collective dose estimates are not as sensitive as individual dose estimates to the location, timing and rate of release of radioactive materials to the environment. For example, the sequential release of two radionuclides will produce essentially the same collective dose as simultaneous release of those nuclides, even though individual doses might differ significantly. Therefore, while collective dose estimates require more detailed estimates of biosphere characteristics, there is an offsetting reduction in the needed precision of release estimates derived from geosphere and engineered barrier analyses.

1.2.4 Collective Dose by EPA's Method

The collective dose estimates used by EPA to develop its high-level waste standards were not produced by summing individual dose estimates. Instead, EPA defined a "world-average" biosphere model, with specified fractions of released radioactive material entering each exposure pathway of the model (see EPA 520/5-85-026, "Environmental Pathway Models for Estimating Population Health Effects . . ."). For example, EPA estimated that 1.3×10^{-4} of the world-wide river flow is consumed as drinking water, and EPA assumed that the same fraction would apply to releases of radioactive material to a river near a repository. Thus, EPA assumed that the release of one curie of any radionuclide results in consumption of 1.3×10^{-4} curies via drinking water, without regard to whether that activity is consumed by a small or a large number of individuals. Similar assumptions were made for other exposure pathways, allowing EPA to estimate collective doses without first calculating individual doses.

EPA's method is quite attractive for the generic rulemaking purpose to which it was applied by EPA. This method does not require identification of a "critical group," or any other site-specific demographic information. EPA's method is also relatively insensitive to the location, timing and rate of releases. Thus, the performance of the engineered and geologic barriers of a repository need not be estimated with the same precision as would be required for standards based on protection of individuals.

A disadvantage of EPA's method is the lack of any truncation of the contributions to the collective dose estimate, either with distance or at a negligible individual dose rate. This makes it difficult to compare EPA's impact estimates to other risk estimates, such as those cited later in this paper. EPA's method will also be seen by many as inappropriate for a site-specific evaluation of collective doses. However, given the very large uncertainties in projections of the sizes, locations, and lifestyles of future populations, EPA's assumption of world-average characteristics might be as good as any other.

1.2.5 Overall Evaluation

Any of the four measures of repository performance discussed above could have been used by EPA in deriving its HLW standards. Individual dose estimates do not require extensive demographic projections of the populations affected by potential releases, but do require relatively precise estimates of the nature of projected releases, including the location, timing and rate of release. In contrast, population dose estimates do require demographic projections, but are less sensitive to uncertainties in the nature of the release. Given the sizeable uncertainties in projections of either individual or population doses, EPA's "world-average" biosphere model appears to be a workable approach for deriving generic release standards for HLW disposal.

The principal advantage of EPA's cumulative release limits, as contrasted with release rate or concentration limits derived from an individual protection goal, is that such limits encourage isolation, rather than dilution, of wastes. A significant disadvantage of EPA's cumulative release limits is inconsistency with more commonly applied radiation protection standards, which emphasize protection of individuals. Another disadvantage is that EPA's cumulative release limits do not recognize any de minimis level of radiation exposure. Thus, releases that cause very small doses to large numbers of people are considered equivalent to releases that cause larger doses to smaller populations.

The NRC staff has not previously objected to the population-impacts basis for EPA's standards. EPA's decision to protect populations rather than individuals was viewed as a decision properly within EPA's discretion, given EPA's authority to develop generally applicable environmental radiation-protection standards. Moreover, the staff does not believe that the derivation of release criteria corresponding to protection of individuals would be any more technically rigorous than EPA's derivation of its current release limits from a population protection goal.

The NRC staff does not perceive any significant implementation differences for standards based on protection of populations or on protection of individuals. If EPA were to base its standards on protection of individuals, a generic biosphere model could be used to translate its radiation protection objectives into allowable concentrations of radioactive materials permitted to be released to the environment. Such a translation would be very similar to EPA's previous conversion of a population protection goal into allowable cumulative releases of radionuclides. In either case, the important implementation concern is conversion of a radiation protection goal to a release limit format, eliminating speculative long-term environmental transport and dosimetry issues from a licensing review.