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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 23 1991

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Margo Oge, Acting Director
Office of Radiation Programs, ANR-458
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Ms. Oge:

Enclosed are comments of the staff of the U.S. Nuclear Regulatory Commission (NRC) on Working Draft 3 of the U.S. Environmental Protection Agency (EPA) environmental standards for management and disposal of high-level and transuranic radioactive wastes. These comments also reflect the views of the Commission's Advisory Committee on Nuclear Waste (ACNW).

Our review of Draft 3 indicates that a number of our comments on Draft 2 have been addressed by EPA. I am pleased at the progress that has been made. I also appreciate EPA's willingness to solicit the views of other interested parties regarding our suggested concept for the probabilistic containment requirements section of the standards. In the event that comments on this approach are supportive, the staff urges EPA to adopt a qualitative, rather than a quantitative distinction between "unlikely" and "very unlikely" release categories, similar to that originally suggested by the staff.

Of utmost concern in our comments, however, is the need for further consideration of the fundamental basis underlying the containment requirements of the standards. The draft Supplementary Information accompanying Draft 3 suggests that EPA will continue to advance "technical achievability" as the basis for these requirements. This approach has led to widespread controversy regarding the stringency of the standards and a growing concern that the standards may not be truly "generally applicable" to the range of sites or technologies for which the NRC may be required to make a licensing determination. Specifically, we note that every disposal concept currently being considered in the U.S. differs substantially from the conceptual models assumed by EPA when deriving its cumulative release limits.

Furthermore, EPA's reliance on a judgment of "technical achievability" as a basis for these limits casts serious doubt on whether the standards are health-based. An enclosed comment elaborates on our reservations about the appropriateness of basing standards on "technical achievability" and we reiterate our view that EPA should place greater emphasis on comparisons with other risks and radiation protection standards.

In addition, the NRC staff continues to object to EPA's assurance requirements, criteria for demonstrating compliance, and implementation guidance. In the staff's view, these are matters of implementation that go beyond EPA's standard-setting authority, and the staff recommends deletion of these sections from the standards. If EPA should receive review authority for DOE facilities not subject to NRC licensing authority, it may be appropriate for EPA to issue these sections in the form of implementing regulations, rather than as environmental standards.

Finally, our comments address the questions posed in the draft Supplementary Information and suggest some additional questions on which the NRC staff believes EPA should seek public comment.

Thank you for the opportunity to review and comment on Working Draft No. 3. We look forward to working closely with EPA during reissuance of your standards.

Sincerely,

Robert M. Bernero

Robert M. Bernero, Director
Office of Nuclear Material Safety
and Safeguards

Enclosure:
NRC Comments on Working Draft 3
of EPA's HLW Standards

NUCLEAR REGULATORY COMMISSION COMMENTS ON WORKING DRAFT 3
OF ENVIRONMENTAL PROTECTION AGENCY'S HIGH-LEVEL WASTE STANDARDS

1. In the Nuclear Regulatory Commission (NRC) staff's comments on Working Draft 2, concerns were raised about the fundamental basis underlying the containment requirements of the U.S. Environmental Protection Agency's (EPA's) high-level radioactive waste (HLW) standards. Those comments recommended that EPA reexamine the stringency of the standards in light of other risks experienced by society and the risk levels used as the basis for other safety standards, particularly those for the uranium fuel cycle. EPA's analyses of hypothetical repository performance would then play a less prominent role in supporting the standards. The NRC staff wishes to elaborate on its earlier comment regarding the technical achievability basis underlying EPA's containment requirements.

First, it is the staff's view that EPA's analyses of hypothetical repository performance, as documented in EPA's 1985 "Background Information Document" (EPA 520/1-85-023), provide only a limited basis for judging the waste-isolation capabilities of geologic repositories. Of particular concern is the incompleteness of EPA's analyses. Table 8.9.1 of the 1985 document indicates that only four disruptive events were evaluated by EPA -- fault movement, brecciation, drilling for petroleum, and volcanism. Many other disruptive processes and events could contribute to releases, including development of pluvial conditions, other climate modification such as the "greenhouse effect," gaseous release of carbon-14, elevation of the water table at an unsaturated site, and exploratory drilling for non-petroleum minerals. The incompleteness of EPA's analyses may have caused EPA to underestimate the level of releases likely to occur and, in turn, to set release limits for the standards that might not be achievable at a real repository site.

The NRC staff is also concerned that EPA did not evaluate the full range of disposal technologies under consideration for disposal of high-level and transuranic wastes. In deriving its release limits, EPA evaluated a single disposal technology -- a repository for spent fuel located in the saturated zone of a geologically quiescent site. Every disposal concept currently being considered in the U.S. differs in a substantive way from the assumptions used by EPA. For example, a repository at Yucca Mountain would be located in the unsaturated zone where gaseous releases of carbon-14 might be larger than projected by EPA. EPA has not demonstrated that such releases would pose an unacceptable threat to public health or the environment, yet EPA's standards might require costly remedial measures to control those releases. Similarly, the waste forms and packaging destined for the Waste Isolation Pilot Plant are much different from those assumed for a spent fuel repository. Additional processing of those wastes might be needed to meet EPA's release limits, even though no threat to public health or the environment has been demonstrated. Finally, various "greater confinement" and near-surface disposal concepts have been explored for disposal of transuranic and Hanford tank wastes. EPA has not evaluated the performance capabilities of these disposal technologies, yet EPA proposes that such facilities meet the same release limits as a deep geologic repository. If EPA is unable to demonstrate that such a stringent level of performance is necessary to protect public health or the environment, EPA might arbitrarily eliminate from consideration alternative disposal methods capable of providing an acceptable degree of waste isolation.

The NRC staff is concerned about EPA's ability to develop a defensible basis of support for its cumulative release standards using technical achievability considerations. The wide range of potential technologies and the lack of development of many of them raise questions about EPA's approach. Current concerns over the release limits for carbon-14 show that standards derived from the projected performance of a particular type of disposal facility may not be appropriate for the unique release pathways associated with other types of facilities. An alternative standard, expressed in terms of radiation dose and derived from comparisons with the risk levels of other accepted standards and activities, would help to ensure that EPA's standards could be reasonably applied to different types of disposal facilities. For this reason, the NRC staff urges EPA to derive its standards from an evaluation of the acceptability of various risk levels, including those previously determined to be acceptable for uranium fuel cycle facilities, and to consider adding a dose-based alternative to the cumulative release limits of the standards.

2. There appears to be an editing error on page 45 of the draft Supplementary Information, where EPA states that assessments of compliance with the individual-protection requirements "must assume that individuals consume all of their drinking water (2 liters per day) from any portion of an underground source of drinking water outside of the 'controlled area' surrounding the disposal system." EPA has deleted this provision from Working Draft 3, as we recommended in our comments on Working Draft 2.

3. In the NRC staff's comments on Working Draft 2, we recommended that EPA reevaluate the technical base underlying the guidance on frequency and severity of potential human intrusion. There we noted that EPA has apparently based its guidance on data from petroleum exploration. Exploration for non-petroleum resources may take much different forms, including multiple, closely spaced boreholes with highly site-specific drilling frequencies and borehole sealing practices. We continue to urge EPA to reexamine the basis for its guidance, including the credit, if any, given by EPA for deterrence of potential intrusion by passive institutional controls.

4. The NRC staff appreciates EPA's solicitation of comment on the staff's suggested concept for rewording the probabilistic containment requirements. We note, however, that our suggestion included a qualitative, rather than a numerical, definition of the boundary between "unlikely" and "very unlikely" release categories. If comments on the staff's basic concept are supportive, the staff urges EPA to reconsider the wisdom of a numerical classification of releases of such low likelihood.

5. EPA's probabilistic containment requirements refer to the "likelihood" of releases from a repository. Two extremes of interpretation of "likelihood" are possible, neither of which seems to be that intended by EPA. To some observers, the only permissible way to estimate the likelihood of a release is to extrapolate from the past frequencies of occurrence of the processes and events contributing to a release. In this interpretation, "likelihood" implies a degree of scientific rigor that may be unattainable because the data

base for previous occurrences may be sparse or nonexistent. On the other hand, the Bayesian school of probability theory would interpret "likelihood" as a "degree of belief" on the part of an analyst or decision-maker. In this school of thought, the degree of belief may be established independent of any scientific basis. Neither interpretation seems to be that intended by EPA.

Compounding potential implementation difficulties is a tendency to use the term "probability" or "likelihood" to refer to a combination of (1) the projected probability of a scenario leading to a release, (2) uncertainties in the estimate of that probability, and (3) uncertainties in the estimate of the size of the release. When all three of these uncertainties are combined into a single CCDF, it is possible to interpret EPA's standards as requiring a 90% level of confidence that releases will not exceed the values of Table 1, and a 99.9% level of confidence that releases will not exceed ten times the values of the table. However, it is our understanding that EPA's containment requirements are intended to refer only to the projected probability of release.

In order to more clearly express EPA's intent, we recommend that EPA distinguish between the projected probabilities of releases and the uncertainties in those projections. This distinction could be made by adding the following definition to EPA's standards:

> "Likelihood" means the probability of a scenario leading to a release of a particular size as projected from (1) the existing state of scientific knowledge regarding the frequencies of previous occurrences of the processes and events that could cause the release, and (2) for processes and events that have not previously occurred, the existing state of scientific knowledge regarding the frequency with which such processes and events are expected to occur in the future. "Likelihood" does not refer to uncertainties in projections of probabilities and sizes of releases or to the level of confidence with which the probability of a release must be projected.

6. The draft Supplementary Information accompanying Working Draft 3 includes six questions on which public comment would be solicited by EPA. The NRC's views, including those of the Advisory Committee on Nuclear Waste, on these questions are discussed below.

Question 1: Two options are presented in Sections 191.03 and 191.14, pertaining to maximum exposures to individuals in the vicinity of waste management, storage, and disposal facilities: a 25 millirems/year ede [effective dose equivalent] limit and a 10 millirems/year ede limit. Which is the more appropriate choice and why?

NRC View: The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) recommend an overall dose limit of 100 millirem/year averaged over the lifetime of an individual. This limit applies to the total radiation exposure received from all sources and practices excluding medical and natural sources. Exposures of short duration are permitted to be larger, provided that the lifetime average remains within the recommended limit. Because post-closure radionuclide releases from a high-level waste repository, if they occur, could continue for a number of years, EPA's dose limits should be apportioned from the 100 millirem/year recommended limit.

Limits for specific sources of exposure, such as a repository, are to be apportioned in a way that ensures that combined doses from all sources will not exceed 100 millirem/year. For EPA's HLW standards, the proper apportionment must take into account the range of facilities to which the dose limits would be applied. EPA proposes to apply the dose limit of Section 191.03 to the combined doses from HLW facilities and all other uranium fuel cycle facilities. Since the uranium fuel cycle includes several potential sources of exposure, it seems reasonable to allow a relatively large fraction of the overall dose limit for these facilities. Absent a clear demonstration by EPA that the 10 millirem/year limit is necessary to protect public health and safety, 25 millirem/year would be the more appropriate dose limit for the combined doses addressed by Section 191.03.

The proposed dose limit of Section 191.14 would apply only to the projected post-closure performance of a repository -- not to the combined doses from a repository and other sources. For this section, a dose limit of 10 millirem/year would allow an ample margin so that other future sources of radiation exposure would not cause total doses to exceed the limits recommended by ICRP and NCRP.

We also note that sections 191.03 and 191.14 both impose limits on the radiation dose "to any member of the public." Consistent with the recommendations of ICRP and NCRP, EPA should revise these sections to limit the average dose within the "critical group" of individuals expected to receive the largest doses.

Question 2: A new assurance requirement is presented in Section 191.13 that would require a qualitative evaluation of expected releases from potential disposal systems over a 100,000-year timeframe. Are such evaluations likely to provide useful information in any future selecting of preferred disposal sites?

NRC View: We recognize that specification of the 10,000-year time limit is somewhat arbitrary. It is important that geologic or climatic changes not occur in the near-term period following the 10,000-year limit if such changes could cause significant releases of radioactive material. The siting criteria and performance objectives of 10 CFR Part 60 are intended to reduce the potential for, and the consequences of, such disruptive changes. Thus, the NRC is sympathetic to EPA's concerns about repository performance in the post-10,000 year period. However, EPA's HLW standards are being promulgated under Atomic Energy Act authority. Accordingly, they should be "generally applicable environmental standards" as defined in Reorganization Plan No. 3 of 1970, that is, "limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment . . . ." Therefore, we do not believe that a requirement for comparison of alternative sites is an appropriate subject for EPA to address in these standards. Any long-term comparison of candidate sites should be part of a broader evaluation of alternatives under the provisions of the National Environmental Policy Act.

If EPA is concerned that the post-10,000 year performance of a repository could cause significant releases of radioactive material to the environment, an environmental standard, rather than an "assurance requirement," should be considered. Such an environmental standard would provide a basis for judging the acceptability of a single proposed repository site, rather than comparing the merits of alternative sites. However, the large uncertainties in projections of post-10,000 year performance raise questions about the practicality of such a standard. Because 10 CFR Part 60 already contains siting criteria and performance objectives that reduce the potential for significant post-10,000 year releases, NRC recommends that EPA limit application of its standards to 10,000 years.

Question 3: Two options are presented in Sections 191.14 and 191.23, pertaining to the length of time over which the individual and ground water protection requirements would apply: a 1,000-year duration and a 10,000-year duration. Which is the more appropriate timeframe and why?

NRC View: EPA states that "our own analyses show that either time frame is achievable." However, we are not aware that EPA has ever published those analyses or subjected them to independent review. NRC urges EPA to make available the analyses that support EPA's views on achievability of the individual and groundwater protection requirements.

More importantly, EPA has not demonstrated that either time period is appropriate for protection of public health or the environment. Other regulatory criteria, including those for disposal of radioactive and non-radioactive hazardous wastes, generally provide protection for shorter periods of time. EPA should explain the basis for believing that a longer period of protection is needed for disposal of high-level radioactive wastes.

Question 4: In Subpart C the Agency [EPA] proposes to prevent degradation of "underground sources of drinking water" beyond the concentrations found in 40 CFR 141--the National Primary Drinking Water Regulations. The Agency is aware, however, that there may be some types of ground waters that warrant additional protection because they are of unusually high value or are more susceptible to contamination. Should the Agency develop no-degradation requirements for especially valuable ground waters? If so, what types of ground waters warrant this extra level of protection?

NRC View: The NRC opposes adoption of a no-degradation requirement for special sources of groundwater. EPA's previous attempt to apply graduated levels of protection to groundwaters of different characteristics caused an unnecessary level of complexity in the standards. The simplicity and improved clarity of the groundwater protection requirements of Working Draft 3 represent a significant improvement over earlier drafts. The NRC strongly recommends that EPA not regress to the multiple groundwater classifications and protection levels of earlier drafts, especially in light of the extremely stringent protection levels imposed by the groundwater protection requirements of Working Draft 3.

We believe it is important to recognize that the dose rate from underground sources of drinking water, even if contaminated to the limits specified in the National Primary Drinking Water Regulations, would still contribute only a small fraction (4 percent) of the current long-term dose rate limit (100 millirem/year) for members of the public. Even if EPA adopts a 10 millirem/year individual protection standard for an HLW repository, groundwater complying with the Drinking Water Regulations would contribute no more than 40 percent of the dose rate limit. In this sense, application of the Drinking Water Regulations to a repository represents additional stringency, especially because the primary pathway for public exposures from undisturbed performance of such facilities is through drinking water.

As EPA is aware, long-term projections of the performance of an HLW repository will contain significant uncertainties. These uncertainties might make it impossible to demonstrate compliance with a no-degradation requirement, even for a relatively good site. Thus, a no-degradation requirement could become a de facto criterion for eliminating certain candidate repository sites. Instead, evaluation of the resource value of groundwaters present at a potential site should be made within the context of the National Environmental Policy Act evaluation of alternatives, rather than application of EPA's HLW standards.

Question 5: Two options are presented in Notes 1(d) and (e) of Appendix B pertaining to the transuranic waste unit: a 1,000,000 curies option and a 3,000,000 curies option. Which is the more appropriate TRU waste unit and why?

NRC View: As discussed in Comment No. 1 above, the release limits to which these notes apply were derived from EPA's analyses of the waste-isolation capabilities of a deep geologic repository for spent nuclear fuel. EPA's fundamental premise is that the fractional releases permitted from a transuranic waste disposal facility must be no greater than those thought to be achievable by a spent fuel repository. However, EPA has not demonstrated that either option is appropriate for protection of public health or the environment. As noted in Comment No. 1, the NRC strongly urges EPA to derive its standards from an evaluation of the acceptability of various risk levels, including those previously determined to be acceptable for uranium fuel cycle facilities. This derivation would include a determination by EPA of the appropriate transuranic waste unit to use for application of the release limits.

Question 6: The Agency is investigating the impacts of gaseous radionuclide releases from radioactive waste disposal systems and whether, in light of these releases, changes to the standards are appropriate. To assist us in this effort, we would appreciate any information pertaining to gaseous release source terms, chemical forms, rates, retardation factors, mitigation techniques and any other relevant technical information.

NRC View: Two reports that may be helpful are:

1. W.B. Light, et al., "C-14 Release and Transport from a Nuclear Waste Repository in an Unsaturated Medium," Lawrence Berkeley Laboratory, Report LBL-28923 (June 1990).

2. W.B. Light, et al., "Transport of Gaseous C-14 from a Repository in Unsaturated Rock," Lawrence Berkeley Laboratory, Report LBL-29744 (September 1990).

The "C-14 issue" illustrates the reason for the NRC staff's concern about the technical achievability basis underlying EPA's standards. When EPA originally derived its release limits, gaseous releases of C-14 were not foreseen. Now, it appears that the C-14 release limit of EPA's standards might not be achievable at reasonable cost even though EPA has not shown that exceeding the limit would pose a significant threat to public health or the environment. It is possible that other release modes remain to be discovered which will again require reevaluation of EPA's release limits. Standards based on comparisons with other risks and safety standards, rather than on technical achievability, would not be vulnerable to such surprises in the future.

At the September, 1990 symposium hosted by the National Research Council's Board on Radioactive Waste Management, R. Guimond of EPA suggested that an individual dose rate criterion might be considered as an alternative to the cumulative release limits of EPA's containment requirements. Such an alternative appears to be particularly appropriate for C-14. The individual dose rate limit would protect against very rapid or highly concentrated releases, while allowing a degree of flexibility in the event that the cumulative release limits could not be achieved at reasonable cost. The NRC strongly urges EPA to further develop the concept suggested by Mr. Guimond, and to solicit public comment on its merits.

7. In the NRC staff's view, there are several additional questions that EPA should ask, to solicit public comment on the standards:

-Is the technical achievability basis underlying the "containment requirements" an appropriate way to derive the standards, or should EPA base the standards on comparisons with other risks and radiation-protection standards, including those for the uranium fuel cycle?

-Is the two-step, probabilistic formulation of the "containment requirements" necessary, or would it be more appropriate to simply require that no credible release of radioactive material exceed the limits of Table 1?

-NRC's Advisory Committee on Nuclear Waste has suggested that the "containment requirements" be limited to releases caused by natural processes and events, and that separate standards be established to limit the potential for releases due to human intrusion. Would such standards be feasible and, if so, how should they be formulated?

-Are separate individual and ground water protection requirements necessary, or should they be combined into a single individual protection requirement?

-The ground water protection requirements of these standards delete a feature of the 1985 standards that allowed an incremental increase in radionuclide concentrations in ground waters that exceed EPA's drinking water standards before repository construction. The effect of this deletion may be to eliminate from consideration any candidate sites with high natural radionuclide concentrations. Should the incremental increase provision of the 1985 standards be restored?

-EPA's drinking-water standards were derived from evaluations of the water-treatment capabilities of public water-supply facilities. Does this provide a reasonable basis for evaluating the waste-isolation capabilities of waste management facilities? Should EPA require compliance with potential changes in the drinking-water regulations without first evaluating the achievability of the new regulations at waste-management facilities?

-EPA proposes to impose its individual protection and ground water protection requirements only for "undisturbed performance." Recognizing that some disturbances might be quite likely to occur, at least for certain repositories, would "anticipated performance" be a more appropriate set of conditions for these sections of the standards?

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

DEC 20 1991

MEMORANDUM FOR: The Commissioners

FROM: James M. Taylor
Executive Director
for Operations

SUBJECT: TRANSMITTAL OF INFORMATION REGARDING EPA'S HLW STANDARDS

SECY-91-266, dated August 20, 1991, informed the Commission of the staff's intent to transmit to the U.S. Environmental Protection Agency (EPA) two items of information: (1) a short bibliography of technical literature on the risks associated with radiological safety standards, uranium fuel cycle facilities, and other safety standards and facilities, and (2) example calculations illustrating how compliance might be demonstrated for the probabilistic portion of EPA's high-level waste (HLW) standards and for the NRC staff's proposed alternative concept. Enclosed, for the Commission's information, are the materials transmitted to EPA.

James M. Taylor
Executive Director
for Operations

Enclosure:
December 3 letter to Margo Oge

cc: SECY
OGC

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DEC 03 1991

Ms. Margo T. Oge, Acting Director
Office of Radiation Programs, ANR-458
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Ms. Oge:

On August 27, 1990, the staff of the U.S. Nuclear Regulatory Commission (NRC) commented on Working Draft No. 2 of the U.S. Environmental Protection Agency's (EPA's) high-level waste (HLW) standards. Included were recommendations to (1) provide comparisons with other regulations and risks as part of the support for the standards and (2) reword the probabilistic containment requirements. When we met on July 12, 1991, our discussions centered on these two topics, and your follow-up letter of July 18 raised a number of questions about them. Enclosure 1 to this letter responds to your July 18 questions.

Enclosure 2 is a short bibliography that might be useful for developing a perspective on the risk level allowed by EPA's HLW standards. Of particular interest are the papers by Kocher which compare EPA's standards to the risks allowed by other radiological standards. Kocher appears to have converted EPA's population impact goal into an individual risk by averaging over the entire U.S. population. Since this approach causes significant "risk dilution," EPA might wish to make its own estimate of the risk within the smaller population actually affected by a release from a repository.

Enclosure 3 presents several example calculations illustrating how compliance might be evaluated for EPA's 1985 containment requirements and for the NRC staff's proposed alternative. I think that most or all of your questions about the proposed alternative wording for the containment requirements (the "three-bucket approach") will be answered by the examples of Enclosure 3.

I hope the enclosed information will answer the questions of your July 18 letter. Please let me know if we can be of further assistance.

Sincerely,

Robert M. Bernero

Robert M. Bernero, Director
Office of Nuclear Material Safety
and Safeguards

Enclosures:
1. Staff's views on EPA's questions
2. Bibliography
3. Example calculations

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Enclosure 1

NRC STAFF VIEWS ON EPA'S
JULY 18 QUESTIONS

Three-bucket alternative

1. What technical analysis is there to support the contention that the level of protection is equivalent for the three-bucket methodology and the 1985 presentation of the containment requirements?

The example calculations of Enclosure 3 illustrate how an applicant might demonstrate compliance with the 1985 EPA standards and with the NRC staff's proposed alternative. For these examples, the two standards are of identical stringency when a scenario screening criterion of 1E-3 is used for the NRC staff's alternative and when 1E-4 is used for EPA's standards. If a screening criterion of 1E-4 were used for both standards, the NRC staff's alternative would be somewhat more stringent because it would apply to a broader range of scenarios than would EPA's 1985 standards.

It should be noted that differences in the two alternatives are probably more theoretical than real. Probabilities in the range of 1E-3 to 1E-4 (over 10,000 years) are very difficult to project with any real accuracy. Therefore, it will seldom be possible to produce probability estimates of the precision suggested in these examples. Indeed, that is the reason for the NRC staff's proposed alternative -- to allow a meaningful regulatory examination of unlikely disruptive scenarios while avoiding the difficulties involved in trying to predict the probabilities of unlikely processes and events.

Classification of human-initiated events as "unlikely" is not an inherent part of the NRC staff's alternative. Nevertheless, Example No. 3 illustrates how the NRC staff's alternative would be applied if human initiated events were to be classified as "unlikely." The effect would be a ten-fold increase in allowable releases (compared to classification as "likely"), the same as would be the case with EPA's 1985 standards. Since both formulations for the standards have the same effect on the allowable size of releases, the NRC staff views classification of human-initiated events as a separate issue from possible adoption of the staff's proposed alternative wording for the standards.

2. Why is the use of a deterministic analysis preferable at scenarios with a probability below 0.1? How would the uncertainties in the consequences be handled in the second bucket in order to consider the different possible orders of occurrence and the change in their probability over time, (what are the options and rationale for recommended method)?

A major difficulty in implementing EPA's 1985 standards is the need to produce both consequence and frequency estimates for unlikely releases. There is often no good statistical basis to use for the frequency estimates, so they must rely heavily on subjective judgments. Such judgments are expected to be speculative, controversial, and difficult to evaluate during a licensing review. A standard that requires only a consequence analysis (which may include an estimate of uncertainties in projected releases) is preferable to a risk-based standard because it avoids the difficulties involved in attempting to project the frequencies of occurrence for unlikely events while still providing protection for the public.

Consequence analyses for the NRC staff's proposed alternative would be no different than for EPA's 1985 standards. In either case, it would be necessary to consider the order of occurrence of events by, for example, selecting the order that causes the largest releases, or by treating the times of occurrences of all events as random variables.

3. To what extent (either quantitative or qualitative) is the three-bucket methodology felt to reduce the uncertainty of the analysis and make it more meaningful, and how can this be shown?

The NRC staff's proposed alternative makes a repository safety analysis more meaningful by focusing attention on the estimates of the sizes of potential releases rather than on the highly uncertain frequencies with which those releases are projected to occur. As demonstrated in the enclosed example calculations, the level of safety imposed by the NRC staff's alternative is essentially the same as that of EPA's 1985 standards.

4. What kind of statistical analysis and presentation would be appropriate for determining compliance for analyses in the second bucket?

The enclosed example calculations illustrate the NRC staff's concepts.

5. What criteria should be used to decide at what probability level the development of the CCDF for the first bucket should be started?

The NRC staff anticipates including all scenarios with frequencies greater than 0.01 over 10,000 years, as illustrated in the enclosed example calculations.

6. How would one develop the analysis without definitive quantitative probability value boundaries between the buckets?

The NRC staff anticipates that numerical guidance would be provided to assist in classification of processes, events and scenarios. This guidance could be a single numerical value, as suggested in the enclosed example calculations, or could be a more complex formulation that would include consideration of the number of scenarios to be screened and, possibly, qualitative estimates of the sizes of the releases associated with screened scenarios.

7. What would be the rationale for a predetermination that no intrusion events were to fall into bucket 1, as might be inferred by the Commission's definition of "anticipated" events? Would this approach also preclude using intrusion events in developing the bucket 1 CCDF while at probabilities at less than 0.1 probability?

First, the NRC staff notes that potential classification of human intrusion as "unlikely" is an entirely separate issue from adoption of the staff's alternative language for EPA's containment requirements. A determination of the likelihood of intrusion would be necessary for either EPA's 1985 standards or for the NRC staff's alternative.

If the NRC were to classify human intrusion as "unlikely," such classification would be based on a recognition of the differences between the NRC's regulatory requirements for a repository and the assumptions made by EPA when deriving its standards. As EPA noted in the Background Information Document for the standards,

> The Agency . . . has estimated drilling rates that are intended to be upper bounds on the future likelihood of drilling at a repository site. In estimating these values, no credit has been taken for the communication to future generations of the presence of the repository, except . . . for 100 years after disposal . . .

EPA's estimated drilling rates are apparently derived by assuming that the drilling rates of the recent past can be extrapolated for 10,000 years into the future. Such an extrapolation would clearly be an upper bound estimate for an unmarked, unrecorded repository since past random drilling practices have already been largely replaced by targeted drilling aimed at known or inferred resource locations. Thus, even for a "stealth" repository of the type assumed by EPA, actual drilling rates are likely to be lower than the upper bounds estimated by EPA.

The NRC's repository regulations (10 CFR Part 60) would not permit licensing of a repository of the type assumed by EPA. Part 60 requires an extensive site characterization program, including identification and evaluation of potential resources at the repository site. Part 60 also requires Federal government ownership of land and mineral rights within the controlled area, and establishment of such controls outside the controlled area as are necessary to prevent human interference with waste isolation. Finally, Part 60 requires use of monuments and land-use records to warn potential future intruders of the existence and dangers of a repository. These regulatory requirements were judged to be adequate to classify human intrusion as "unanticipated" in Part 60, and could also serve as a basis to classify intrusion as "unlikely" for purposes of implementing EPA's standards. Such classification would exclude intrusion from the CCDF for "likely" releases.

8. What are the alternative rationales for having the analysis cut off at a low probability of one in one thousand vs. one in ten thousand? Which should be used and why?

The enclosed example calculations suggest that one in one thousand would generally impose the same level of safety as EPA's 1985 standards since "unlikely" events would be assigned a conservatively high probability of $\leq .01$. Nevertheless, if there were a large number of scenarios with releases exceeding ten times the table of release limits, a cut-off of one in ten thousand might be needed. The NRC staff prefers a qualitative criterion, as suggested in our Working Draft No. 2 comments, with a numerical guideline offered by EPA in its Supplementary Information. A qualitative regulatory criterion would allow the NRC the flexibility to develop an appropriate numerical value for each specific repository.

Alternative Risk Basis for EPA Standard

1. What would be the proper basis to use for the present acceptable risk to present generations, and how would this be expressed?

As noted by both the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP), risks which are less than 1/100,000 per year and which are also "as low as reasonably achievable" (ALARA) can be considered acceptable for current non-occupational radiation exposure (exclusive of medical and natural background exposure). The ICRP, the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) all recommend that future radiation exposures be limited to this same level of risk. These organizations further recommend apportionment of a suitable fraction of this risk level for a specific activity such as disposal of high-level wastes. As stated by the ICRP:

> To allow for dose contributions from present practices and to provide a margin for unforeseen future activities, the [ICRP] recommends that national authorities select a fraction of the dose limits as a source upper bound for each source of exposure to ensure that the exposure of individuals will remain below the relevant dose limit.

Determination of the appropriate fraction of the overall limit to be allocated to disposal of HLW would include consideration of the existing level of non-medical, anthropogenic radiation exposures and of the fraction to be reserved for future activities.

2. EPA staff have reviewed some assessments of the uranium fuel cycle and its collective risk, but such evaluations seem to be quite old. Does NRC have a more current assessment of the collective risk of the uranium fuel cycle that reflects dose commitment, current dose conversion, and emission estimates?

The most recent information of which we are aware is that of NCRP Reports 92 and 93. This information is relatively old (late 70's and early 80's) and is derived primarily from models of facility performance rather than from actual measurements. The NCRP estimates that the total annual effective dose equivalent per person in the U.S. is 3.6 mSv (360 mrem), of which 0.014% is attributable to the nuclear fuel cycle. The nuclear fuel cycle is also estimated to cause an annual population exposure to regional populations of 1.36 person-Sv (136 person-rem) per gigawatt, 87% of which results from uranium mining and milling.

3. Since both the commercial sector and the DOE will be using the repository would you think that the present releases and impacts of both these activities should be analyzed in order to arrive at intergenerational equity?

To the extent that both commercial and defense activities are expected to contribute to long-term radiation exposures, either through continued operations or through discharges of long-lived radioactive materials, their impacts are relevant for determining the fraction of the overall risk limit to be allocated to disposal of HLW.

The important concept advanced by the ICRP and others is establishment of an overall limit on allowable radiological impacts for the future. In order to ensure that the activities of future societies are not unduly constrained, the ICRP recommends that a suitable fraction of the recommended limit be allocated for each specific type of activity or facility. Factors to consider when determining the fraction of the limit to be allocated to a specific activity or facility would include the number of people likely to be affected by a release and the duration of expected releases. For example, if a release is likely to be wide-spread and long-lasting, as with gaseous release of C-14, a small fraction would be appropriate to allow an ample margin for future activities. On the other hand, releases that are more restricted in time and/or space can be somewhat larger because such releases will impose fewer restrictions on future societies. In particular, sources of exposure located in relatively isolated areas where future radiological activities are unlikely (e.g., uranium mill tailings in the U.S.) can be allocated a larger fraction of the limit than could similar facilities located in or near urban areas. Since repository locations in the U.S. are likely to be in relatively isolated areas, allocation of a reasonably large fraction of the recommended limit (perhaps 10%) would not seem unreasonable.

4. Initial considerations of this approach indicate that it might not provide a basis to discern a "good" repository. Is it the NRC belief that this should not be a role for the EPA standard?

EPA's standards should provide a basis for distinguishing an acceptable repository from an unacceptable one. The NRC staff does not object to the notion that EPA's standards might be based, in part, on a desire to keep releases ALARA. However, the NRC staff would object to any standards that would require a quixotic search for "the best" repository.

As noted in our comments on Working Draft No. 2, we recommend that EPA "place increased emphasis on comparisons with other regulatory standards and guidance, and with other risks experienced by society" when deriving the release limits of the standards. We do not think that the technical achievability rationale used by EPA to support the 1985 standards are inherently inappropriate.

Rather, we note that those analyses were relatively simple and may not adequately represent the level of performance to be expected from a real repository. Supplementing those analyses with the recommended comparisons with other standards and risks would provide a stronger basis of support for the standards.

Enclosure 2

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EXAMPLES OF COMPLIANCE DEMONSTRATIONS

FOR 40 CFR PART 191 CONTAINMENT REQUIREMENTS

AND THE NRC STAFF'S PROPOSED ALTERNATIVE

1. INTRODUCTION

Most radiation protection standards are non-probabilistic -- that is, the standards contain no explicit statement of the probabilities of the conditions to which the standards apply. Examples are the uranium fuel cycle standards of the U.S. Environmental Protection Agency (EPA). Those standards simply require that uranium fuel cycle facilities be operated "in such a manner as to provide reasonable assurance" that certain dose limits will not be exceeded. The term "reasonable assurance" is not defined, nor do the standards provide a probabilistic definition of the range of operating conditions to which the dose limits are to be applied.[1]

Parts of EPA's high-level radioactive waste (HLW) standards[2] are also stated non-probabilistically. EPA's standards for operations (Subpart A) essentially extend EPA's uranium fuel cycle standards to include operations at an HLW repository. Similarly, EPA's post-closure standards for protection of individuals and groundwater are applicable only to "undisturbed performance." Thus, for these sections of the standards, there is no need to evaluate the likelihood of processes and events that might disrupt the performance of a repository.

EPA could have used a similar format for its environmental standards for the disturbed performance of a repository. For example, EPA could have simply required that disturbed performance not cause projected impacts greater than some multiple of the level of impacts allowed for undisturbed performance. This type of standard would have directly limited the impacts that might be caused by a repository without requiring a numerical estimate of the likelihood that any specific level of impact would occur. However, EPA chose instead to formulate its standards in a way that requires numerical estimates of both the sizes of possible releases from a repository and the probabilities that those releases will occur. Specifically, EPA's standards require that:

---

[1]It is implicitly understood that EPA's uranium fuel cycle standards apply only to "normal" operations, and that there is no requirement to design a facility to comply with those standards in the event of an unlikely accident.

[2]EPA's HLW standards, 40 CFR Part 191, were promulgated in 1985, but were partially remanded by a Federal court decision in 1987. In this paper, references to EPA's HLW standards mean the standards as promulgated in 1985.

> Disposal systems . . . shall be designed to provide a reasonable expectation . . . that the cumulative releases . . . for 10,000 years after disposal . . . shall:
>
> (1) Have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1 . . .; and
>
> (2) Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 . . . .

Evaluating compliance with these "containment requirements" would require numerical estimates of the probabilities of processes and events with likelihoods as low as 10^{-7} to 10^{-6} per year. Probabilities this low are very difficult to estimate, and any estimates produced will be very uncertain. In fact, EPA's requirement for numerical estimates of probabilities this low has caused many observers to question whether EPA's standards would be workable in the NRC's formal licensing process.

On August 27, 1990, the NRC staff recommended that EPA consider an alternative formulation for its containment requirements. The NRC staff's proposal retained EPA's probabilistic formulation for relatively likely releases, but substituted a non-probabilistic consequence limit for unlikely releases. The following text for EPA's containment requirements was suggested to implement the staff's proposal:

> Disposal systems . . . shall be designed to provide a reasonable expectation that, for 10,000 years after disposal:
>
> (1) anticipated performance will not cause cumulative releases of radionuclides to the accessible environment to have a likelihood greater than one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix B); and
>
> (2) the release resulting from any process, event, or sequence of processes and events that is sufficiently credible to warrant consideration will not exceed ten times the quantities calculated according to Table 1 (Appendix B).

EPA solicited public comment on the NRC staff's proposal after substituting the phrase "have a likelihood between one chance in 10 and one chance in 10,000" for "is sufficiently credible to warrant consideration." Questions have arisen regarding the NRC staff's proposal, including:

(1) How would an applicant demonstrate compliance with the NRC staff's alternative standards?

(2) Would the NRC staff's alternative require an identical (or nearly equivalent) level of repository safety?

(3) Should the scope of regulated repository disruptions be defined qualitatively, as in the NRC staff's proposal, or would EPA's numerical

modification be more appropriate? If a number is desired, what should it be?

The example calculations presented in this paper are intended to help answer these questions. Section 2 provides some background information on the distinction between the repository system and its environment, the use of modified "event trees" for scenario analyses, and the use of the "complementary cumulative distribution function" (CCDF) to display the estimated uncertainties in repository performance. Section 3 then presents several example calculations comparing EPA's probabilistic standards to the NRC staff's proposed alternative.

2. BACKGROUND INFORMATION

2.1 The Repository System and its Environment.

As illustrated in Figure 1, the entire regulated repository system, including engineered and natural components, can be treated as a system that exists within, and responds to, an evolving external environment. Possible

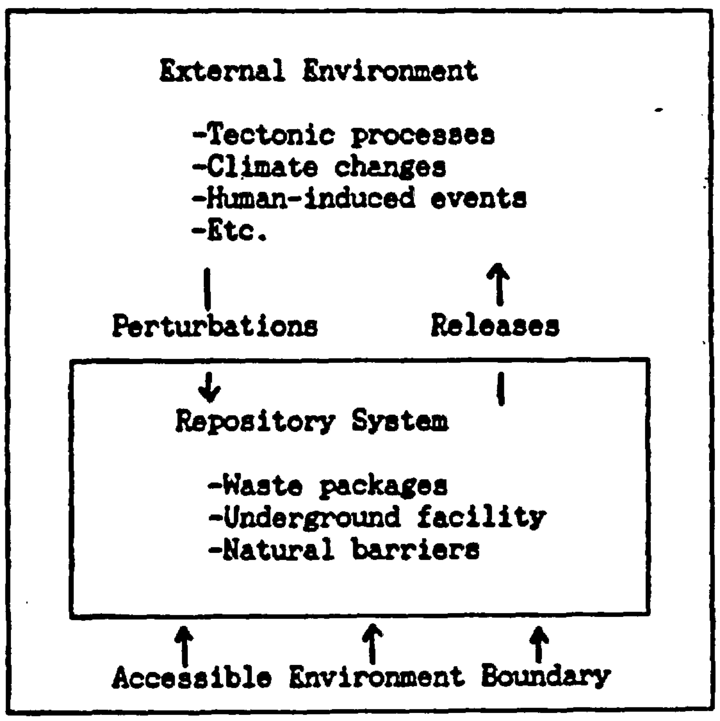

Figure 1. Conceptual representation of repository system and its environment.

evolutions of the repository environment are identified as "scenarios," while uncertainties about the performance of the system within its environment (e.g., corrosion of waste packages) are assumed to be incorporated into the models of the system. Thus, in the example calculations presented in this document, the term "scenario" refers only to external processes and events in the repository environment that could perturb repository performance. Uncertainties about the initial conditions of the repository system and about its response to external perturbations are not included in scenario analyses because they are assumed to be incorporated into the models of the system.

2.2 Scenario Analyses.

In these example calculations, scenarios are constructed using diagrams similar to the event trees used in probabilistic risk assessments. Figure 2 illustrates an example of such a diagram.

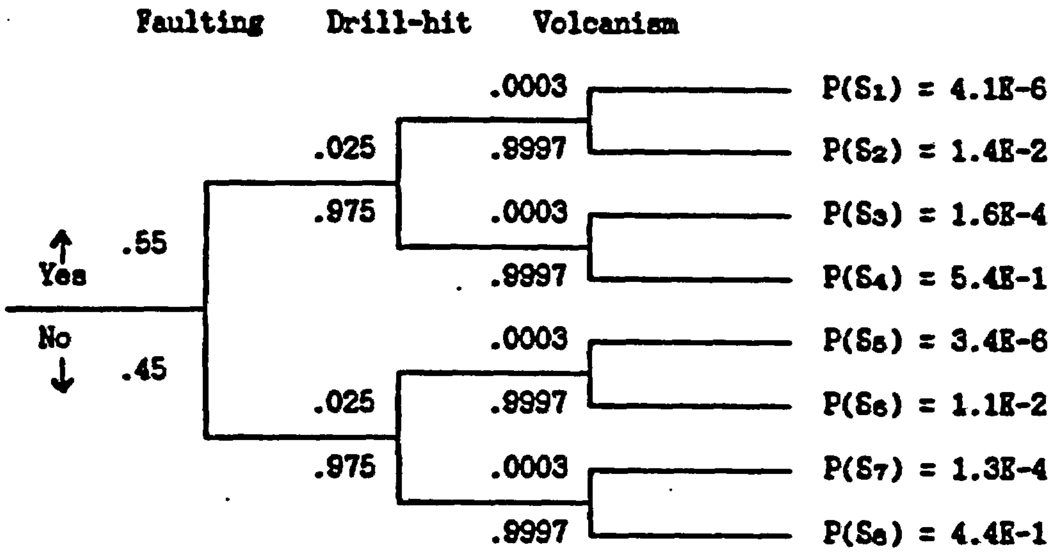

Figure 2. Example of a scenario analysis.

In Figure 2, each branch point represents the potential for a disruptive process or event to occur. The numbers above and below the branch point indicate the probability that the process or event does or does not occur. In Figure 2, the left branch point represents the potential for fault movement, .55 is the probability (over 10,000 years) that fault movement does occur, and .45 is the probability of no fault movement. Similarly, the center and right branches illustrate the potential for, and the probabilities of, drilling that hits a waste package and volcanism.

Each path from left to right through Figure 2 represents a potential evolution of the repository environment, or a "scenario." Multiplication of the event probabilities along each path gives the probability that the scenario will occur. For example, the top scenario (S_1) represents the sequential occurrence of all three events, and has a probability of 4.1E-6 over 10,000 years. No disruptive events occur in the bottom scenario (S_8) where the estimated probability is 4.4E-1. Scenarios S_2-S_7 involve other possible combinations of the three potentially disruptive events.

One step in a scenario analysis is identification of potentially disruptive processes and events. Possible variations in locations, magnitudes, and other characteristics could cause the number of processes and events to become so large that a scenario analysis would be unmanageable. It is necessary, therefore, to use a single process or event to represent a larger class of similar processes or events. For example, movement of a specified magnitude on a particular fault could be taken as an approximation of all other potential fault movements near a site. Approximations of this type clearly involve trade-offs between the realism (or accuracy) of a scenario analysis and its complexity. As iterative performance assessments are carried out for a particular repository, the number of processes and events needed to achieve a desired degree of realism can be determined.

2.3 Complementary Cumulative Distribution Function (CCDF).

Estimates of projected releases from a repository will contain many uncertainties, some of which can be quantified in a meaningful way. One format for displaying the quantifiable uncertainties is the "complementary cumulative distribution function" (CCDF). The CCDF is a curve showing, on the vertical axis, the probability that releases will exceed the values on the horizontal axis. Figure 3 is an example of a CCDF where the size of a projected release is measured in multiples of EPA's table of release limits. Also shown in Figure 3 is a "stair-step" limit representing the maximum releases allowed by EPA's HLW standards.

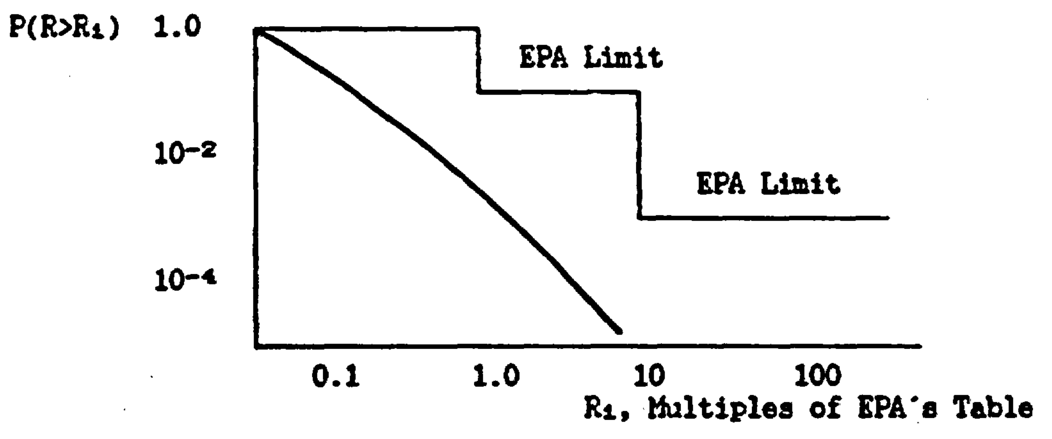

Figure 3. Example of a Complementary Cumulative Distribution Function (CCDF).

In Figure 3, the vertical axis displays the probability that releases will be larger than the values on the horizontal axis. Release probabilities are obtained by summing the probabilities of processes and events that could cause releases. If the regulatory limit applies to releases with probabilities of 1E-3, as illustrated in Figure 3, it will be necessary to include in the summation all processes and events with probabilities greater than about 1E-4 to assure completeness of the CCDF.

2.4 Conditional CCDF.

The releases projected for an individual scenario can be displayed using a "conditional CCDF." A conditional CCDF represents uncertainties in projected releases, assuming the occurrence of a scenario. If conditional CCDF's are calculated for each scenario, a composite CCDF for a repository can be formed using the relationship

$$P(R>R_i) = \Sigma\, P(S_j)P(R>R_i|S_j)$$

where $P(S_j)$ is the probability that scenario S_j will occur and $P(R>R_i|S_j)$ is the conditional probability that releases will exceed R_i assuming that S_j occurs.

3. EXAMPLE CALCULATIONS

An evaluation of compliance with EPA's 1985 standards would involve six steps, as follows.

Step 1 -- Identify disruptive processes and events. All potentially disruptive processes and events that could occur external to the repository system would be identified. In general, processes and events occurring within the repository system, such as waste package corrosion, would be included in models of repository performance. However, when processes and events are initiated outside the repository system, or result from phenomena occurring outside the repository system, they would be considered to be "external." Examples would include drilling that penetrates a repository and movement of a fault that intersects the repository system.

Step 2 -- Screen processes and events. Processes and events could be eliminated from the list of Step 1 on the basis of low probability (including physical impossibility) or the insignificance of estimated releases. EPA's 1985 standards suggest elimination of processes and events with probabilities less than 1/10,000 over 10,000 years.

Step 3 -- Form scenarios. Processes and events would be combined into scenarios as discussed previously in Section 2.2.

Step 4 -- Screen scenarios. Scenarios could be eliminated from further analysis using the same screening criteria as in Step 2.

Step 5 -- Estimate scenario releases. Releases from all processes and events included in each scenario would be estimated.

Step 6 -- Form CCDF. The probability and release estimates for all scenarios would be combined into a CCDF of the form described in Section 2.3. This CCDF would be compared to the two release limits imposed by EPA's standards.

Evaluating compliance with the NRC staff's proposed alternative standard would be virtually identical, except for Step 6. With the staff's alternative, Step 5 would be followed by a test for compliance with the requirement that the release associated with each scenario be less than ten times EPA's table of release limits. If that requirement were met, all likely scenarios (those with probabilities >.01) would be combined into a CCDF to determine the cumulative likelihood of releases larger than EPA's table.

The example calculations presented here start with a "baseline example." This is largely a reproduction of one of the analyses included in EPA's "Background Information Document" (BID) which provides the technical support for EPA's standards.[3] The baseline example uses single value estimates of the probabilities and consequences of three potentially disruptive events to illustrate construction of a CCDF and comparison of that CCDF with the release limits of EPA's HLW standards. A second example then shows how the information from the baseline example would be used to evaluate compliance with the alternative standards proposed by the NRC staff. Additional examples consider variations from the baseline example and illustrate application of the two standards to those variations. Finally, the single value estimates of probabilities and releases are replaced by distributed estimates to illustrate how uncertainties might be incorporated into an evaluation of compliance.

EPA's BID presents analyses of the projected performance of hypothetical spent fuel repositories in four geologic media: basalt, bedded salt, tuff and granite. Five disruptive events were considered: fault movement, breccia pipe formation (salt only), drilling (does not hit a canister), drilling (hits a canister), and volcanic activity. For most events in most media, EPA estimated probabilities much higher or much lower than would be of interest for these example calculations. Only brecciation in salt and volcanic activity in tuff were estimated to have probabilities in the range of interest (10^{-7} to 10^{-8} per year). Brecciation in salt either caused no releases or the estimated releases were not reported by EPA. Therefore, EPA's hypothetical tuff site was chosen for the example calculations presented below.

The following probability and release estimates for EPA's tuff repository were inferred from information in Tables 8.9.1 and 8.10.1 of EPA's BID.

Table 1. Estimates of probabilities of disruptive events and resulting releases.

Event	Probability in 10,000 yr	Release over 10,000 years (Multiples of EPA's Table)
Fault Movement	5.5E-1	5.4E-3
Drilling (hits Canister)	2.5E-2	8.6E-2
Volcanic Activity	3.0E-4	8.0E0

[3]"Background Information Document: Final Rule for High-Level and Transuranic Radioactive Wastes," U.S. Environmental Protection Agency Report Number EPA 520/1-85-023, August, 1985.

Table 8.9.1 of EPA's BID estimates the frequency of fault movement to be 8E-5/yr. Treating fault movement as a Poisson process, the probability of at least one occurrence of fault movement in 10,000 years would be
1 - exp-(8E-5)(10,000) = 0.55. The probabilities that drilling and volcanic activity will occur within 10,000 years are simply 10,000 times the annual estimates in EPA's BID.

Table 8.10.1 of EPA's BID lists EPA's estimates of the expected number of fatal cancers over 10,000 years due to fault movement and drilling. It is important to note that Table 8.10.1 gives expected value estimates which are the product of the actual estimate of fatal cancers and the probability that the disruptive event will occur. In Table 1, above, the release estimates are based on actual fatal cancer estimates derived by dividing EPA's expected value estimates by the probabilities of Table 1.

Tables 8.9.1 and 8.10.1 of EPA's BID do not provide an estimate of the number of fatal cancers that would result from volcanic activity. However, Table 8.9.1 does estimate that the fraction of the repository inventory that would be dispersed to the environment would be 4E-4. At 1,000 years, the repository inventory is about 2E4 times EPA's table of release limits. Assuming 4E-4 as the fraction released, the release would be 8 times Table 1.

Example 1 -- Baseline Example.

This example attempts to reproduce EPA's evaluation of the projected performance of a spent fuel repository in unsaturated tuff.

Step 1 -- Identify disruptive processes and events.

For this example, it is assumed that the only conceivable disruptive processes and events are the five identified by EPA: fault movement, brecciation, drilling (misses waste packages), drilling (hits waste package), and volcanic activity.

Step 2 -- Screen processes and events.

Brecciation is eliminated from further consideration because of physical impossibility in a tuff medium. Drilling (misses waste packages) is also eliminated on the basis of EPA's estimate that no releases would occur.

Step 3 -- Form scenarios.

The eight scenarios for this example are illustrated in Figure 4.

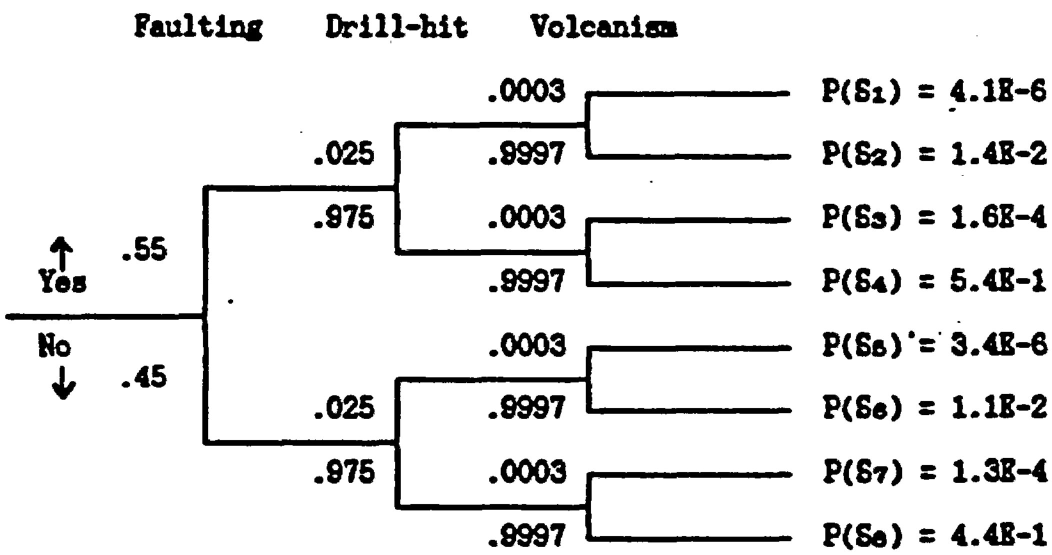

Figure 4. Scenarios for Example 1.

Step 4 -- Screen scenarios.

In this example, scenarios S_1 and S_5 would be eliminated from further consideration because the estimated probabilities are below EPA's specified cut-off of 1E-4.

<u>Step 5</u> -- Estimate scenario releases.

The release estimates for disruptive events are assumed to be those of Table 1. If a scenario includes more than one event, the scenario release is assumed to be the sum of the releases caused by the constituent events.

<u>Step 6</u> -- Form CCDF.

Table 2 illustrates how a CCDF is constructed by listing the scenarios in order of decreasing size of releases, and by calculating the cumulative probability that the release exceeds the value for each scenario.

Table 2. CCDF data for Example 1.

Scenario	Probability	Release	Cumulative Probability
S_3 F,V*	1.6E-4	8.005**	1.6E-4**
S_7 V	1.3E-4	8.000	2.9E-4
S_2 F,D	1.4E-2	.091	1.429E-2
S_6 D	1.1E-2	.086	2.529E-2
S_4 F	5.4E-1	.005	5.6529E-1
S_8 Undisturbed	4.4E-1	0	1.0***

*Notation indicates Scenario S_3 in which faulting and volcanism occur.
**Digits are not all significant, but are presented to illustrate summations of releases and probabilities.
***Rounding may cause a sum slightly different from 1.0.

Plotting the third and fourth columns of Table 2 gives the curve of Figure 5.

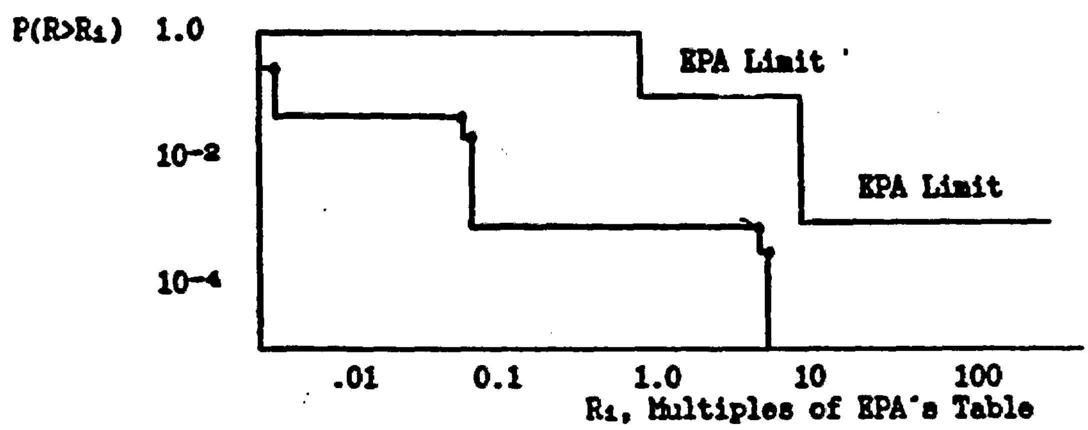

Figure 5. CCDF for Example 1, showing compliance with EPA's release limits.

Figure 5 is a reasonable approximation of the CCDF presented by EPA in Figure 8.10.3 of EPA's BID.

Example 2 -- NRC Staff's Alternative.

This example uses the same data as Example 1 to illustrate the similarities and the differences between EPA's 1985 standards and the NRC staff's proposed alternative.

Step 1 -- Identify disruptive processes and events.

Same as Example 1.

Step 2 -- Screen processes and events.

Same as Example 1.

Step 3 -- Form scenarios.

The eight scenarios for this example are illustrated in Figure 6. The scenarios are essentially the same as in Example 1, except that only a bounding probability estimate of <.01 is provided for the unlikely volcanism event. A probability of .01 over 10,000 years, or 10^{-6}/yr, is often considered to be at the lower range of probability values that can be meaningfully quantified.

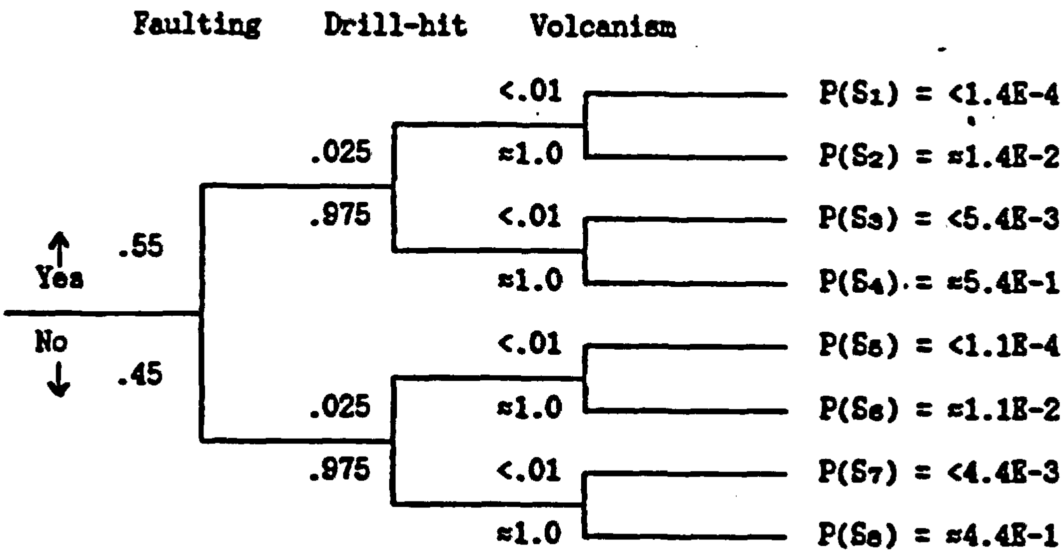

Figure 6. Scenarios for Example 2.

Step 4 -- Screen scenarios.

Because it is so difficult to meaningfully quantify probabilities in the range of 1E-7 to 1E-8 per year, the NRC staff's proposed alternative suggested a qualitative screening criterion (sufficiently credible to warrant consideration) to determine which scenarios should be retained for further analysis. Nevertheless, if a bounding value of <.01 is assigned to unlikely events as in Figure 6, it would be possible to use a numerical screening criterion. Using EPA's suggested numerical value of 1E-4, scenarios S_1 and S_5

would be retained, even though they were eliminated in Example 1. Thus, a value of 1E-4 would make the NRC staff's alternative somewhat more stringent than EPA's current standards. 1E-3 is used in this example, eliminating scenarios S_1 and S_5.

<u>Step 5</u> -- Estimate scenario releases.

Same as Example 1.

<u>Step 6</u> -- Test releases for compliance.

The NRC staff's alternative requires that the release from each scenario be less than ten times EPA's table of release limits. In this example, all scenarios meet this requirement.

<u>Step 7</u> -- Form CCDF for anticipated performance.

Table 3 illustrates construction of a CCDF only for those scenarios with probabilities >.01, i.e., those scenarios likely to contribute significantly to the CCDF in the region of P = 0.1.

Table 3. CCDF data for Example 2.

Scenario	Probability	Release	Cumulative Probability
S_2 F,D	1.4E-2	.091	1.4E-2
S_6 D	1.1E-2	.086	2.5E-2
S_4 F	5.4E-1	.005	5.65E-1
S_8 Undisturbed	4.4E-1	0	1.0

Plotting the data of Table 3 gives the curve of Figure 7.

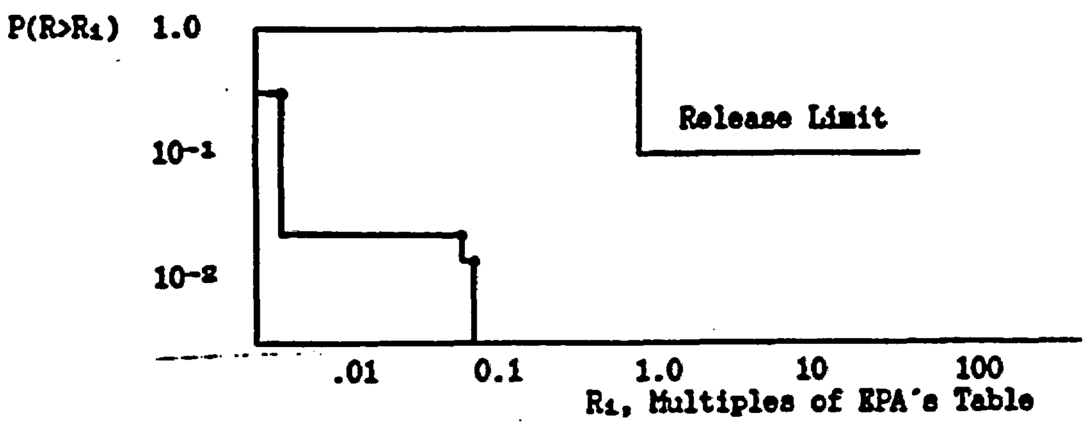

Figure 7. CCDF for Example 2, showing compliance with the NRC staff's alternative standard for anticipated performance.

Example 2 illustrates the importance of the screening criterion for excluding scenarios from further analysis. Use of bounding probability estimates (<.01) for unlikely events produces bounding estimates for scenario probabilities as well. Because scenario probabilities are overestimated, highly unlikely scenarios may be retained in the analysis if EPA's screening criterion of 1E-4 is used. In this example, a criterion of 1E-3 retains the same scenarios that were retained in Example 1.

Example 3 — Human Intrusion Classified as "Unlikely."

The NRC's HLW repository regulations, 10 CFR Part 60, now classify human-initiated disruptions as "unanticipated." An equivalent treatment under the NRC staff's proposed alternative would classify human intrusion as "unlikely." This example illustrates the significance of such classification.

Step 1 — Identify disruptive processes and events.

Same as Example 1.

Step 2 — Screen processes and events.

Same as Example 1.

Step 3 — Form scenarios.

The eight scenarios for this example are illustrated in Figure 8. The scenarios are essentially the same as in Example 1, except that bounding probability estimates of <.01 are provided for both volcanism and drilling (hits waste package).

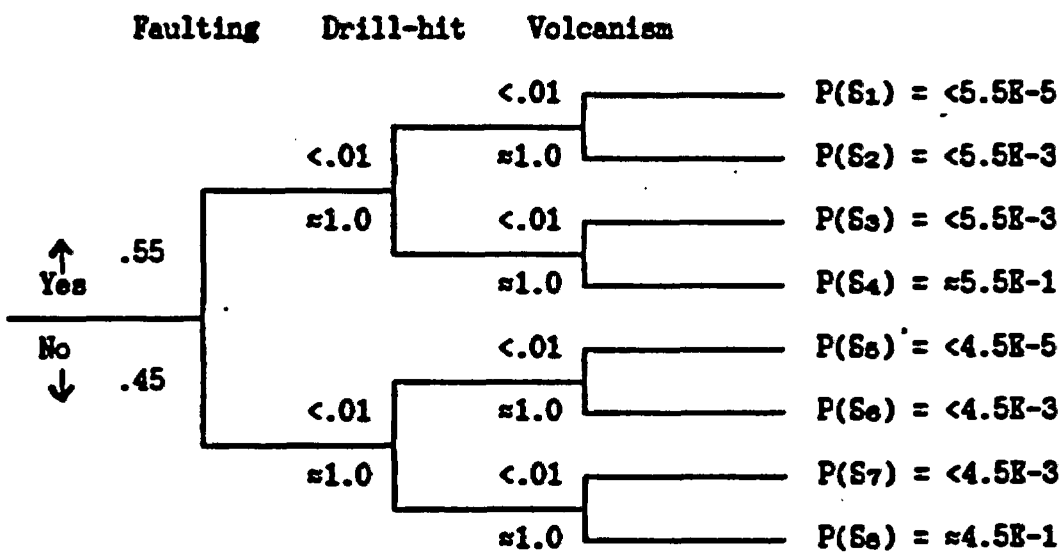

Figure 8. Scenarios for Example 3.

Step 4 — Screen scenarios.

Scenarios S_1 and S_5 are eliminated because the estimated probabilities are much less than 1E-3.

Step 5 — Estimate scenario releases.

Same as Example 1.

Step 6 — Test releases for compliance.

The NRC staff's alternative requires that the release from each scenario be less than ten times EPA's table of release limits. In this example, all scenarios meet this requirement.

Step 7 -- Form CCDF for anticipated performance.

Table 4 illustrates construction of a CCDF only for those scenarios with probabilities >.01, i.e., those scenarios likely to contribute significantly to the CCDF in the region of P = 0.1. In this example, only two scenarios are included in the CCDF.

Table 4. CCDF data for Example 3.

Scenario	Probability	Release	Cumulative Probability
S_4 F	5.4E-1	.005	5.5E-1
S_8 Undisturbed	4.4E-1	0	1.0

Plotting the data of Table 4 gives the curve of Figure 9.

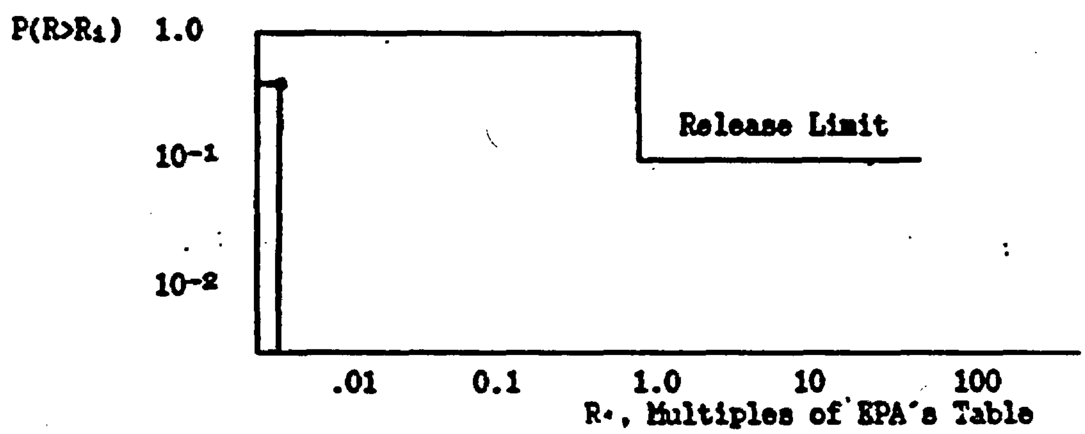

Figure 9. CCDF for Example 3, showing compliance with the NRC staff's alternative standard for anticipated performance.

Classification of human-initiated events as "unlikely" would remove human intrusion scenarios from the CCDF of Figure 9. Instead, releases from human intrusion scenarios would be compared scenario-by-scenario to a limit of ten times EPA's table of release limits. The effect would be to allow a ten-fold increase in releases from human intrusion scenarios. It is important to note, however, that the change in the allowable size of release does not result from adoption of the NRC staff's alternative wording for the standards. Using EPA's 1985 standards, the NRC could also specify a probability for human intrusion of <0.01. Doing so would have the same effect of allowing a ten-fold increase in releases from human intrusion.

Example 4 -- Higher Probability and Larger Release for Volcanism - Evaluation of Compliance with EPA's HLW Standards.

In this example, the probability of volcanism and the estimated release are increased by a factor of ten. The increases are sufficient to cause a marginal violation of EPA's 1985 standards, as illustrated in this example.

Step 1 -- Identify disruptive processes and events.

Same as Example 1.

Step 2 -- Screen processes and events.

Same as Example 1.

Step 3 -- Form scenarios.

The eight scenarios for this example are illustrated in Figure 10. The scenarios are the same as in Example 1 except that the probability estimate for volcanic activity is increased by a factor of ten.

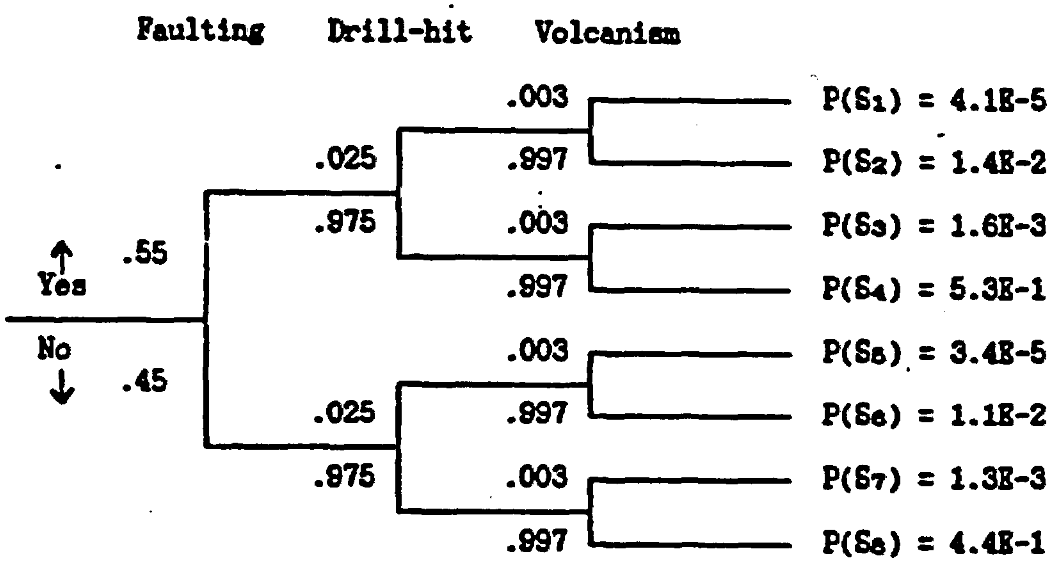

Figure 10. Scenarios for Example 4.

Step 4 -- Screen scenarios.

In this example, scenarios S_1 and S_5 would be eliminated from further consideration because the estimated probabilities are below EPA's specified cut-off of 1E-4.

Step 5 -- Estimate scenario releases.

Same as Example 1 for fault movement and drilling (hits waste package). For this example, the release from volcanism is postulated to be ten times larger than in Example 1. Therefore, the release from scenario S_3 is estimated to be 80.005 times EPA's table of release limits and the release from scenario S_7 is estimated to be 80.0 times EPA's table.

Step 6 — Form CCDF.

Table 5 illustrates construction of a CCDF for this example.

Table 5. CCDF data for Example 4.

Scenario	Probability	Release	Cumulative Probability
S_3 F,V*	1.6E-3	80.005	1.6E-3
S_7 V	1.3E-3	80.000	2.9E-3
S_2 F,D	1.4E-2	.091	1.69E-2
S_6 D	1.1E-2	.086	2.79E-2
S_4 F	5.4E-1	.005	5.679E-1
S_8 Undisturbed	4.4E-1	0	1.0

Plotting the data of Table 4 gives the curve of Figure 11, illustrating a violation of EPA's release limit.

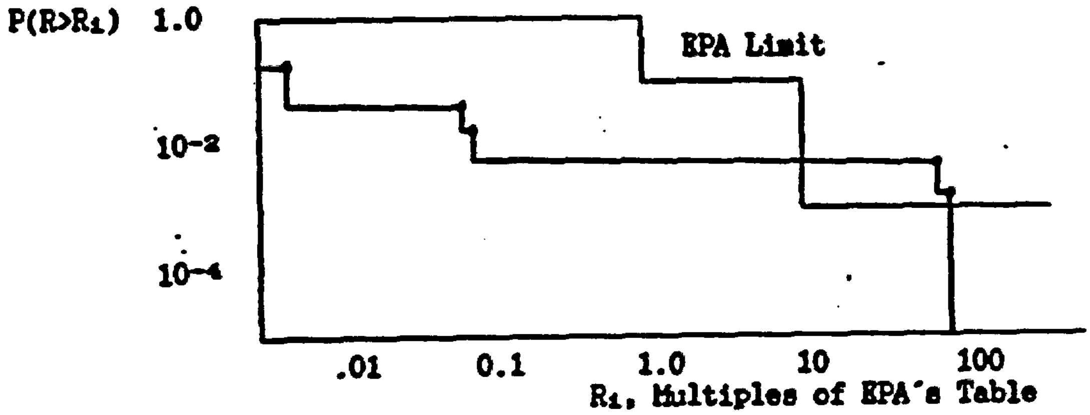

Figure 11. CCDF for Example 4, showing a violation of EPA's release limits.

Example 5 -- Higher Probability and Larger Release for Volcanism - NRC Staff's Alternative.

This example uses the same probability and release estimates as Example 4 to determine whether the NRC staff's proposed alternative will also identify a violation.

Step 1 -- Identify disruptive processes and events.

Same as Example 1.

Step 2 -- Screen processes and events.

Same as Example 1.

Step 3 -- Form scenarios.

The scenarios for this example are illustrated in Figure 12. The scenarios are essentially the same as in Example 1, except that only a bounding probability estimate of <.01 is provided for the unlikely volcanism event.

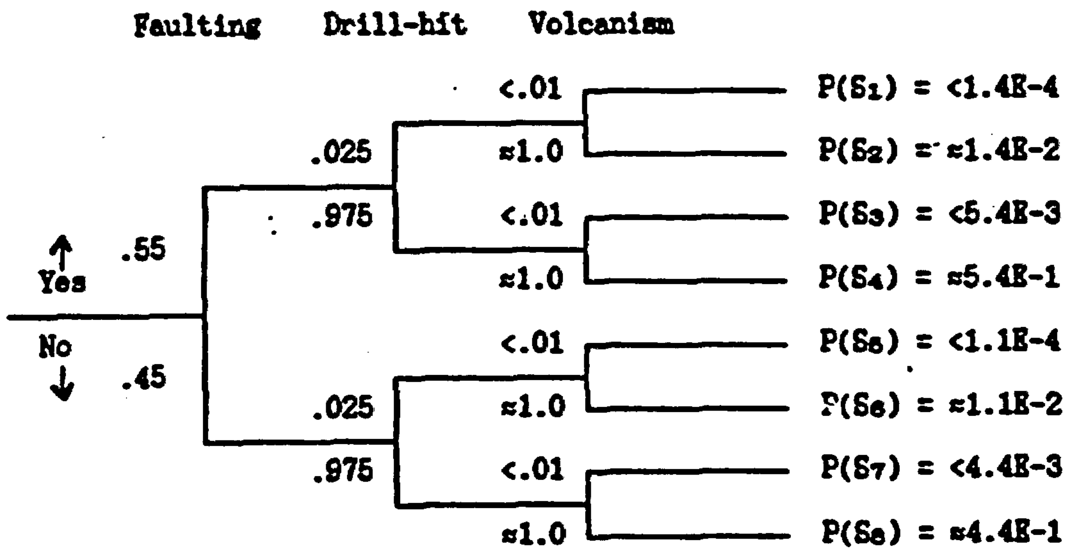

Figure 12. Scenarios for Example 5.

Step 4 -- Screen scenarios.

This example again illustrates the importance of the screening criterion for excluding scenarios from further analysis. Using EPA's value of 1E-4, scenarios S_1 and S_5 would be retained, making the NRC staff's alternative somewhat more stringent than EPA's current standards. For this example, a criterion of 1E-3 is used, eliminating scenarios S_1 and S_5.

<u>Step 5</u> -- Estimate scenario releases.

Same as Example 4, where the release from volcanism is postulated to be ten times larger than in Example 1. The release from scenario S_3 is estimated to be 80.005 times EPA's table of release limits and the release from scenario S_7 is estimated to be 80.0 times EPA's table.

<u>Step 6</u> -- Test releases for compliance.

The NRC staff's alternative requires that the release from each scenario be less than ten times EPA's table of release limits. In this example, scenarios S_3 and S_7, which include volcanism, fail to meet this requirement.

<u>Step 7</u> -- Form CCDF for anticipated performance.

For this example, there is no need to develop a CCDF for anticipated performance since individual scenario releases already indicate non-compliance with the NRC staff's proposals. If a CCDF were to be plotted for anticipated performance, it would be identical to that for Example 2.

In this example, the requirement that no scenario cause a release greater than ten times EPA's table is equivalent to EPA's CCDF formulation for identifying the unacceptable release from volcanism. This example again shows that a scenario screening criterion of 1E-4 would make the NRC staff's proposed alternative more stringent than EPA's 1985 standards, although for this example there would be no practical effect since the release limit is exceeded even with a criterion of 1E-3.

Example 6 -- Additional Low-Probability, High-Release Event - Evaluation of Compliance with EPA's HLW Standards.

The potential for differences between EPA's 1985 standards and the NRC staff's proposed alternative is greatest when more than one low-probability, high-release event must be evaluated. Examples 6 and 7 provide a comparison.

Step 1 -- Identify disruptive processes and events.

A sixth event is added to the five events of Example 1 -- a very unlikely, but very severe climate change capable of causing significant releases.

Step 2 -- Screen processes and events.

Brecciation and drilling (misses waste packages) are deleted. Fault movement, drilling (hits waste package), volcanism and climate change are retained.

Step 3 -- Form scenarios.

The sixteen scenarios for this example are illustrated in Figure 13.

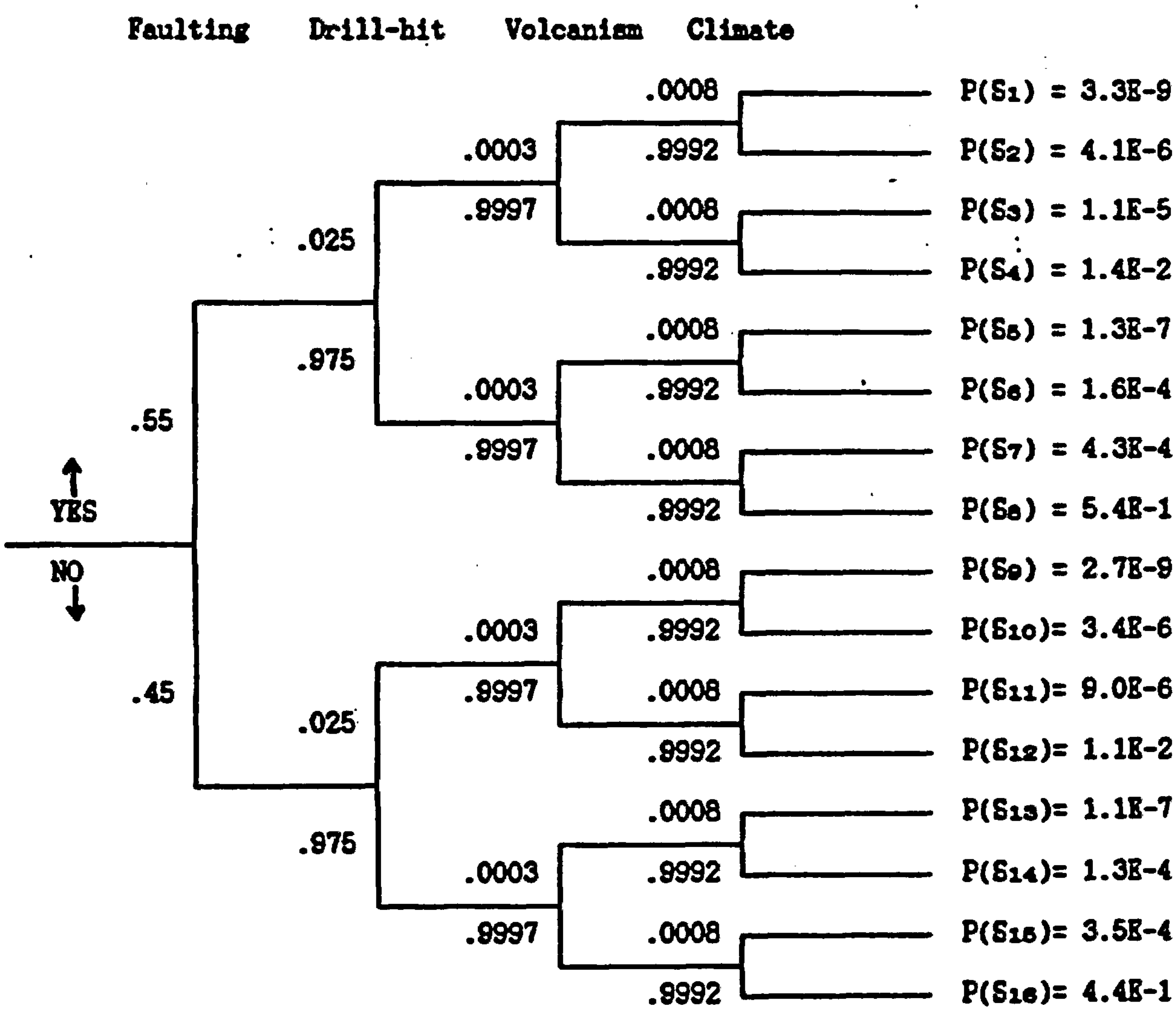

Figure 13. Scenarios for Example 6.

Step 4 — Screen scenarios.

Scenarios S_1, S_2, S_3, S_5, S_9, S_{10}, S_{11}, and S_{13} would all be eliminated because the estimated probabilities are less than EPA's criterion of 1E-4.

Step 5 — Estimate scenario releases.

Releases associated with fault movement and drilling (hits waste package) are the same as in Example 1. For volcanism, the higher release of Example 4 is assumed. The release postulated for severe climate change is 20 times EPA's table of release limits.

Step 6 — Form CCDF.

Table 6 illustrates construction of a CCDF for this example.

Table 6. CCDF data for Example 6.

Scenario	Probability	Release	Cumulative Probability
S_6 F,V	1.6E-4	80.005	1.6E-4
S_{14} V	1.3E-4	80.0	2.9E-4
S_7 F,C	4.3E-4	20.005	9.2E-4
S_{15} C	3.5E-4	20.0	1.07E-3
S_4 F,D	1.4E-2	.091	1.507E-2
S_{12} D	1.1E-2	.086	2.707E-2
S_8 F	5.4E-1	.005	5.6707E-1
S_{16} Undisturbed	4.4E-1	0	1.0

Plotting the data of Table 6 gives the curve of Figure 14, illustrating a violation of EPA's release limits.

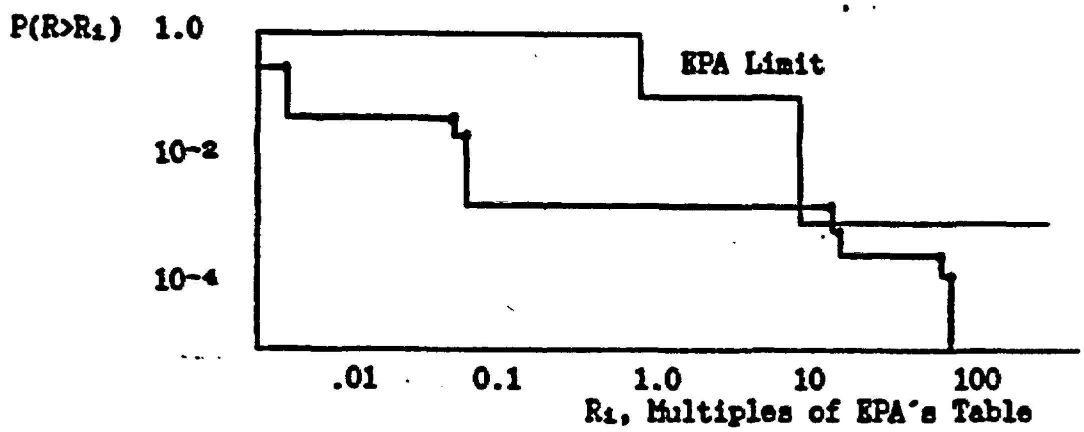

Figure 14. CCDF for Example 6, showing a violation of EPA's release limits.

It is important to emphasize that the releases from volcanism and from climate change are not summed when constructing a CCDF because it is not credible that both events will occur. Instead, the probabilities are summed to determine the cumulative probability that either event will occur.

Example 7 — Additional Low-Probability, High-Release Event - NRC Staff's Alternative.

This example uses the same data as Example 6 to determine whether the NRC staff's proposed alternative will identify the marginal violation of EPA's release limits illustrated in Figure 14.

Step 1 — Identify disruptive processes and events.

Same as Example 6.

Step 2 — Screen processes and events.

Same as Example 6.

Step 3 — Form scenarios.

The sixteen scenarios for this example are illustrated in Figure 15.

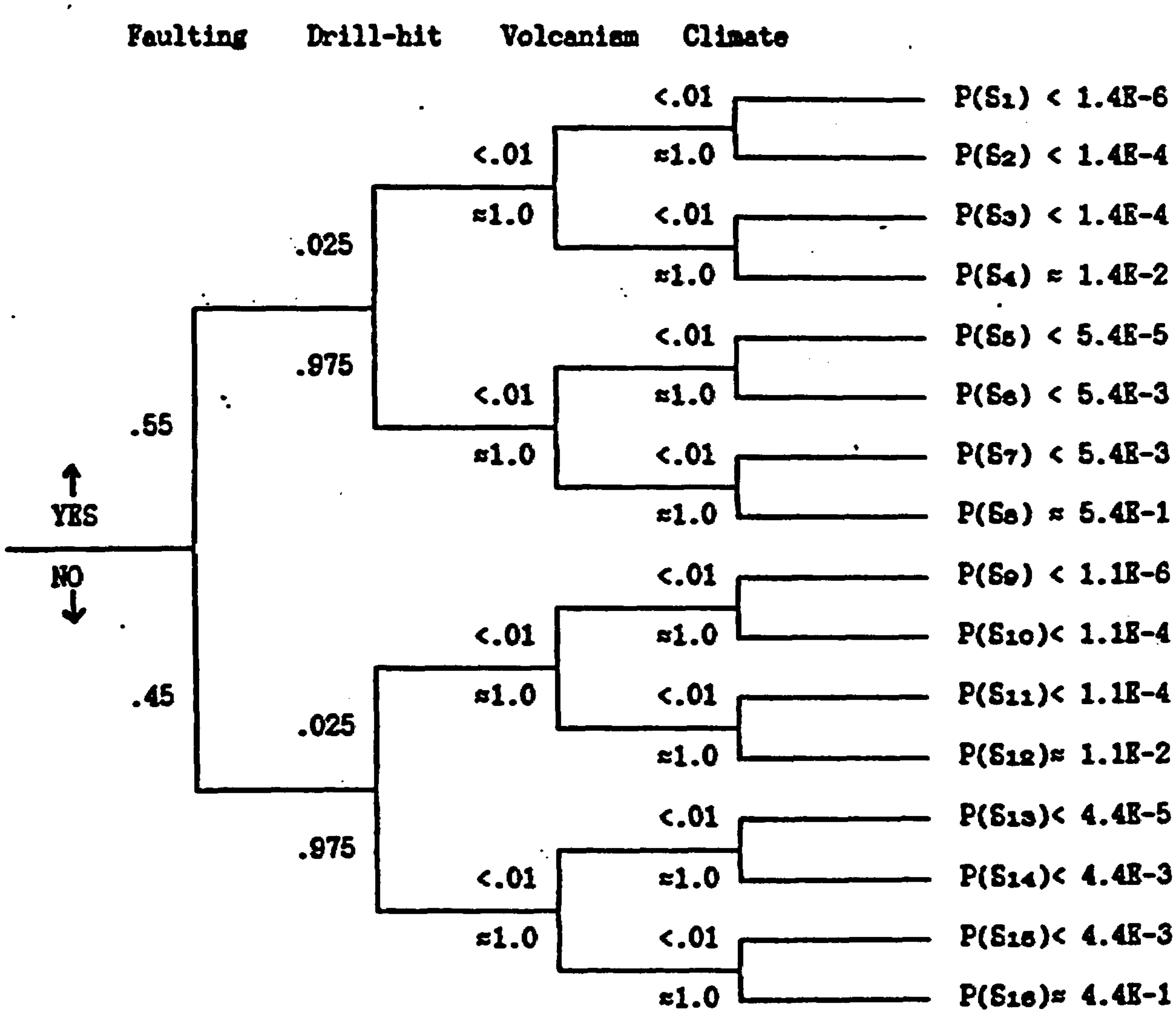

Figure 15. Scenarios for Example 7.

Step 4 -- Screen scenarios.

Scenarios S_1, S_2, S_3, S_5, S_9, S_{10}, S_{11}, and S_{13} would all be eliminated from further consideration if the screening criterion were 1E-3, but scenarios S_2, S_3, S_9, and S_{10} would be retained if the screening criterion were 1E-4. For this example, a criterion of 1E-3 is used.

Step 5 -- Estimate scenario releases.

Same as Example 6.

Step 6 -- Test releases for compliance.

The NRC staff's alternative requires that the release from each scenario be less than ten times EPA's table. Scenarios S_6 and S_{14}, which include volcanism, have higher releases. Scenarios S_7 and S_{15}, which include severe climate change, also fail to meet the criterion.

Step 7 -- Form CCDF for anticipated performance.

Since Step 6 already identified a violation, there is no need to construct a CCDF for likely release. However, Table 7 illustrates how a CCDF would be constructed using those scenarios with probabilities >.01.

Table 7. CCDF data for Example 7.

Scenario	Probability	Release	Cumulative Probability
S_4 F,D	1.4E-2	.091	1.4E-2
S_{12} D	1.1E-2	.086	2.5E-2
S_8 F	5.4E-1	.005	5.65E-1
S_{16} Undisturbed	4.4E-1	0	1.0

Plotting the data of Table 7 gives the curve of Figure 16.

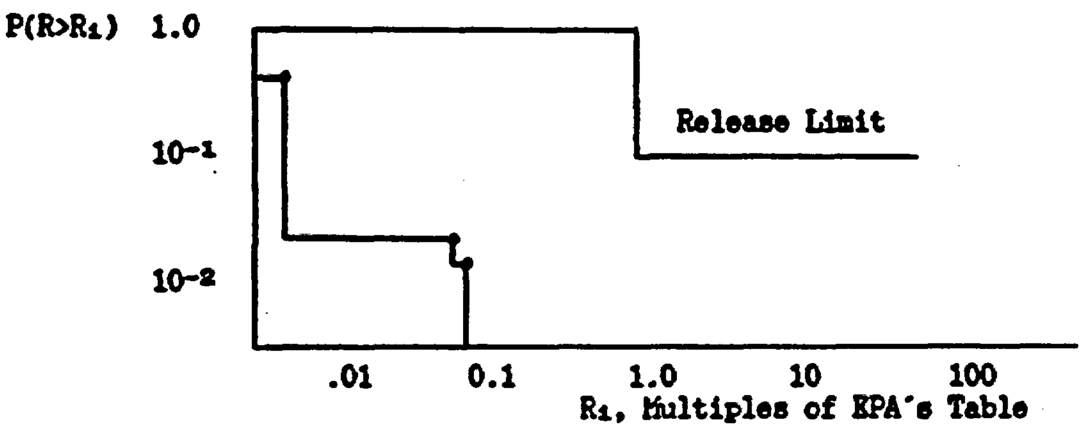

Figure 16. CCDF for Example 7.

Example 7 again shows that the NRC staff's proposed alternative is at least as stringent as EPA's 1985 standards for evaluating the acceptability of scenarios with releases exceeding ten times EPA's table of release limits. If a scenario screening criterion of 1E-4 were used, the NRC staff's alternative would be somewhat more stringent than EPA's standard because more scenarios would be retained in the analysis.

Example 8 — Uncertainties in Release and Probability Estimates Evaluation of Compliance with EPA's HLW Standards

Examples 1 - 7 used single-valued estimates of both probabilities and releases associated with disruptive scenarios. This example first illustrates how uncertainty (or variability) in release estimates could be incorporated into an analysis of compliance with EPA's HLW standards. Then, incorporation of uncertainties in probability estimates is illustrated.

First, it should be noted that the single-valued estimates of previous examples can be displayed in CCDF format. Figure 17 represents the conditional CCDF for Scenario S_3 of Example 1.

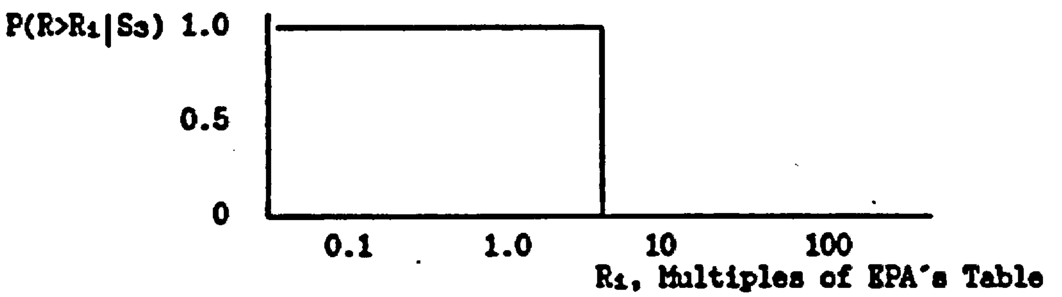

Figure 17. Conditional CCDF for Scenario S_3 of Example 1.

The contribution of each conditional CCDF to the total CCDF for a repository is then obtained by multiplying the vertical axis of Figure 17 by the scenario probability. Figure 18 gives the result for Scenario S_3 of Example 1.

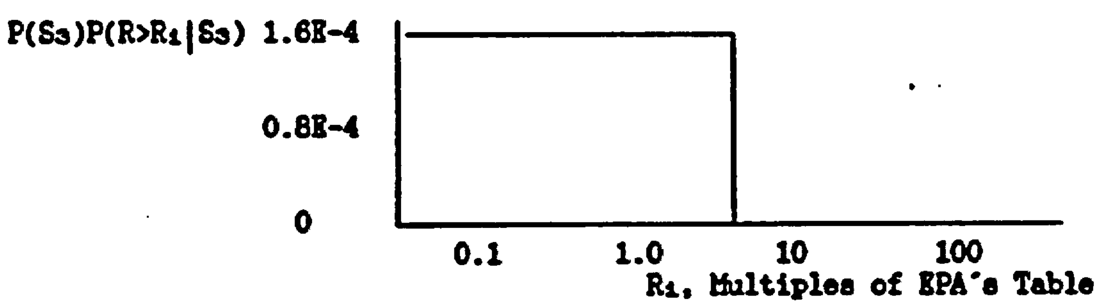

Figure 18. Probability-weighted conditional CCDF for Scenario S_3.

The overall CCDF for a repository is constructed by summing the probability-weighted conditional CCDFs for all scenarios or, conceptually, by stacking them one on top of another, as illustrated in Figure 19.

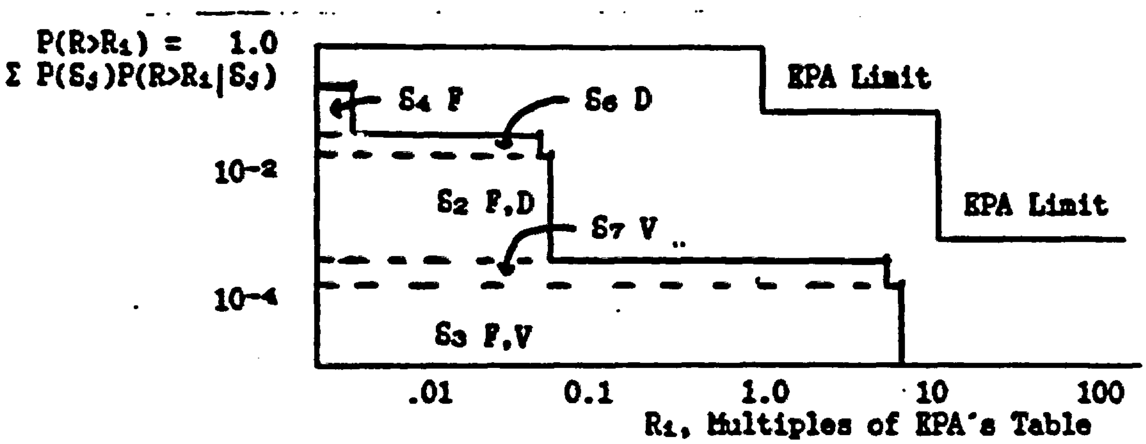

Figure 19. Overall CCDF for Example 1 Constructed by Summing Probability-Weighted Conditional CCDFs.

When conditional CCDFs include estimates of uncertainties in releases, an overall CCDF would be constructed in the same way as indicated in Figures 17 - 19. The overall CCDF for Example 1 might appear as illustrated in Figure 20.

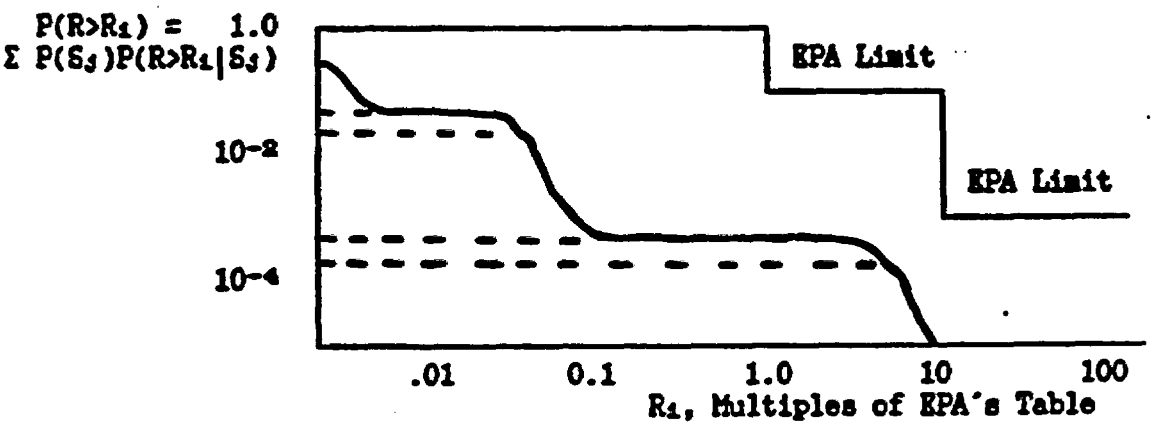

Figure 20. Overall CCDF Including Uncertainties in Releases for Example 1 Constructed by Summing Probability-Weighted Conditional CCDFs.

Uncertainties in the estimated probabilities of disruptive events can be incorporated into an analysis by applying the Monte Carlo technique to the scenario analysis. To illustrate, suppose that the probability estimates for the events of Example 1 were the following:

Table 8. Uncertainty estimates for the probabilities of the disruptive events of Example 1.

Event	Distribution	Mean	Range*
Fault Movement	Uniform	5.5E-1	4.0E-1 to 7.0E-1
Drilling (hits waste package)	Normal	2.5E-2	2.5E-1 to 2.5E-3
Volcanic Activity	Lognormal	3.0E-4	3.0E-2 to 3.0E-6

*For normal and lognormal distributions, the range is from the 5th to the 95th percentiles.

A single probability value for each event would be randomly selected from within the range for that event. The values obtained might be 4.7E-1 for fault movement, 3.3E-2 for drilling, and 5E-3 for volcanism. These values would then be used for a scenario analysis, as illustrated in Figure 21.

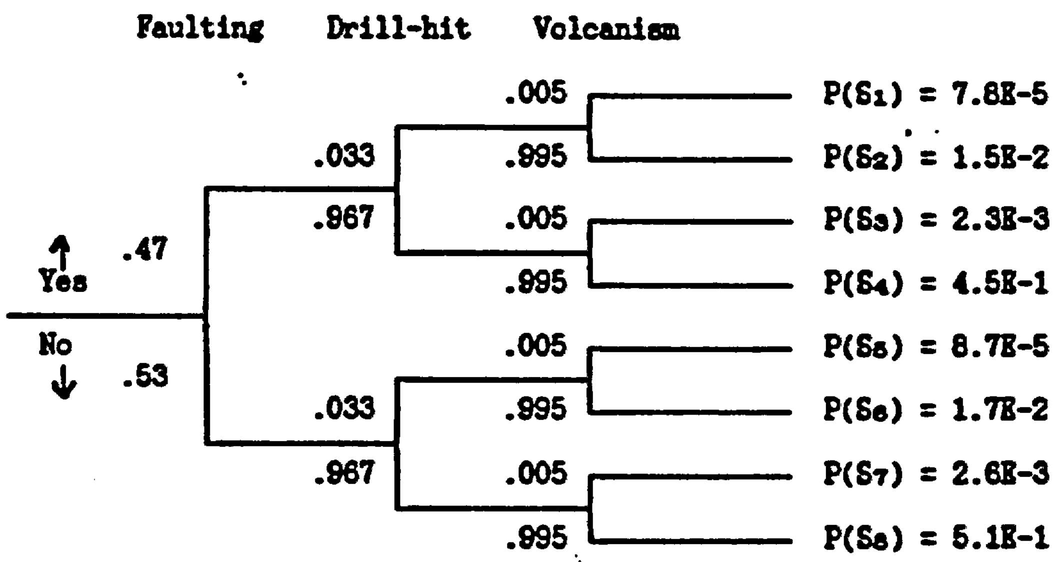

Figure 21. Scenario analysis for randomly selected probability values.

The scenario probabilities of Figure 21 would be combined with estimates of releases to produce a CCDF of the type illustrated in Figure 19 or Figure 20. Then, another set of probability values would be obtained by random sampling, another scenario analysis would be performed, and the resulting scenario probabilities would be used to construct a second CCDF. The process would be continued to produce a "family" of CCDFs of the type shown in Figure 22. The acceptability of a repository for which several CCDFs exceed EPA's release limit would need to be determined in light of the significance of the unquantifiable uncertainties not represented in the CCDFs, any conservatism in the parameters incorporated into the CCDFS, and any other information relevant to a finding of "reasonable assurance" of compliance with EPA's standards.

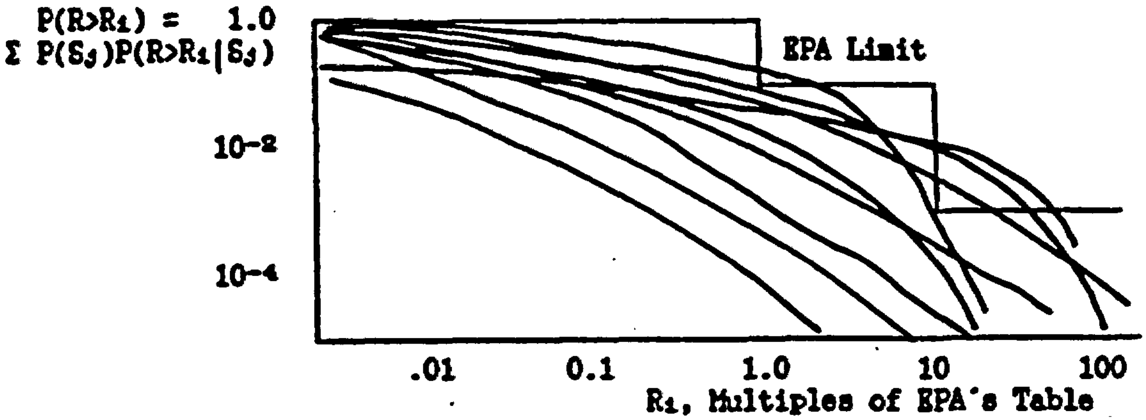

Figure 22. "Family" of CCDFs illustrating uncertainties in the probabilities of disruptive events.

Example 9 -- Uncertainties in Release Estimates - NRC Staff's Alternative.

Evaluation of compliance with the NRC staff's proposed alternative standards would involve two tests. The release estimates for relatively likely scenarios (those with probabilities >.01) would be assembled into a CCDF using the techniques illustrated in Example 8. Such a CCDF might appear as indicated in Figure 23.

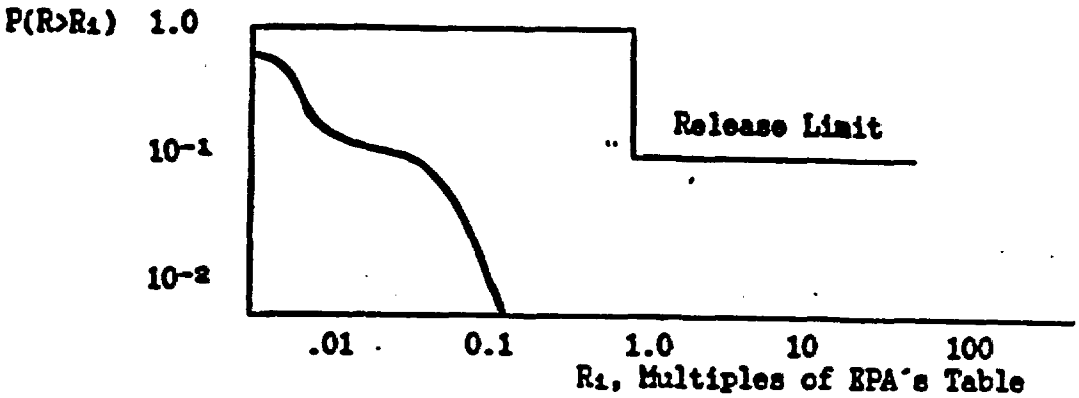

Figure 23. CCDF for likely releases, including estimates of uncertainties in releases.

If information is available about uncertainties in the probabilities of disruptive events, a "family" of CCDFs could be produced as discussed in Example 8.

The estimated release from each unlikely scenario would be compared to a consequence limit of ten times EPA's table of release limits. When uncertainties in releases are estimated, a question arises regarding the fraction of the release estimates that would be required to meet the release criterion, as illustrated by the conditional CCDFs of Figure 24.

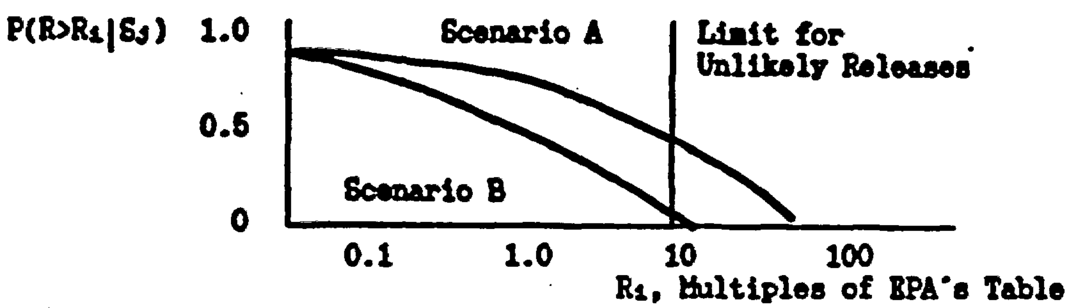

Figure 24. Uncertainties in estimated releases for two unlikely scenarios.

Decisions about the acceptability of the releases illustrated in Figure 24 would need to consider the significance of unquantifiable uncertainties not represented by the curves of Figure 24 as well as any other information relevant to a finding of "reasonable assurance" of compliance with the proposed alternative release limit. No generally applicable numerical confidence level would be specified for acceptance or rejection of curves such as those of Figure 22.

4. SUMMARY

The example calculations presented here illustrate how an applicant might demonstrate compliance with the 1985 EPA standards and with the NRC staff's proposed alternative. For these examples, the two standards are of identical stringency when a scenario screening criterion of 1E-3 is used for the NRC staff's alternative and when 1E-4 is used for EPA's standards. If a screening criterion of 1E-4 were used for both standards, the NRC staff's alternative would be somewhat more stringent because it would apply to a broader range of scenarios than would EPA's 1985 standards.

The reason for the increased stringency of the NRC staff's alternative when using a screening criterion of 1E-4 is the use of bounding (<.01) probability estimates for unlikely processes and events. The bounding probability estimates in these examples are more than ten times higher than the "true" probability values. Therefore, use of a screening criterion of 1E-4 tends to retain scenarios in an analysis that would be eliminated if more precise probability estimates were available. Use of a screening criterion of 1E-3 tends to offset the conservatism imposed by the bounding probability estimates.

It should be noted that differences in the two alternatives are probably more theoretical than real. Probabilities in the range of 1E-3 to 1E-4 (over 10,000 years) are very difficult to project with any real accuracy. Therefore, it will seldom be possible to produce probability estimates of the precision suggested in these examples. Indeed, that is the reason for the NRC staff's proposed alternative -- to allow a meaningful regulatory examination of unlikely disruptive scenarios while avoiding the difficulties involved in trying to predict the probabilities of unlikely processes and events. If any numerical screening criterion is to be specified by EPA, the regulatory language should reflect the lack of precision expected for probability estimates. A criterion to eliminate scenarios with probabilities "on the order of 1E-3 or less" would be preferable to specification of an unqualified number.

Department of Energy
Washington, DC 20585

November 26, 1991

Ms. Margo T. Oge
Acting Director, Office of
Radiation Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Ms. Oge:

I am pleased to be able to provide you with information in response to your request regarding potential gaseous releases from repositories in the unsaturated zone. Although the models and data needed to provide definitive answers to the questions that were asked are still in the early stages of development, the Office of Civilian Radioactive Waste Management (OCRWM) has been able to conduct preliminary analyses of these potential releases. The enclosed information summarizes the current understanding resulting from these analyses. It is our hope that this information is of help to you.

If you have any questions regarding the enclosed information, please contact me on (202) 586-9896 or Steve Brocoum on (202) 586-9247.

Sincerely,

John P. Roberts

John P. Roberts, Acting
Associate Director for
Systems and Compliance

Enclosure

INFORMATION REQUESTED BY

THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ON GASEOUS RELEASES FROM AN UNSATURATED REPOSITORY

November 13, 1991

Question 1. <u>Please provide information pertaining to gaseous release source terms, chemical forms, release rates and retardation factors.</u>

Chemical Forms:

Park and Pflum (1990) reported that carbon-14 is produced in nuclear fuel elements during the reactor operation primarily by neutron reactions with nitrogen-14, carbon-13, and oxygen-17 in the fuel and in the cooling water via $^{14}N(n,p)^{14}C$, $^{13}C(n,\gamma)^{14}C$, and $^{17}O(n,\alpha)^{14}C$ reactions. Little of the carbon-14 in the spent fuel is likely to be produced by fission of the fuel itself. Most of the carbon-14 in a spent fuel element is expected to reside in the UO_2 pellet, the zircaloy cladding, and the hardware associated with the fuel assembly. Some carbon-14 originally in the pellet matrix will migrate to grain boundaries and the pellet-cladding gap, thereby becoming more readily releasable upon breach of the cladding. A small amount of carbon-14 is also present in the deposits ("crud") on the cladding surface.

The chemical forms of carbon-14 in the fuel elements are not known, but may include elemental carbon, carbides, and oxycarbides (Van Konynenburg, 1991). At the Yucca Mountain site some of this carbon-14 would be released as CO_2 due to reaction with the oxygen. In addition, carbon-14 leached from the spent fuel could travel in the water as HCO_3^-, the predominant carbon species present in the water at the Yucca Mountain site.

Source Terms and Release Rates:

The gaseous-release source term depends on the time-dependent inventory of the radionuclides in the repository, the fraction of this inventory that is available to be transported as a gas, the degree of containment of gases provided by the waste packages, and the rate of release of the gaseous fraction from the waste packages once containment has been lost. Radionuclides of principal importance to the postclosure performance of the repository that could exist in gaseous form include tritium (hydrogen-3), carbon-14, krypton-85, iodine-129, and radon-222. Because of considerations of initial inventory, decay rate, or chemical reactivity that would limit transport, the only one of these of concern to the DOE at present is carbon-14. This radionuclide has a long half-life (5,730 years) and is expected to have a significant inventory in the repository.

Van Konynenburg (1991) carefully evaluated the potential for carbon-14 in the spent fuel from the current information available (Davis, 1977; Croff and Alexander, 1980; Roddy et al, 1986; DOE, 1987). From current projections for reactor operations he concluded that the expected carbon-14 inventory in the spent fuel will be about 1 Ci per MTHM for both PWR and BWR spent fuel. The total inventory in a 70,000 MTHM spent fuel repository would therefore be about 70,000 Ci.

The modes of release in the gas phase are currently not well understood. It is believed that a fraction of the inventory will be available to be released rapidly upon loss of containment of radionuclides in the waste package. In addition, some of the carbon-14 may be released more gradually from the spent fuel after containment is lost due, for example, to leaching by ground water followed by off-gassing of CO_2 from the water. The fractions available in each case are not known. Analyses of the limited data that are available regarding the rapid release fraction suggest that this fraction could range between 0.2 and 10 percent of the inventory (Park and Pflum, 1990; Smith and Baldwin, 1989). The fraction of the inventory that would be released to the gaseous transport pathways as a result of off-gassing of water following leaching of carbon-14 from the waste form will depend sensitively on the particular conditions at the site. The analyses of the partitioning of CO_2 between water and air by Ross et al (1991) suggest that the fraction that would be off-gassed would be between 5 and 10 percent under an assumption of equilibrium conditions and for the temperature and pH conditions that are expected to prevail at the Yucca Mountain site.

The current estimate for the fractional leach rate of carbon-14 from spent fuel under saturated conditions is between one part in 1,000 and one part in 10,000 per year (Apted et al, 1991). The fractional release rate for unsaturated conditions would depend on the amount of moisture that would exist in the vicinity of the waste and the fraction of the surface area of the waste that would be contacted by moisture.

The potential for loss of containment of the carbon-14 by the waste packages cannot be determined at this time since waste package materials and designs have not yet been selected. The current approach of the DOE is to assume that containment would be substantially complete for at least 300 years and containment for most waste packages would be maintained for several thousand years (DOE, 1988). On this basis it is possible to define a conservative source term for carbon-14 gaseous release that includes a rapid release (e.g., on the order of 0.1 Ci/MTHM) occurring on the order of 1,000 years after permanent closure, followed by a gradual fractional rate of release that is on the order of one part in 10,000 per year.

formulated?

[60.113 Subsystem perf. criteria]

Retardation Factors:

The retardation factor for gaseous transport of carbon-14 through the unsaturated zone at the Yucca Mountain site has been estimated by Ross et al (1991). That analysis led to an estimated retardation factor of 30 to 75, depending on the porosity and saturation of the host rock, the concentration of carbon in the liquid and gas phases of the transporting media, and the temperature and pH conditions. Other estimates have been consistent with this range (Knapp, 1987; Light et al, 1990) when these same conditions were taken into account.

Question 2. <u>How certain or uncertain is DOE's current understanding of the potential for gaseous releases and what, if any, additional information is needed to more confidently project the potential long-term impacts of gaseous releases?</u>

There is currently considerable uncertainty in the understanding of the potential for gaseous releases from a geologic repository at an unsaturated site. The only assessments of this potential for a high-level waste repository have been simple calculations for the Yucca Mountain site. The main sources of uncertainty are (1) the inventory of carbon-14 that is available for gaseous release, (2) the degree of containment that will be provided by the waste packages and other engineered barriers, and (3) the travel time of the gas from the repository to the surface.

Current estimates suggest that the inventory of carbon-14 that is available for gaseous release is likely to range between 0.002 and 1 Ci/MTHM. Because the calculated releases are directly related to this inventory, this uncertainty in the inventory leads to an uncertainty in the projected cumulative releases of about two orders of magnitude.

The degree of containment provided by the waste packages is not known because materials and designs have not been selected. In addition, the possible ranges of performance for materials that might be used has not been established. Current estimates of the expected time of complete containment by the waste package range from several tens of years to several tens of thousands of years. The 10,000-year cumulative release of carbon-14 does not depend strongly on the containment provided by the waste packages if this containment lasts only a few hundred years or less; consequently, the uncertainty in the degree of containment only introduces an uncertainty of about one order of magnitude in the estimate of the cumulative release.

Modeling of the radionuclide travel time has been done by Ross et al (1991). This modeling suggests that the travel time at the Yucca Mountain site is expected to range between 1,000 and 6,000 years, depending on the location within the repository boundaries and the variation in site characteristics such as the temperature and permeability of the host rock. Analyses by others (Thorstenson et al, 1989; Knapp, 1987) indicate that the uncertainty in these estimates could be an order of magnitude or more. Consequently, there is an associated uncertainty in the estimated releases of an order of magnitude or more.

There are other uncertainties in aspects of the analysis that could result in uncertainties in the estimates of the gaseous releases as well. For example, the models for release of gas from breached waste packages and for gaseous release of carbon-14 leached from the waste form are not yet completely known. Likewise, uncertainties will exist in the implementation of the conceptual models into computational models. The magnitude of these uncertainties is not known.

Many of these uncertainties may not be significantly reduced in the site characterization program. For example, a principal source of uncertainty in the transport of gases at the Yucca Mountain site arises from the variability in site properties; the program to characterize this site will not be able to address all aspects of this variability. Some of the uncertainties in the source term may be addressed in the waste characterization program through reactor operation analysis and laboratory tests (DOE, 1988). With regard to the other uncertainties, it is likely that the DOE will need to rely on bounding analyses of the types that have already been conducted.

Question 3. To what extent does DOE believe that gaseous releases of carbon-14 or other radionuclides from repositories in the unsaturated zone are likely to exceed the release limits found in 40 CFR 191 and the release rate limitations found in 10 CFR 60 under normal (i.e., undisturbed) conditions?

The probability of exceeding the release rate limit for carbon-14 specified in 10 CFR 60.113 is not known at present. Current information suggests that this limit could well be exceeded in both the rapid-release mode and in the more gradual aqueous leaching mode. The limit would be exceeded in the rapid-release mode if the rapid-release fraction in the waste packages that fail annually exceeds one part in 100,000 of the total repository inventory of carbon-14. If 10 percent of the inventory in any package is available for rapid release, the limit would be exceeded if only three of the anticipated 30,000 waste packages fail in a given year. The waste package release rate due to leaching by ground water could also be significant. The current information indicates that the release rate of carbon-14 from spent fuel under saturated conditions could be as much as two orders of magnitude greater than the release rate limit (Apted et al, 1991). Under unsaturated conditions, this limit could be exceeded if the leach rate for near-field conditions in the repository approaches a few percent of the leach rate expected for saturated conditions.

A projection of the cumulative gaseous releases of carbon-14 that is based on the foregoing considerations is shown in the attached figure. This figure shows the probability distributions for rapid release, for gradual release due to off-gassing of leached carbon-14, and for the sum of these two contributions. The models used for these estimates are very simple and do not take into account many of the details of the processes involved in the transport and release of carbon-14; nevertheless, the results are instructive. The expected releases are less than the release limit for carbon-14 specified in the EPA standard; however, the estimates are greater than 10 percent of this limit, indicating the marginal nature of the performance based upon this model. In fact, the probability of exceeding the release limit is estimated to be about 10 percent in this model. The criterion specified in the containment requirements of the EPA standard is that the probability should not exceed 10 percent, as shown by the dashed "staircase" in this figure; therefore, from this point of view, the performance is marginal as well.

The specific parameters of the model used in the analysis are provided in the attached table. The analysis did not consider any of the uncertainties discussed in the answer to Question 2, other than those parameter uncertainties represented by the probability distributions in the table. It is possible that if the other uncertainties were to be taken into account, the current estimate of the probability of exceeding the release limit could be greater than amount shown in the figure.

Question 4. In light of DOE's current understanding of the potential for gaseous releases, does DOE believe changes to the NRC and/or EPA regulatory requirements are warranted?

The DOE believes that several changes in the regulatory requirements are warranted. As indicated in the answer to Question 3, the current estimates of gaseous releases indicate a significant probability that the release limit for carbon-14 could be exceeded. However, simple estimates of the effects on public health and safety associated with the release limit for carbon-14 indicate that this limit appears to be much more stringent than necessary to protect public health and safety. For example, the dose to a maximally-exposed individual at the Yucca Mountain using models very similar to those used to estimate the cumulative gaseous release has been calculated to be only a few microrem per year (Park and Pflum, 1989). Likewise, the dose to an average member of the global population has been estimated to be on the order of ten microrem per year (Quan et al, 1990). These quantities are many orders of magnitude below the dose an individual receives each year from natural background radiation or from the carbon-14 naturally present in the body.

The release limit specified in the 1985 rule is not consistent with the levels of acceptable risk on which other standards are based. As indicated in the Background Information Document for the 1985 rule, the goal for the repository is that there be no more than 1,000 health effects in 10,000 years per 100,000 MTHM of spent fuel in the repository. Dividing this goal by 10,000 years and by 10 billion which is the population considered in the estimation of the release limits by the EPA and taking into account a factor of 70 years in the average lifetime of an individual and a factor of 100 to scale from 100,000 MTHM to 1,000 MTHM results in an estimated lifetime risk to an individual of approximately 7×10^{-12} per 1,000 MTHM of spent fuel. The level of risk considered acceptable for the development of other standards (e.g., standards for safe drinking water, for hazardous air pollution, and for operations of nuclear fuel cycle facilities) is much higher than this. For example, the level of risk considered acceptable for nuclear power plants is about 10^{-6} per year lifetime risk to an average individual. Assuming about 1,000 MTHM of spent fuel over the 30-year lifetime of a typical reactor, this corresponds to an acceptable risk that is six to seven orders of magnitude larger than the risk considered acceptable for a repository.

It could be argued that a standard establishing a reduced level of risk is appropriate for geologic disposal in view of the unique function of waste isolation for 10,000 years and because of potential difficulties in remediation should the postclosure performance of a repository be unsatisfactory. However, the DOE believes that the extremely low level of risk required for the repository system is arbitrary and inconsistent with the objectives of geologic disposal. For example, if the waste is simply left in storage facilities at reactor sites or other surface facilities, the risks could be as much as seven orders of magnitude greater than for geologic disposal and this higher level of risk would be considered to be acceptable. While some differences may be warranted, a difference of seven orders of magnitude from other standards does not appear to be reasonable or consistent.

Other groups such as the ICRP and IAEA have also concluded that a level of risk significantly lower than that of above-ground sources of radiation exposure is not warranted for geologic disposal. For example, the individual dose limit for geologic disposal recommended by these groups is the same as those for other nuclear facilities such as power reactors.

The DOE believes that the overall objective of 1,000 health effects in 10,000 years per 100,000 MTHM of spent fuel in the repository is unnecessarily stringent and inconsistent with goals for public health and safety established for other standards. As a result, the release limits established by the EPA to accomplish this goal are unnecessarily restrictive. The DOE believes that an acceptable level of risk that is at most one or two orders of magnitude below the level considered appropriate for other facilities would adequately protect public health and safety and would account for the unique functional requirements and risks associated with a repository. The DOE recommends that the EPA adopt an overall objective that is consistent with such a level of risk.

Question 5. <u>DOE's 1988 Site Characterization Plan for Yucca Mountain identifies several alternative approaches to carbon-14 control including one which involves removing carbon-14 from the exterior of the spent fuel cladding and assembly components by heating before emplacement. (See Chapter 8, Section 8.3.5.10, Engineered Barrier System Release Rates.) Please provide any information pertaining to the availability and feasibility of this or any other techniques for limiting carbon-14 and other gaseous radionuclide releases that DOE may be examining.</u>

As indicated in this request, DOE has contemplated several approaches to mitigating the potential for gaseous release of carbon-14. However, so far the development of the technology needed has not been accomplished either because of focus on other areas (such as characterization of the site) or because of questions of feasibility.

The DOE has considered that the potential of such gaseous release could be mitigated if the waste packages could maintain containment of gases long enough that releases could not occur within 10,000 years. As indicated above, the potential for such containment of the carbon-14 by the waste packages cannot be determined at this time since waste package materials and designs have not yet been selected. Furthermore, the technology for waste package designs that could accomplish this degree of containment has not yet been proven.

Another option that the DOE has considered is to vent the carbon-14 before emplacement in the repository. Releases of the carbon-14 at this stage would easily meet the applicable requirements of 40 CFR Part 190, 40 CFR 191, Subpart A, and 10 CFR Part 72. However, the technology for this process, as it might apply to the large number of spent fuel elements that is anticipated, also has not yet been proven. It is likely to be difficult to vent or otherwise rid fuel elements of carbon-14 without significant processing. Any efforts to rid the fuel elements of carbon-14 would require handling of the elements and any technique for such handling is expected to be difficult and costly. It is not clear that the additional risks associated with such operations would not be greater than those associated with the potential release of carbon-14 from the repository. The DOE does not have an active program of research in this area at the present time.

not to mention significant releases ~~[illegible]~~ Fischal for [illegible] other nuclides

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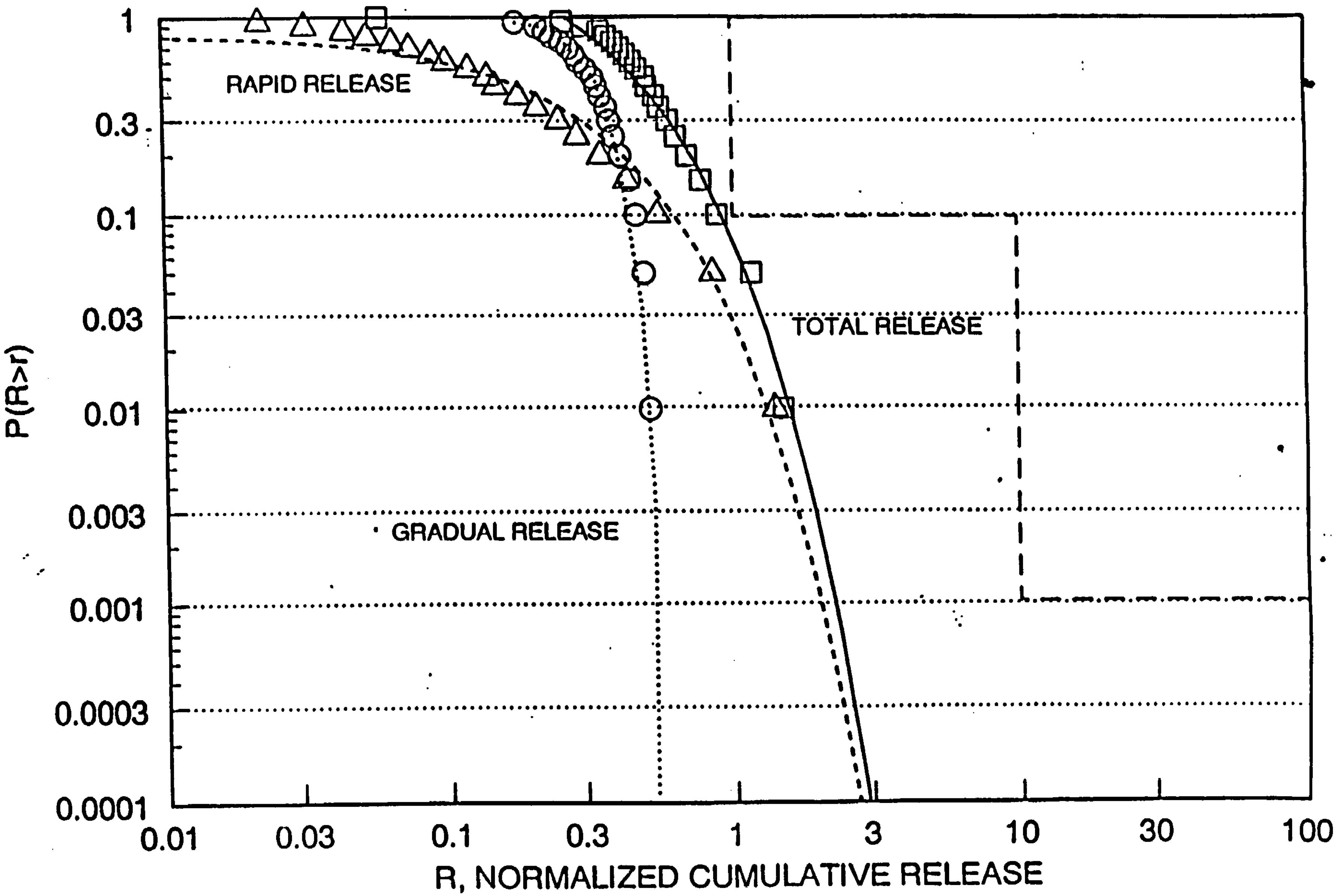
GASEOUS RELEASE OF CARBON-14



Parameters Used In Assessment of Gaseous Release of Carbon-14

Repository loading:	70,000 MTHM
Initial carbon-14 inventory:	1 Ci/MTHM
Waste package breach time:	Normally distributed Mean 1,000 years Standard deviation 350 years

<u>Rapid Release Fraction</u>

Rapid release fraction:	Lognormally distributed Mean of normally distributed data 0.025 Standard deviation of normally distributed data 1.1
Radionuclide travel time:	Variable (treated as uniformly distributed between 2,000 and 6,000 years)

<u>Gradual Release Fraction</u>

Fraction of spent fuel surface area in breached waste packages contacted by leachant:	1
Fractional leach rate:	Lognormally distributed Mean of normally distributed data 0.0009/yr Standard deviation of normally distributed data 1.1
Fraction of leached C-14 reaching gas pathways:	Uniformly distributed between 0.05 and 0.1
Radionuclide travel time:	Sum of a fraction (uniformly distributed between 0 and 20 percent) of the ground-water travel time (mean of 13,000 years) and the gas travel time (distributed uniformly between 2,000 and 6,000 years)

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NRDC

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December 13, 1991

William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460

Dear Administrator Reilly:

Attached please find NRDC's comments on Working Draft #3 of EPA's proposal to revise the Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste (40 CFR 191). As you know, the First Circuit Court of Appeals vacated the disposal standards in litigation led by NRDC.

We cannot emphasize enough the extent to which the public is looking to these standards as a critical gauge of the safety of nuclear waste repositories. If it becomes clear that EPA is revising the standards in an attempt to ease the licensing of existing or potential sites -- rather than to ensure proper site selection and sound engineering -- this will both seriously undermine the credibility of the federal government's efforts to site a nuclear waste repository and invite further litigation.

We look forward to working with you to develop technically rigorous and legally sound standards.

Sincerely

Thomas B. Cochran
Senior Scientist

Dan W. Reicher
Senior Attorney

cc: Ms. Margo Oge

Natural Resources Defense Council

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Comments of the
Natural Resources Defense Council

on

Working Draft #3 of
U.S. Environmental Protection Agency
Proposal to Revise 40 CFR Part 191:
Environmental Standards for Management and
Disposal of Spent Nuclear Fuel, High-Level and
Transuranic Radioactive Waste

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December 13, 1991

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The Natural Resources Defense Council (NRDC) is pleased to submit these comments on Working Draft #3 of the Environmental Protection Agency proposed revisions of 40 CFR Part 191: Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste. In these comments we answer the six questions presented in the draft preamble, discuss some other critical issues, and provide additional specific comments. It must be emphasized, however, that these comments are preliminary in nature and do not address all of the relevant issues or concerns. We will submit more comprehensive comments when the standards are officially proposed.

Assuming the appropriate choice of the options presented, we believe Working Draft #3 takes some positive steps toward strengthening and clarifying the regulations but that additional revisions are necessary if the standards are to adequately protect human health and the environment and properly respond to the decision of the First Circuit Court of Appeals in NRDC v. EPA, 824 F.2d 1258 (1st Cir. 1987).

I. SIX QUESTIONS

QUESTION 1

Two options are presented in Section 191.03 and 191.14 pertaining to maximum exposures to individuals in the vicinity of waste management, storage and disposal facilities: a 25 millirems/year ede limit and a 10 millirems/year ede limit. Which is the more appropriate choice and why?

NRDC does not agree with either the 25 millirem or 10 millirem option for 191.03 or 191.14. In the case of 191.03 management and storage standards we believe that 10 millirem is unnecessarily high. There is no reason why management and storage facilities cannot and should not meet a far stricter standard. The routine liquid and gaseous radioactive emissions at waste management and storage facilities should be essentially zero.

We believe that a standard on the order of 2 millirem is appropriate for 191.03. This would entail a 1-in-10,000 lifetime cancer risk as opposed to a 1-in-2000 risk at 10 millirem and 1-in-800 risk at 25 millirem. This risk level is still not even close to the 1-in-1,000,000 lifetime risk objective that EPA applies to pesticides in foods.[1]

In the case of 191.14, we believe that 4 millirem is a more appropriate and equally achievable figure. This would bring the standard in line with the SDWA standard. In its analyses of individual risk, EPA assumes that drinking water will be the exclusive exposure pathway. See "High-Level and Transuranic Radioactive Wastes, Background Information Document for Final Rule," (August, 1985) at 8-7. A 4 millirem exposure would entail a lifetime risk of a fatal cancer of 1-in-5000.

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[1] See, for example, Environmental Protection Agency, "Captan: Intent to Cancel Registrations; Conclusion of Special Review, Notice of Final Determination" Federal Register, February 24, 1989, pp. 8121-8122.

In the draft preamble (p. 49) EPA attempts to justify the 10 millirem limit pointing to its consistency with 40 CFR 61, the EPA standards for radioactive air pollutants. This is not an apt comparison. These air pollution standards set limits on radioactive emissions from current nuclear activities. Individuals who bear the risks of the emissions from such facilities are also likely to enjoy some of the benefits of the regulated activities. In contrast, the future individuals who will have to bear the risks of nuclear waste will almost certainly not enjoy any direct benefits of the activities which produced it. These individuals also have no voice in today's decision. Under these circumstances, more restrictive exposure limits are appropriate.

Strict limits are also important to ensure the selection of a robust geologic site, the development of substantial engineered barriers and cannisters, and the use of a high-integrity waste form. Lax standards do not aid in making choices with respect to these key features of a repository.

We are troubled by EPA's failure to explicitly incorporate the As-Low-As-Reasonably-Achievable (ALARA) concept in 191.03 and 191.14 as well as other applicable sections of Part 191. ALARA is, and has always been, a fundamental tenet of radiation protection that should figure prominently in the EPA standards.

QUESTION 2

A new assurance requirement is presented in Section 191.13 that would require a qualitative evaluation of expected releases from potential disposal systems over a 100,000-year timeframe. Are such evaluations likely to provide useful information in any future selecting [sic] of preferred disposal sites?

NRDC believes the requirement for site comparisons based on qualitative comparisons of potential releases over 100,000 years could prove very useful. However, EPA should not limit the requirement to a qualitative evaluation. Instead, the agency should recommend a quantitative comparison where possible, recognizing the uncertainties involved in projecting releases and risks far into the future.

QUESTION 3

Two options are presented in Section 191.14 and 191.23 pertaining to the length of time over which the individual and ground water protection requirements would apply: a 1,000-year duration and a 10,000-year duration. Which is the more appropriate timeframe and why?

In the draft Preamble EPA recognizes: (1) that the 10,000-year timeframe is achievable for repositories which are carefully sited and designed (p. 48); (2) that adopting a 10,000-year timeframe would make the individual protection requirement consistent with the containment requirement and other EPA regulations (UIC and RCRA no-migration) (p.48); (3) that in most of the cases studied, no exposures occurred for more than one thousand years after disposal (p. 76), i.e. that radionuclide releases may not even occur at any sites within 1,000 years (p.

25). Basic logic and sound health protection therefore dictate adoption of a timeframe no shorter than 10,000 years.

Additionally, the First Circuit raised serious doubts about the legitimacy of the 1000-year limit. The standards would likely be challenged again if EPA maintained the same timeframe in the new regulations in the absence of compelling new information contradicting the agency's current conclusions about the efficacy of the 10,000-year timeframe.

QUESTION 4

> In Subpart C the Agency proposes to prevent degradation of "underground sources of drinking water" beyond the concentrations found in 40 CFR 141--the National Primary Drinking Water Regulations. The Agency is aware, however, that there may be some types of ground waters that warrant additional protection because they are of unusually high value or are more susceptible to contamination. Should the Agency develop no-degradation requirements for especially valuable ground waters? If so, what types of ground waters warrant this extra level of protection?

EPA should definitely develop no-degradation requirements for especially valuable ground waters. EPA recognizes that the standards at issue are intended to influence site selection and design for a repository as opposed to setting traditional "end-of-the-pipe" limits. Therefore, it is critical that the standards be written so as to either effectively rule out the siting of a repository in an area with especially valuable groundwater, or require a design that ensures a zero-release. Any concern about the stringency of such a no-degradation approach should be lessened by the fact that it would have limited application given the handful of sites that might be considered for a repository. While we cannot provide a complete list of ground waters warranting no-degradation protection, it should at least include the waters referred to in assurance requirement 191.13(f) with the definition of "ecologically vital ground water" expanded as described infra in our comment on definition 191.01(o).

QUESTION 5

Two options are presented in Notes 1(d) and (e) of Appendix B pertaining to the transuranic waste unit; a 1,000,000 curies option and a 3,000,000 curies option. Which is the more appropriate TRU waste unit and why?

NRDC believes that 3,000,0000 curies is the minimum acceptable transuranic waste unit. See the April 2, 1991 Comments of the New Mexico Environmental Evaluation Group, pp. 12-15. As indicated in the draft preamble (p. 30), under some circumstances a value of 6,000,000 curies, or even higher, would be more appropriate. EPA should define both a minimum value and a procedure for calculating whether a higher value is warranted.

QUESTION 6

The Agency is investigating the impacts of gaseous radionuclide releases from radioactive waste disposal systems and whether, in light of these releases, changes to the standards are appropriate. To assist us in this effort, we would appreciate any information pertaining to gaseous release source terms, chemical forms, rates, retardation factors, mitigation techniques and any other relevant technical information.

Of course EPA must regulate all potential gaseous radionuclide releases from disposal systems, including C-14. EPA has already resolved the issue of whether gaseous radionuclides should be controlled when it established 40 CFR 190, to regulate similar releases from other parts of the uranium fuel cycle.

Some industry officials have argued that the proposed C-14 standard under Part 191 should be weakened. We believe, however, that it should be tightened. Kr-85 (which is controlled under Part 190) is similar to C-14 in that once it is released to the environment it spreads globally and can result in a significant number of health effects even though the individual risks may be small. It obviously makes no sense to weaken or eliminate controls on C-14 which produces even larger numbers of health effects. This was the position NRDC took in our September 15, 1975 comments on Part 190 with respect to whether C-14 should be regulated. Logically, the two radionuclides, Kr-85 and C-14, should meet the same basic standard in terms of health effects permitted by their release. There is no basis for establishing a weaker standard for C-14 under Part 191 (waste disposal) than what has already been implemented for Kr-85 under Part 190 (fuel reprocessing).

40 CFR 190.10 (b) permits the release of only 50,000 Ci Kr-85/Gw-y, which translates into about 1700 Ci/1000 MTHM. In terms of committed effective dose equivalent/curie, C-14 is about 1000 times more hazardous than Kr-85. Therefore, the release limit

for C-14 in Table 1 should be on the order of 2 curies, instead of 100 curies, to be compatible with 40 CFR 190.10 (b).

In its November 26, 1991 and December 5, 1991 comments, DOE argues that EPA's release limit for C-14 is not consistent with the levels of acceptable risk on which other standards are based. DOE's argument is totally flawed, because it does not recognize the difference between individual risk limits and collective dose limits. C-14 exposes an immense number of people -- essentially the global population over many generations -- to individually small doses. Even though the individual risk may be small, the total projected health effect can be very large. If one took DOE's argument seriously, EPA should never have promulgated 40 CFR 190(b) to control Kr-85, I-129 and H-3, where the individual risks are also small. As the EPA staff fully recognizes, we control these emissions to limit total health impacts not individual risks.

One of DOE's proposed solutions for meeting the EPA C-14 release limit would be to vent the C-14 before emplacement in the repository. This is an outrageous proposal that demonstrates the lengths DOE might go to avoid environmental requirements. Will DOE next propose to dispose of high-level waste by diluting it in the Great Lakes? EPA should include an explicit provision prohibiting release of waste to the environment to avoid the Part 191 requirements.

II. OTHER CRITICAL ISSUES

In this section we comment on three critical issues not adequately addressed above in our answers to the EPA Questions: the stringency of standards; whether emplacement of wastes in a repository constitutes underground injection; and how human intrusion should be dealt with in the standards. EPA should consider adding additional questions on these and other topics in the draft preamble.

A. Stringency of Standards

In the wake of the First Circuit decision striking down the standards, we were hopeful that interested parties would take the Court's decision to heart and support a strengthening of the standards consistent with the law. Instead, we see a strong push from many quarters to weaken the standards. The call seems to have gone out that the standards must be adjusted to fit the existing sites.

We feel strongly that this is the wrong approach and sends the wrong signal to the public. The result can only be to further undermine public confidence in the high-level waste program. A recent University of Pennsylvania study of public attitudes toward siting the Yucca Mountain repository found that the imposition of strict standards is a critical element in convincing residents of a potential host state that a repository will be safe.[2]

We also believe EPA would have a difficult time trying to provide a fair and objective basis for diverging from the Safe Drinking Water Act levels. Drinking water supplies are among our most important natural resources, especially in the western United States. To adopt standards that permit contamination of these precious supplies at levels above what the law provides is not only an affront to future generations but to our own as well.

On a related note, increasingly one hears the EPA high-level waste standards criticized for being so much more stringent than EPA's hazardous waste landfill requirements. The high-level waste standards apply for 10,000 years while the hazardous waste standards generally focus attention on a site for a 30-year period. This is a specious comparison.

As the First Circuit found, the regulatory equivalent of deep geologic disposal of radioactive waste is not surface disposal but instead deep well injection of hazardous waste. EPA's deep well injection regulations for restricted hazardous waste, in fact, track the high-level waste standards. The regulations require that a petition for a variance from the ban on injection of solvent waste demonstrate, among other things, that "fluid movement conditions are such that the injection fluids will not migrate within 10,000 years." The supposed

[2] Kunreuther, H. et al, "Public Attitudes Toward Siting a High-Level Nuclear Waste Repository in Nevada," Risk Analysis, Vol. 10, No. 4, 1990, p. 469.

disparity between the high-level and hazardous waste standards is thus unfounded.

B. Whether Emplacement of Wastes in a Repository Constitutes Underground Injection.

In the draft preamble, EPA concludes that disposal of radioactive waste in a geologic repository does not constitute underground injection. EPA's conclusion is completely unsupportable and totally at odds with the SDWA, EPA's own UIC regulations, and case law. EPA's sole argument is that somehow "well injection" under Subpart C does not cover situations where wastes are emplaced by mechanical means and are not fluid at the time of injection. EPA's only attempt at support for this is an obscure reference to the legislative history of the SDWA for the proposition that Congress focused on injection practices when directing EPA to control underground injection and therefore (somehow) mechanically-emplaced wastes that are not fluids at the time of injection are not subject to Part C of the SDWA. The most charitable thing that can be said about this argument is that it is creative.

Whatever its focus in considering the SDWA, Congress clearly concluded that "[t]he definition of 'underground injection' is intended to be broad enough to cover any contaminant which may be put below ground level and which flows or moves, whether the contaminant is in semi-solid, liquid, sludge, or any other form or state." Congress did not, as it could have, limit the means by which wastes covered by the UIC provisions are "put below ground level" nor did it, as EPA suggests, indicate that the wastes could not be solids at the time of injection.

Moreover, the definition of "fluids" under EPA's <u>own</u> regulations actually encompasses solids, i.e. a "fluid" is "[any] material...in a semi-solid, liquid, sludge, gas or <u>any other form or state</u>." 40 CFR 146.3 (emphasis added). It must also be noted that DOE intends to dispose of semi-solids and even some free liquids in at least one repository. Thus the draft Preamble (p. 5) acknowledges that at the WIPP facility in New Mexico, DOE will dispose of "contaminated organic and inorganic sludges" and in the 1990 Final Supplemental Environmental Impact Statement on WIPP DOE states that "[m]inor liquid residues remaining in well-drained bottles, cans and other containers are acceptable." <u>See</u> FSEIS, Vol. 2, p. A-7, DOE/EIS-0026-FS. DOE will also clearly dispose of some wastes in gaseous form at repositories, for example the C-14 and Kr-85, in spent fuel cannisters that will be regulated under the 191.12 containment requirements.

EPA's conclusion that mechanical emplacement of wastes somehow is not covered by the UIC provisions is also flawed. EPA's <u>own</u> definition of "well injection" -- which is taken "almost directly from the legislative history accompanying the SDWA" (Draft Preamble p. 57-58) -- encompasses "subsurface emplacement of fluids through a bored, drilled, or driven well..." 40 CFR 146.1 The term "well" means a bored, drilled or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension." <u>Id</u>. There is simply nothing in the

SDWA, its legislative history, or EPA's regulations indicating that mechanical emplacement of wastes falls outside of these definitions.

The First Circuit, confronted by the overwhelming weight of this legislative history and regulatory language, concluded that a "narrow and constrained reading of Part C of the SDWA...would do violence to the intent of Congress" and therefore that emplacement of waste in a repository "would likely constitute an 'underground injection' under the SDWA." In light of this, EPA proceeds at extreme legal peril in adopting the contrary position.

At the same time, we readily acknowledge and very much support the proposal to conform the standards with the SDWA limits despite the decision that emplacement does not constitute injection. We must emphasize, however, that this proposal, if adopted, would not fully satisfy the agency's legal obligations or the public's rights under the SDWA.

C. <u>How Human Intrusion Should Be Considered In the Standards</u>

In it December 5, 1991 comments, DOE made the very troubling suggestion that EPA separate consideration of human intrusion from the comprehensive analysis required by the containment requirements. As currently designed, the implementing agency would determine compliance with the containment requirements by evaluating the extent to which various events and processes affecting a repository are likely to lead to releases. Such an evaluation, using the Table 1 release limits, would consider both natural processes and events (e.g., faulting, groundwater flow) and the effects of inadvertent human intrusion.

Essentially, DOE is suggesting that the Table 1 release limits only apply to natural processes and events and that human intrusion be dealt with in a different and more qualitative fashion. DOE has not provided any specific ideas about how this would be implemented.

We strongly object to DOE's approach. The release limits in Table 1 were meant to correspond to a risk objective of no more than 1000 fatal cancers over 10,000 years. Adopting DOE's approach would mean that EPA has decided to allow extra fatal cancers above what the agency deemed appropriate in 1985. And by analyzing human intrusion in a qualitative fashion, EPA would essentially be writing a standard with no limits on permissible risk. This is particularly troubling because EPA's own generic repository analyses in support of 40 CFR 191 indicated that human intrusion will often be the most important cause of radionuclide releases from repositories.

At least one of DOE's motivations is quite clear: the consequences of human intrusion at WIPP appear to violate the containment requirements. Apparently, DOE's preferred solution is to weaken the standards. Instead, the Department should incorporate a more robust barrier system and/or modify the existing waste form. In fact, a DOE task force is apparently investigating just such changes. If implemented, they could not only bring the facility into compliance with the containment requirements but also make WIPP a safer repository which, in the end, is what this exercise is supposed to be about.

Thus we believe that it is critical that human intrusion remain an integral part of the analysis of compliance with the containment requirements. In fact, we believe that the guidance in Appendix C on the frequency and severity of human intrusion should be codified in the containment requirements. To the extent that the assumptions about borehole frequency and other matters are not appropriate for a particular site, the implementing agency should seek alternative provisions under 191.17.

The guidance on inadvertent human intrusion in Appendix C suggests that intrusions that could result in major disruptions to a repository would stem from "widespread societal loss of knowledge regarding radioactive wastes..." However, recent work on inadvertent human intrusion suggests that even where societal knowledge is not lost there may be massive off-site activities in the vicinity of a repository (explosions, water withdrawals etc.) that could inadvertently affect the integrity of waste containment. These should be considered in any analysis of human intrusion.

III. ADDITIONAL COMMENTS

Below we provide specific additional comments on the draft regulations.

Subpart A -- Management and Storage Standards

<u>191.01 (Definitions)</u>

(o) "Ecologically vital ground water": This definition is unnecessarily limited. First, it is not clear why the definition is restricted to "Congressionally designated Federal Lands...." Under the Federal Land Policy and Management Act, the Secretary of the Interior may also designate federal lands for ecological protection on a temporary basis. Additionally, the President has, without statutory authorization or Congressional approval, designated lands for a range of purposes including ecological protection.[3]

Second, the definition of ecologically vital ground water should be expanded to include water located on non-federal land. DOE has considered many sites for radioactive waste disposal on non-federal lands. Some of these may contain ground water supplying an ecosystem which is managed by governmental or non-governmental entities for the purpose of ecological protection.

<u>191.02 Applicability</u>

Section 191.02(2) limits the applicability of the Subpart A standards to management and storage <u>at</u> a DOE disposal facility. DOE management and storage facilities not associated with a

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[3] <u>See</u> Getches, "Managing Public Lands: The Authority of the President to Withdraw Lands," 22 Nat. Resources J. 279 (1982).

disposal facility would apparently be exempt. We strongly object to this provision. Spent fuel, high-level, and transuranic waste storage facilities at the Savannah River Site, Idaho National Engineering Laboratory, Rocky Flats, Hanford and other locations could operate free from these critical standards. This creates a double standard between NRC-licensed management and storage facilities not associated with a disposal facility -- which apparently are covered by the standards -- and similar DOE facilities which would be exempt. EPA has advanced no technical or legal rationale for this distinction. It is particularly troubling in light of concerns about potential threats to human health and the environment at a number of DOE storage facilities, among them the infamous Hanford tanks. EPA must eliminate this exemption or face a likely legal challenge.

Subpart B -- Disposal Standards

191.11 Applicability

We are very concerned about the provision in this section which exempts "disposal that occurred before August 15, 1985" (the date the final standards were first issued). It is not at all clear what existing wastes this provision would exempt given varying definitions of disposal and varying intentions about the fate of specific wastes both at the time they were deposited and subsequently.

The provision is not only unclear but also unnecessary. To the extent that application of the disposal standards to wastes already deposited is inappropriate or problematic, then section 191.17 of the proposed standards allows the Administrator to substitute alternative provisions. This is the appropriate approach to existing wastes. The proposed provision would add unnecessary confusion and may lead to litigation.

191.12 Containment Requirements

NRDC does not support the proposed change in (b) which would explicitly allow DOE as the "implementing agency" to self-certify compliance. DOE self-regulation has produced massive nuclear waste problems that will require tens of billions of dollars to address. We believe that, at a minimum, EPA should review and concur in any DOE determination of compliance. More appropriately, EPA should make the compliance determination in the first instance.

191.13 Assurance Requirements

We object to the exemption of NRC-licensed facilities from the assurance requirements. We believe that EPA's authority under the Atomic Energy Act and Reorganization Plan Number 3 gives the agency the latitude to set assurance requirements applicable to NRC-licensed facilities.

We also object to the EPA decision under 191.13(d) to drop the requirement for "maximum achievable technology." This is the closest measure EPA has proposed to the ALARA principle which, as we state in our answer to EPA Question #1 supra, should be incorporated into the proposed standard throughout.

Assurance requirements (e) and (f) are also entirely unacceptable. They both appear to be triggered only when an implementing agency is "comparing alternative sites for a disposal system..." Since DOE is not investigating "alternative sites" to WIPP and Yucca Mountain, these critical assurance requirements may not be triggered. This loophole must be eliminated from both (e) and (f). In the case of assurance requirement (e) (the 100,000 year analysis), the most appropriate approach would be to add the provision to the Containment Requirements.

191.14 Individual Protection Requirements

See answers to EPA Questions #1 and #3 supra.

191.15 Demonstration of Capability to Comply

As explained in our comment on 191.12 supra, we do not believe that DOE should self-certify compliance with these standards.

191.16 Emplacement for Experimental Purposes

We do not believe that the standards should allow the emplacement of any wastes for experimental purposes. We have yet to see any convincing evidence that experimental data can be generated through in situ testing whose value outweighs the risks that the emplaced wastes will not or cannot be retrieved. However, if experimental emplacement is allowed, EPA must require that all wastes are retrieved at the conclusion of the test. Also, EPA must set a limit on waste quantity that represents the minimum amount necessary to conduct the proposed experiment. Additionally, EPA must require in 191.16(1) that the preliminary performance assessment indicates that the facility can meet the overall requirements and in 191.16(3) that there are not only procedures for removal but also a site that will accept the wastes once they are retrieved.

Subpart C -- Groundwater Protection

191.21 Applicability

As discussed in our comments on 191.11, we object to the exemption for wastes disposed of before August 15, 1985.

191.23 Disposal Standards

As discussed in EPA Question 3 *supra* we support, at a minimum, a 10,000 year duration for the standard (Option B).

Appendix B, Table 1

EPA derived the release limits in Appendix B, Table 1 to insure that there are no more than 1000 deaths per 10,000 years per repository sized to contain 100,000 MTHM of waste. While this may be comparable to the health risks from the original uranium ore bodies had they remained unmined, we believe a standard that permits ten public deaths per reactor lifetime (approximately 0.33 deaths/Gw-y) is unnecessarily high.[4]

Appendix B, Application of Table 1, Note 2:

Under Note 2(b) NRDC supports Option B as discussed in our answer to EPA Question #5 <u>supra</u>.

Appendix C

We strongly support the use of iterative performance assessments. A one-shot performance assessment prior to waste emplacement is simply inadequate. New and unpredictable circumstances could arise in the course of waste operations at a site which cast serious doubt on the ability of the facility to contain wastes adequately. As EPA has stated:

> [P]erformance assessment can and should be used throughout the entire process of siting, developing, and operating disposal systems. Performance assessment...can be used to periodically confirm that a system is performing as expected. New information should be continuously integrated and models continuously updated to improve the

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[4] We assume the annual discharge of spent fuel from a 1 Gw reactor is on the order of 33 MTHM, and the reactor lifetime is 30 years. Therefore a, a 1 Gw reactor would discharge 1000 MTHM over its lifetime.

reliability of and confidence in the performance assessments.[5]

In regard to the discussion of iterative performance assessments in Appendix C, we would note that the permissive language of the sentence "The implementing agency should demonstrate that the disposal system complies with Subpart B before any waste is placed in the system for disposal" may conflict with the mandatory language of 191.15 ("The implementing agency shall demonstrate that a disposal system is capable of complying with all the requirements of this Part before any radioactive waste is emplaced in the system").

[5] EPA Comments Regarding the National Academy of Science Board on Radioactive Waste Management Paper Entitled "Rethinking High-Level Radioactive Waste Disposal" at 3.

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December 14, 1991

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COMMENTS ON WORKING DRAFT No. 3, 40 CFR 191

Dear People,

These comments are submitted by Southwest Research and Information Center (SRIC) and Concerned Citizens for Nuclear Safety (CCNS) in response to your note of December 3, 1991 regarding submission of comments on Working Draft No. 3. SRIC is a 20-year old nonprofit educational organization that has been involved in nuclear waste issues for more than 14 years. CCNS is a nonprofit organization based in Santa Fe, New Mexico, that iss actively involved with nuclear safety issues.

We appreciate EPA's interest in obtaining comments from various interested parties. We look forward to EPA carefully considering these comments in preparing the proposed revisions to 40 CFR 191.

We first note that we will submit more complete comments when the draft revisions are proposed. We believe that EPA should make a special effort to ensure that interested parties are aware of the standards when they are re-proposed, and we would encourage the agency to hold public hearings to gather comments on the standards -- at least in New Mexico and Nevada as well as in Washington, D.C. These comments are offered to provide information and guidance to EPA, they are in no way to be considered as our definitive position on the adequacy of any proposal that the agency issues. Because of the short time available, we cannot provide exhaustive comments now.

The following are overall comments and specific comments, which include responses to EPA's six questions.

OVERALL COMMENTS

1. EPA should make issuance of draft revisions of 40 CFR 191 -- consistent with the 1st Circuit Court of Appeals decision in NRDC v. EPA -- a high priority. The agency should carefully consider public comments on the draft standards and then issue final standards.

More than four years have passed since the 1st Circuit remanded Subpart B. EPA has been unreasonably slow in proposing new standards that are consistent with the requirements of the Court's decision regarding the inadequacies of the "old" standards. There has been much discussion by the interested public and by Congress about the need for new and more stringent standards -- but there has been virtually no action by EPA. The agency has promised Congress on several occasions that the new standards would be in effect before now. EPA has a responsibility to all parties to make issuance of the draft standards a priority and to use the necessary resources to fully consider comments on the proposal and to then issue the new, more stringent standards.

2. Working Draft No. 3, with some changes, provides a reasonable basis for that proposal. We are pleased that some concerns that we have long held are being recognized in Working Draft No. 3. We would, however, encourage EPA to eliminate some of the options presented because they do not adequately protect public health and the environment and to consider some additional measures, which will be discussed in the specific comments that follow.

3. This rulemaking is of great interest and importance to present and future generations. Because of the importance of the new standards to the proposed repositories at WIPP and Yucca Mountain, people in New Mexico and Nevada are looking to EPA to issue standards that will be protective of public health and the environment. Hundreds of New Mexicans have carried signs to DOE and Congressional hearings (as recently as at the Senate Energy Committee hearing on September 21, 1991) that say:

WIPP MUST MEET NEW E.P.A. STANDARDS

Those people and many more like them fully expect that EPA will carry out its responsibilities <u>this time</u> to issue standards that are consistent with legal requirements and are protective of public health and safety for present generations and the thousands of future generations that will be affected if the permanent waste repositories do not perform extremely well. There is <u>certainly no</u> reasonable justification for weakening release limits that already allow a largenumber of deaths -- 1,000 over 10,000 years. In fact, we support more stringent requirements, especially since EPA's own analysis shows that a higher level of safety is achievable.

4. EPA should support statutory changes if it feels that necessary provisions in the new standard are currently beyond its statutory authority. We are particularly concerned about the need for an independent determination of compliance with the standards for unlicensed repositories, such as WIPP, and the need for continuing determinations that a repository will meet the requirements even after the initial determination is made.

Working Draft No. 3, like the 1985 standards, allows the Department of Energy (DOE), as implementing agency, to self-certify its compliance with the EPA standards at unlicensed facilities. Of course, at licensed sites, the NRC requires, among other things, a showing that the standards will be met in order to grant a construction license. (10 CFR 60.31(a)(2))

Public confidence in both the adequacy of the standards and the adequacy of compliance requires that an independent agency develop and issue the standards (so that they are not designed to ratify an already selected site) and that an independent agency make a determination that compliance has been achieved. Based on its past statements, including page 13 of the draft preamble, EPA does not believe that it currently has the authority to designate itself or some other independent agency to certify DOE's compliance with the standards at an unlicensed repository. EPA should note that gap in its preamble to the proposed revisions. The agency also should vigorously support passage of legislation to redress that inadequacy.

As to the concern about continuing demonstrations of compliance with the standards, the new provisions of Appendix C regarding iterative performance assessment are a step in the right direction. However, we believe that the guidance provided for iterative performance assessments should be more specific. For example, it should specify that implementing agency's "frequent opportunities for public and external peer review" be done in conformance with the requirements of the Administrative Procedure Act (5 U.S.C. 551 et seq. and 701 et seq.). It also should at least suggest how much time should pass between the "frequent reviews" -- perhaps every two years.

SPECIFIC COMMENTS

1. The proposed subsection 191.16 is not well supported. It should be greatly strengthened or eliminated in the proposal. Like the 1985 rules, Working Draft No. 3 Subpart B standards are design standards. They do not require waste emplacement in order to demonstrate compliance. Thus, we do not understand, and therefore do not support, this proposed new subsection. Since it has not been adequately explained and since it appears contrary to the fundamental principles of both the 1985 standards and those proposed in Working Draft No. 3, we recommend that the subsection not be included in the proposal.

2. The proposed change in Appendix B notes 1(d) and (e) regarding the transuranic (TRU) waste unit is important, especially in light of the fact that the first use of the standards will be at WIPP, a TRU waste facility. We would advocate for the more restrictive standard for several reasons. First, many of the alpha-emitting radionuclides will be dangerous considerably beyond the 10,000 years specified in Table 1 (indeed the half-life of plutonium-239 is almost 2.5 times that time

period). Thus, EPA is allowing a repository to meet its standards even if the facility would allow dangerous releases to the environment after 10,00o years. If EPA is not going to extend the time period for the containment requirements to a more reasonable time period (such as 240,000 years), it must use more conservative calculations for the hazards posed by the long-lived radionuclides. Second, the TRU waste forms are much more diverse than the other radioactive wastes covered by the standards. Such diversity adds additional uncertainties to long-term performance assessment. Accordingly, additional conservatism is warranted for TRU wastes. Third, TRU wastes are not being treated as conservatively by DOE as other radioactive wastes. For example, multiple engineered barriers have not been included in the WIPP design. Fourth, Working Draft No. 3 continues to allow DOE (as the implementing agency) to self-certify its compliance with the standard (see Overall Comment 4), so an additional margin of safety is needed because of that agency's historic record of promoting its self-interest rather than protecting public safety. (See, for example, the Office of Technology Assessment's Complex Cleanup, 1991.) Thus, we believe that the most reasonable restrictive standard for the TRU waste unit -- at least 3,000,000 curies -- should be used.

3. The option of a 25 millirems/year ede for maximum exposures to individuals should be eliminated. We do not necessarily endorse a limit as high as 10 millirems/year, but of the two options presented it is preferable because it provides better protection for the public. Individual protection requirements are an essential component of the disposal standards, and the most restrictive limits should always be set.

4. The new assurance requirement that would require a qualitative evaluation of projected releases over 100,000 years is a step in the right direction. As already noted, and as SRIC has long argued in its comments on the 1985 standard, we do not agree that 100,000 years is a sufficiently long timeframe because the hazard of some of the radioactive wastes extends far beyond that time period. Nonetheless, that new assurance requirement would provide some better level of protection for the public and should be included in the proposed revision. In addition, EPA should seriously consider an even longer timeframe.

5. The option of applying a 1,000-year duration in Sections 191.14 and 191.23 should be eliminated from the proposed revision. The 10,000-year time period is comparably more restrictive and therefore more appropriate. We would reiterate that we do not believe that even 10,000 years is a sufficiently long duration.

6. To EPA's question -- "Should the agency develop no-degradation requirements for especially valuable ground waters?" -- we answer yes. That response is required for several reasons.

First, DOE has confined its selected repository sites to the West where surface water is usually in short supply and ground water is frequently used for human and livestock drinking water as well as for irrigation. Thus, ground water should always be protected as stringently as possible. Second, hydrologic flows could change dramatically over 10,000 years (and are perhaps more likely to change over the longer terms of the hazard of some radioactive wastes), so circumstances could arise in which water that is not presently classified as an "underground source of drinking water" might be used by humans. Thus, a non-degration standard for such waters is necessary and appropriate. Third, contamination of such waters probably cannot be reversed. As EPA should be aware from its own experiences with contaminated ground water, remediation is extremely difficult and expensive and in many cases complete restoration of water quality cannot be accomplished. Thus, a no-degradation standard is necessary. Regarding which types of ground waters should be included in such a no-degradation standard, we would refer you to (among other sources) the comments submitted by SRIC and Serious Texans Against Nuclear Dumping of May 1, 1983.

7. We do not support the "three bucket proposal" suggested by NRC staff and urge that it not be included in the proposed revision. Since 1978, the public, the industry, and federal agencies have been aware that EPA would use a probabilistic approach to the containment requirements. To suddenly change that approach in its proposed revision would create confusion and uncertainty and require fundamental reevaluation of many aspects of the standards. Further, there has been no adequate demonstration that such a changed approach is more appropriate because it would be more protective of public health. In fact, we believe that the contrary would be true. Thus, we strongly urge that NRC approach not be included in the proposed revision.

8. We believe that it is appropriate that EPA consider gaseous radionuclide releases because such releases are likely. We have not had the opportunity nor the resources to independently investigate all the appropriate technical information. We would urge EPA to conduct such an investigation, in addition to using whatever suggestions it has received from other commentors.

Thank you for your consideration of these comments. We expect to be actively involved in the development of the new standards and request that you keep both organizations fully informed of your activities.

Sincerely,

Don Hancock | Margret Carde DE

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