March 25, 1983

SECY-83-59A

RULEMAKING ISSUE
(Information)

For: The Commissioners

From: William J. Dircks, Executive Director for Operations

Subject: 10 CFR Part 60 -- Disposal of High Level Radioactive Waste in Geologic Repositories: Technical Criteria and Conforming Amendments

Purpose: To provide the Commissioners with those portions of draft NUREG-0804, not transmitted earlier as part of SECY-83-59.

Discussion: On February 9, 1983, final amendments to 10 CFR Part 60 were forwarded to the Commission as SECY-83-59. The Commission has not yet acted on this paper. It was noted in that staff paper that the detailed staff analysis of public comments (#1-89) received on the proposed technical criteria (46 FR 35280) would be forwarded to the Commission separately. This analysis was not included with those portions of draft NUREG-0804 forwarded to the Commission in SECY-83-59 as conforming changes were necessary to reflect Commission guidance of January 4, 1983, publication of proposed EPA standards, and certain provisions of the Nuclear Waste Policy Act of 1982. These changes have now been made and the analysis is included in Parts A and B of draft NUREG-0804 which is attached to this paper. (Note: Parts A and B as well as Appendix A of draft NUREG-0804 are too voluminous for inclusion here and have been placed on file in the Secretary's office.)

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Enclosure: Draft NUREG-0804

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DRAFT NUREG-0804
February 1983

D R A F T

STAFF ANALYSIS OF
PUBLIC COMMENTS ON
PROPOSED RULE - 10 CFR PART 60
"DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES
IN GEOLOGIC REPOSITORIES"
AND
RATIONALE FOR THE
PERFORMANCE OBJECTIVES
IN 10 CFR PART 60

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24	B. Blanchard, U.S. Department of the Interior	10/22/81
25	R. Uhrig, Florida Power and Light Company	10/23/81
26	R. Bradbury, Stone and Webster Engineering Corporation	10/26/81
27	J. Cohen	10/26/81
28	T. Smith, Institute of Electrical and Electronics Engineers	10/27/81
29	F.S. Feates, Department of the Environment, UK	10/19/81
30	L. Toth	10/28/81
31	R. Dahn	10/28/81
32	D. Nucleare	10/29/81
33	R. W. Deuster, Nuclear Fuel Services	10/30/81
34	J. A. Adam	11/2/81
35	V. McIntyre	11/2/81
36	N. D. Lewis, Energy Facility Site Evaluation Council, State of Washington	11/3/81
37	A. J. O'Donnell, Bechtel National Inc.	11/3/81
38	B. R. McElmurry	11/3/81
39	M. J. Fisher	11/3/81
40	W. J. Bryan III	11/3/81
41	E. Nemethy, Ecology/Alert	11/3/81
42	A. Baum	11/3/81
43	D. M. Petefish	11/3/81
44	R. E. L. Stanford, Utility Nuclear Waste Management Group	11/3/81
45	E. B. Wilson and K. Krauskopf, National Research Council	11/4/81

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46	R. I. Newman, American Institute of Chemical Engineers	11/4/81
47	D. P. Sidebotham, New England Coalition on Nuclear Pollution, Inc.	11/4/81
48	S. Meyers, U.S. Department of Energy	11/5/81
49	P. J. Nickles and C. H. Montange, Covington and Burling	11/5/81
50	C. Walske, Atomic Industrial Forum	11/6/81
51	A. M. Krill, Stearns - Roger	11/6/81
52	R. Roy, Pennsylvania State University	11/6/81
53	T. H. Pigford, University of California, Berkeley	11/6/81
54	M. T. Johnson, Westinghouse Electric Corp.	11/6/81
55	W. O. Parker, Jr, Duke Power Co.	11/6/81
56	J. J. Kearney, Edison Electric Institute	11/9/81
57	B. C. Musgrave, Lawrence Livermore Laboratory	11/9/81
58	R. Nilson, Exxon Nuclear Co.	11/9/81
59	G. R. Thompson, Union of Concerned Scientists	11/9/81
60	C. St. John, Applied Mechanics, Inc.	11/9/81
61	L. Penberthy, Penberthy Electromelt Int'l, Inc.	11/9/81
62	B. H. Sway, State of California, Department of Conservation	11/9/81
63	L. H. Bohlinger, State of Louisiana, Department of Natural Resources	11/10/81
64	W. N. Thomas, Virginia Electric and Power Co.	11/10/81
65	J. W. Green, Jr. State of Mississippi, Department of Energy and Transportation and M. B. E. Bogard, Mississippi Department of Natural Resources	11/10/81
66	W. C. Liebold, Sierra Club	11/12/81
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70	N. K. Olson, South Carolina Geological Survey	11/16/81
71	Dr. T. C. Gustavson, University of Texas at Austin	11/16/81
72	Mr. and Mrs. D. W. Willoughby	11/06/81
73	Mr. and Mrs. M. F. Vega	11/06/81
74	Mr. and Mrs. J. Johnson	11/10/81
75	B. Houston, Hamilton and Associates, for The American Ceramic Society	11/18/81
76	E. R. Weiss, Harmon and Weiss for the Natural Resources Defense Council, Inc.	11/19/81
77	D. Woodbury, J. L. LaFleur, State of Wisconsin, Division of Emergency Government	11/20/81
78	R. H. Neill, State of New Mexico, Environmental Evaluation Group	11/20/81
79	W. G. Counsil and J. P. Cagnetta, Northeast Utilities	11/23/81
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81	Z. N. Jensen, R.N.	12/02/81
82	B. D. Withers, Portland General Electric	12/14/81
83	W. E. Davis, New York State Energy Office	12/28/81
84	B. Blanchard, U.S. Department of the Interior	01/27/82
85	K. B. Robertson, U.S. Geological Survey	03/02/82
86	(misdocketed)	
87	J. P. Wing (misdocketed)	04/08/82
88	R. Montgomery (misdocketed)	04/08/82
89	P. Shewmon, Chairman, U.S. NRC Advisory Committee on Reactor Safeguards	08/24/82
90*	L. M. Muntzing, American Nuclear Society	10/13/82

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91*	S. Brewer, U.S. Department of Energy	10/29/82
92*	P. Walsh, State of Wisconsin, Radioactive Waste Review Board	12/22/82
93*	L. M. Muntzing, American Nuclear Society	02/09/83

*These comment letters were received too late to be included in the Staff Analysis of Public Comments on proposed 10 CFR Part 60. However, copies of these letters are provided in Appendix A.

OVERVIEW

1.0 BACKGROUND

1.1 Introduction

On February 25, 1981, the Nuclear Regulatory Commission (NRC) published rules which establish procedures for the licensing of geologic disposal, by the U.S. Department of Energy (DOE), of high-level radioactive wastes (HLW). 46 FR 13971. On July 8, 1981, NRC proposed technical criteria which would be used in the evaluation of license applications under those procedural rules. 46 FR 35280. NRC received 93 comment letters on these proposed technical criteria, 89 of which were received in time for the Commission to consider in preparing the final technical criteria. No significant new issues were raised in the letters received too late for consideration. The NRC staff has considered all these comments in preparing the technical criteria that they have recommended to the Commission for publication in final form. The principal comments, and the staff's responses, are reviewed in the discussion below. This discussion takes the form of a Statement of Considerations and, hence, appears to state the views of the Commission itself. In reality, it is the staff's analysis cast into a format so as to facilitate Commission consideration of the staff's recommendations on the disposition of the final technical criteria.

This overview is one of several "cuts" at the problem of analysis of the public comments received. In this overview the staff will first discuss six issues on which the Commission had specifically requested public comment. It will then review other principal changes to the rule which have been adopted in the light of comments received. The discussion will then take up suggestions of a policy nature which the staff recommends that the Commission not adopt. Finally, a section-by-section analysis reviews all changes being recommended other than those of a strictly editorial nature. A more detailed analysis of the comments is contained in Parts A and B of this document. Due to the large number of individual comments (about 700) the individual comment letters have been subdivided and categorized according to the headings found in the Table of Contents. Part A of this Staff Analysis contains responses to general comments on 10 CFR

Part 60 and nine itemized issues* not specifically linked to the text of the proposed rule (e.g., Role of the States). Part A addresses Comment Nos. 1-148. Part B contains the NRC staff responses to public comments on the text of the proposed rule and conforming amendments as well as closely associated comments on particular issues. Part B addresses Comment Nos. 149-674. The organization and numbering of these individual comments are presented in the Table of Contents. Part C of this report contains the Rationale for the numerical performance objectives that are part of the final technical criteria being recommended to the Commission. Copies of the full text of the 93 comment letters are found in Appendix A and a comparative staff version of the final rule being recommended by the staff to the Commission is found in Appendix B, as the final rule contains a number of changes, explained in this statement, that reflects concerns addressed in the public comments. Appendix C contains a copy of the assumed EPA standard used in the analysis of the numerical performance objectives. To the extent that the results of the multi-format presentations of comments and analyses of comments are duplicative, redundant or confusing, the staff apologizes. The objective was to be thorough even at the expense of extra verbage.

1.2 Licensing Procedures

The licensing procedures referenced above provide for DOE to submit site characterization reports to NRC prior to characterizing sites that may be suitable for disposal of HLW. NRC would analyze these reports, taking into account public comments, and would make appropriate comments to DOE.

The licensing process will begin with the submission of a license application with respect to a site that has been characterized. Following a hearing, DOE may be issued a construction authorization. Prior to emplacement of HLW, DOE would be required to obtain a license from NRC; an opportunity for hearing is provided prior to issuance of such a license. Permanent closure of the geologic repository and termination of the license would also require licensing action for which there would be opportunity for hearing.

*General comments or the discussion of each issue such as retrievability, discussed in the Supplementary Information at 46 FR 35282, will be answered with those addressing the provisions for retrievability set forth in the proposed rule at 46 FR 35289 (60.111)). This was done to reduce the amount of duplication in staff responses.

1.3 Purpose of the Technical Criteria

The purpose of the technical criteria is to define more clearly the bases upon which licensing determinations will be made and to provide guidance to DOE and information for the public with respect to the Commission's policies in this regard. The criteria also indicate the approach the Commission is taking with respect to implementation of an Environmental Protection Agency (EPA) standard, particularly with respect to the classification of processes and events as "anticipated" or "unanticipated" and the definition of the "accessible environment" from which radionuclides must be isolated.[1]

The Commission anticipates that licensing decisions will be complicated by the uncertainties that are associated with predicting the behavior of a geologic repository over the thousands of years during which HLW may present hazards to public health and safety. It has chosen to address this difficulty by requiring that a DOE proposal be based upon a multiple barrier approach. An engineered barrier system is required to compensate for uncertainties in predicting the performance of the geologic setting, especially during the period of high radioactivity. Similarly, because the performance of the engineered barrier system is also subject to considerable uncertainty, the geologic setting must be able to contribute significantly to isolation.

The multibarrier approach is implemented in these rules by a number of performance objectives and by more detailed siting and design criteria.[2] In addition to the objective of assuring that licensed facilities will adequately isolate

[1]Reorganization Plan No. 3 of 1970 authorizes EPA to establish generally applicable environmental standards for radioactivity. EPA's recently proposed standard would allow higher levels of radioactivity for "unanticipated processes and events" than would be permitted if "anticipated processes and events" were to occur. The proposed standard also relates these levels to places within the "accessible environment." The Commission has assumed that these concepts will be reflected in final standards that may be established by EPA.

[2]Under the Nuclear Waste Policy Act of 1982, the Commission's technical criteria "shall provide for the use of a system of multiple barriers in the design of the repository...as the Commission deems appropriate." Section 121(b)(1)(B). The criteria set forth in this rule represent the criteria which, for purposes of this provision, the Commission deems appropriate.

HLW over the long term, these provisions also address considerations related to health and safety during the operational period prior to permanent closure of the geologic repository.

In this statement of considerations the Commission will first discuss six issues on which it had specifically requested public comment. It will then review other principal changes to the rule which have been adopted in the light of comments received. The discussion will then take up suggestions of a policy nature which the Commission has declined to adopt. Finally, a section-by-section analysis reviews all changes made other than those of a strictly editorial nature. As appropriate, reference is made to relevant provisions of the Nuclear Waste Policy Act of 1982, Pub. L. 97-425, approved January 7, 1983, and to the Environmental Protection Agency's proposed Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes, 47 FR 58195, December 29, 1982. The Commission regards the publication of these rules as constituting full compliance with Section 121(b)(1)(A) of the Nuclear Waste Policy Act, which requires promulgation of the Commission's technical criteria for geologic repositories not later than January 1, 1984.[3]

[3]The technical criteria are explicitly stated to be applicable to construction authorization, § 60.101(b) and to the issuance of licenses to receive and possess high-level radioactive waste at geologic repositories, § 60.101(a). An application to authorize permanent closure requires a license amendment, § 60.51(a); the relevant technical requirements and criteria are set out in the rules here being adopted, inasmuch as the Commission is to be "guided by the considerations that govern the issuance of the initial license, to the extent applicable," § 60.45(b). The Commission interprets the statutory provision pertaining to applications for "decommissioning" to refer to the procedure described in § 60.52, pertaining to termination of a license; such an application would also require a license amendment, and the Commission here, too, would be guided by the present rules to the extent applicable, together with the additional criteria already set out at § 60.52(c). Thus, at every stage of the licensing process, the central inquiry will be the adequacy of DOE's plans and activities as they relate to the isolation of wastes (as well as to safety during operations); and for each decision point we have provided, as is appropriate, for an evaluation that takes into account both the performance objectives and the more detailed criteria that the Commission here adopts. (If Section 121(b)(1)(A) applies to the decommissioning of surface facilities, the required criteria have been included in § 60.132(a). That paragraph provides that surface facilities must be designed to facilitate decontamination or dismantling to the same extent as would be required, under other NRC regulations, for equivalent activities. This topic may be treated again, in greater detail, in connection with the development of rules that would be generally applicable to decontamination and dismantlement of facilities at which activities subject to Commission regulatory authority are carried out.)

The Commission will review these criteria after EPA's environmental standards are published in final form and will initiate subsequent rulemaking actions, as necessary, to take any such standards into account. The Commission further intends additional rulemaking to deal with any changes in licensing procedures that may be necessary in light of the Nuclear Waste Policy Act.

2.0 Issues Raised by the Commission

As noted above, the Commission specifically requested public comment on six issues, each of which will be reviewed here before turning to other considerations. These issues dealt with: (1) a single overall performance standard vs. minimum performance standards for each of the major elements of the geologic repository; (2) the need for, and appropriate duration of, a waste retrievability period; (3) the level of detail to be used in the criteria, particularly with respect to design and construction requirements; (4) the desirability of population-related siting criteria; (5) the application of an ALARA (as low as reasonably achievable) principle to the performance requirements dealing with containment and control of releases; and (6) alternative approaches on dealing with possibilities of human intrusion into the geologic repository.

2.1 Single vs. Multiple Performance Standards

The Commission identified two potentially viable approaches to assuring achievement of the desired isolation goal of controlling releases so as to assure that radioactivity in the general environment is kept to sufficiently low levels. The Commission suggested that a course that would be "reasonable and practical" would be to adopt a "defense-in-depth" approach that would prescribe minimum performance standards for each of the major elements of the geologic repository, in addition to prescribing the EPA standard as a single overall performance standard. However, as an alternative, the Commission invited comment on an approach that would specify the EPA standard as the sole measure of isolation performance.

There was general acceptance of the Commission's multiple barrier approach, with its identification of two major engineered barriers (waste packages and underground facility), in addition to the natural barrier provided by the geologic setting.

While the usefulness of multiple barriers was recognized, the establishment of fixed numerical values for performance was extensively criticized. The criticism took two forms. First, numerous commenters argued that until such time as an EPA standard is established, no logical connection can be demonstrated between the performance of the particular barriers and the overall system performance objective. The values specified by NRC, it was argued, had not been shown to be either necessary or sufficient to meet any particular standard. The second criticism was that the performance appropriate to a particular barrier is greatly dependent upon design features and site characteristics and that values such as those proposed by the Commission could unduly restrict the applicant's flexibility - possibly imposing great additional expense without compensating protection of public health and safety.

The Commission recognizes the force of both these arguments. Nevertheless, if the Commission were simply to adopt the EPA standard as the sole measure of performance, it would have failed to convey in any meaningful way the degree of confidence which it expects must be achieved in order for it to be able to make the required licensing decisions. More should be done. To that end, the Commission considers it appropriate to include reasonable generic requirements that, if satisfied, will ordinarily contribute to meeting the standards even though modifications may need to be made for some designs and locations.

The Commission's response, therefore, has been to apply, for illustrative purposes, an assumed EPA standard and to examine the values for particular barriers that would assist in arriving at the conclusion that the EPA standard has been satisfied. For this purpose, a draft EPA standard which was referred to in some of the comments has been used. A copy of this draft standard has been placed in the PDR and is also contained in Appendix C. Following publication of EPA's proposed standard in the Federal Register on December 29, 1982, a supplemental evaluation was made to take into account certain departures from EPA's earlier draft. In this way, the Commission has been able to demonstrate the logical connection which it makes between the overall system performance objective for anticipated processes and events, as set out in EPA's proposed standard, and the performance of specific barriers. One of the considerations that affects its judgment in this regard is the need to take proper account of uncertainties in the performance of any of the barriers. As one commenter noted, "To provide a safety factor to compensate for this uncertainty, a multi-barrier system has many advantages. Since the Commission cannot answer the global problem and predict every possible combination of circumstances that might cause releases of waste, multiple, independent mechanisms of slowing or limiting the discharge of radioactive materials to the environment are desirable." There is nothing inconsistent between the multiple barrier, defense-in-depth approach and a unitary EPA standard; on the contrary, in view of the many possible circumstances that must be taken into account, the Commission firmly believes that the performance of the engineered and natural barriers must each make a definite contribution in order for the Commission to be able to conclude that the EPA standard will be met. The Commission's task is not only a mathematical one of modeling a system and fitting values for particular barriers into the model in order to arrive at a "bottom line" of overall system performance. The Commission is also concerned that its final judgments be made with a high degree of confidence. Where it is practical to do so, the Commission can and will expect barrier performance to be enhanced so as to provide greater confidence in its licensing judgments. Accordingly, a variance between actual and assumed EPA standards will not necessarily require a change of corresponding magnitude in the individual barrier performance requirements.

While use of an assumed EPA standard provides a basis for specifying anticipated performance requirements for individual barriers, it does not deal with the concern about undue restriction upon the applicant's flexibility. The Commission's response to this has not been to abandon the values altogether, but rather to allow them to be modified as the particular case warrants. Thus, to take one example, the Commission continues to be concerned that thermal disturbances of the area near the emplaced waste add significantly to the uncertainties in the calculation of the transport of radionuclides through the geologic environment. The proposed rule addressed this problem by providing that all radionuclides should be contained within the waste packages for a period of 1,000 years. The Commission continues to consider it important to limit the source term by specifying a containment period (as well as a release rate). But the uncertainties associated with the thermal pulse will be affected by a number of factors, such as the age and nature of the waste and the design of the underground facility. For some repositories, a period substantially shorter than 1,000 years may be sufficient to allow for some of the principal sources of uncertainty to be eliminated from the evaluation of repository performance. For cases analyzed by the Commission on the basis of specified assumptions, a range of 300 years to 1,000 years would be appropriate. (These values appear in § 60.113(a)(ii)(A).) Yet even a shorter designed containment period might be specified, pursuant to § 60.113(b), in the light of conditions that are materially different from those that had been assumed. For example, if the wastes had been processed to remove the principal heat-generating radionuclides (cesium-137 and strontium-90), the 300-year provision would not be controlling. Similarly, the Commission may approve or specify a radionuclide release rate or a pre-waste-emplacement groundwater travel time that differs from the normal values, provided that the EPA standard, as it relates to anticipated processes and events, is satisfied. Appropriate values will be determined in the course of the licensing process, in a manner sensitive to the particular case, using the principles set out in the performance objectives, without having to have recourse to the exemption provisions of the regulations.

The numerical criteria for the individual barriers included in the rule are appropriate, insofar as anticipated processes and events are concerned, in assisting the Commission to determine with reasonable assurance that the proposed EPA standard has been satisfied. It should be noted, however, that in order to meet the EPA standard as it applies to unanticipated processes and events, higher levels of individual barrier performance may be required.

2.2 Retrievability

The purpose of this requirement was to implement in a practical manner the licensing procedures which provided for temporal separation of the emplacement decision from the permanent closure decision. Since the period of emplacement would be lengthy and since the knowledge of expected repository performance could be substantially increased through a carefully planned program of testing, the Commission wished to base its decision to permanently close on such information. The only way it could envision this was to insist that ability to retrieve - retrievability - be incorporated into the design of the geologic repository.

The proposed rule would have required in effect that the repository design be such as to permit retrieval of waste packages for a period of up to 110 years (30 years for emplacement, 50 years to confirm performance, 30 years to retrieve). The Commission solicited comment, noting that it would not want to approve construction of a design that would unnecessarily foreclose options for future decisionmakers, but that it was concerned that retrievability requirements not unnecessarily complicate or dominate repository design.

While the benefits of retaining the option of retrieval were recognized, the length of the proposed requirement, in the opinion of several commenters, was excessive. In their view, the Commission had given inadequate consideration to the additional costs of design, construction, and operations implied in the original proposal; however, no new cost or design information was presented by the commenters.

The Commission adheres to its original position that retrievability is an important design consideration. However, in response to the concerns expressed, the Commission has decided to rephrase the requirement in functional terms. The final rule thus specifies that the design shall keep open the option of waste retrieval throughout the period during which the wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. By that time, significant uncertainties will have been resolved, thereby providing greater assurance that the performance objectives will be met. In particular, the performance confirmation program can provide indications whether engineered barriers are performing as predicted and whether the geologic and hydrologic response to excavation and waste emplacement is consistent with the models and tests used in the Commission's earlier evaluations. While the Commission has provisionally specified that the design should allow retrieval to be undertaken at any time within 50 years after commencement of emplacement operations, this feature is explicitly subject to modification in the light of the planned emplacement schedule and confirmation program for the particular geologic repository.

Some commenters suggested that the technical criteria specify the conditions that would require retrieval operations to be initiated. Such provisions would not belong in Subpart E, which is concerned with siting and design. Nor are they needed elsewhere. In the Commission's view it is clear that retrieval could be required at any time after emplacement and prior to permanent closure if the Commission no longer had reasonable assurance that the overall system performance objective would be met. This situation could exist for a variety of reasons and the Commission believes that it should retain the flexibility to take into account all relevant factors and that it would be imprudent to limit the Commission's discretion by specifying in advance the particular circumstances that would make it necessary to retrieve wastes. It should be noted that DOE may elect to maintain a retrievability capability for a longer period than the Commission has specified, so as to facilitate recovery of the economically valuable contents of the emplaced materials (especially spent fuel). So long as the other provisions of the rule are satisfied this would not be prohibited. This consideration, however, plays no role in the Commission's requirement pertaining to retrievability. The Commission's purpose is to protect public health and safety in the event the site or design proves unsuitable. The provision is not intended to facilitate recovery for resource value.[4]

[4]Under the Nuclear Waste Policy Act of 1982, the Commission's technical criteria "shall include such restrictions on the retrievability of the solidified high-level radioactive waste and spent fuel in the repository as the Commission deems appropriate," Section 121(b)(1)(B). The criteria set forth in this rule represent the criteria which, for purposes of this provision, the Commission deems appropriate.

Section 122 of the Nuclear Waste Policy Act provides that, at the same time a repository is designed, DOE shall specify an appropriate period during which spent fuel could be retrieved for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting recovery of the economically valuable components of such spent fuel. The period of retrievability is subject to approval or disapproval by the Commission as part of the construction authorization process. Insofar as health and safety considerations are concerned, the Commission intends to grant such approval so long as its technical criteria are satisfied, and the Commission further intends to modify the licensing procedures to so specify.

The Commission has also included a specific provision clarifying its prior intention that the retrievability design features do not preclude decisions allowing earlier backfilling or permanent closure. A related clarifying change has been the incorporation of a definition of "retrieval." This definition indicates that the requirement of retrievability does not imply ready or easy access to emplaced wastes at all times prior to permanent closure. Rather, the Commission recognizes that any actual retrieval operation would be an unusual event and may be an involved and expensive operation. The idea is that it should not be made impossible or impractical to retrieve the wastes if such retrieval turns out to be necessary to protect the public health and safety. DOE may elect to backfill parts of the repository with the intent that the wastes emplaced there will never again be disturbed; this is acceptable so long as the waste retrieval option is preserved.

The Commission has thus retained the essential elements of the retrievability design feature, but has provided greater flexibility in its application. The Commission recognizes that retrievability implies additional costs - more, perhaps, for some media and designs than for others - yet it believes this is an acceptable and necessary price to pay if it enables the Commission to determine with reasonable assurance, prior to an irrevocable act of closure, that the EPA standard will be satisfied.

2.3 Level of Detail

The proposed rule contained general and detailed prescriptive requirements, derived from Commission experience and practice in licensing other facilities, with respect to the design and construction of a geologic repository. The Commission noted, however, that it was continuing to examine other possibilities for promulgating the more detailed of these requirements and it invited comments on the topic.

The public response included arguments addressed both to the level of detail generally and to specific criteria which were deemed to be unduly restrictive.

The Commission has concluded that there is merit in describing, in functional terms, the principal features which should be incorporated into geologic repository design - such as protection against dynamic effects of equipment failure, protection against fire and explosions, emergency capability, etc. Certain of these proposed criteria, however, such as those dealing with subsurface ventilation and shaft and borehole seals, were excessively detailed and, in some cases, inappropriate. At this stage of development, the Commission believes it should place emphasis upon the objectives that must be met and not become unduly concerned about the particular techniques that may be used in doing so. The changes that have been made are addressed in some detail in the section-by-section analysis of the rule.

2.4 Population-Related Siting Criteria

The proposed rule did not include any siting requirements which dealt directly with population density or proximity of population centers to a geologic repository operations area. The Commission indicated its belief that a more realistic approach, given the long period of time involved, would be to address the issue indirectly through consideration of resources in the geologic setting.

The numerous comments submitted in response to the Commission's specific question on this issue fell generally into two categories - those that endorsed the proposed approach and those that argued that population factors were important. The latter group addressed not only the geologic repository's long-term isolation capability, but also the relevance of population considerations in connection with the period when wastes are being received and emplaced.

The Commission is persuaded that population factors may need to be considered in connection with the period when wastes are being received and emplaced through evaluation of the adequacy of DOE's emergency plans. That section of the safety analysis report dealing with emergency planning (see 60.21(c)(9)) will be reviewed on a case-by-case basis in the licensing process according to criteria that will be set forth in the future in Subpart I. (It should also be noted that under Section 112(a) of the Nuclear Waste Policy Act of 1982, DOE is required to develop guidelines that, among other things, will specify population factors that will disqualify a site from development as a repository. Issuance of these guidelines is subject to the concurrence of the

Commission. The Commission has made no determination whether such guidelines, when issued, should in some manner be reflected in either the technical criteria or licensing procedures portions of 10 CFR Part 60.)

Population distribution over the long term is immaterial if the geologic repository operates as anticipated. Demographic factors could nevertheless be of concern to the extent that they could increase the probability or the consequences of releases associated with unanticipated processes or events. As to probability, it is difficult to relate the likelihood of releases to population factors; it is the view of the Commission that it is more realistic, as originally stated, to reduce the probability by avoiding sites with significant resource potential and by using records and monuments to caution future generations. Consequences of unanticipated releases would be greater if they should occur in densely populated areas. Nevertheless, it is the view of the Commission that it makes little sense to attempt to limit such consequences by means of a population-related siting criterion, since long-range demographic forecasts are so inherently speculative and unreliable; instead, the Commission is taking the approach that releases that result from the occurrence of unanticipated processes and events must be evaluated and must satisfy the EPA standard.

While the Commission considers, based on the above, that the rule should not now contain explicit requirements, particularly numerical limits, on population density or distance from population centers, it notes that considerations related to future human activities, particularly uses of groundwater, are an important source of uncertainty in assessing future performance of a geologic repository. The Commission would consider it a favorable condition if these sources of uncertainty, which would be affected by a large nearby population, were not present at a particular site. Therefore, the Commission has included in the final rule, as a favorable condition, a low population density within the geologic setting and a controlled area that is remote from population centers.

The Commission anticipates that the selection of a densely populated area would be unlikely even in the absence of expressed constraints in NRC regulations. For one thing, such a site would be disqualified under the guidelines to be developed under the Nuclear Waste Policy Act. Additionally, DOE will need to acquire interests in land within the controlled areas and may have additional powers beyond the boundaries of the controlled area. These requirements may be difficult to satisfy unless a remote location is selected for the geologic repository.

2.5 ALARA

The notice of proposed rulemaking requested comment on "whether an ALARA (as low as reasonably achievable) principle should be applied to the performance requirements dealing with containment and control of releases." Some commenters believed that ALARA should be applied to all licensed activities, and that no exception should be made for geologic repositories. Other commenters argued against incorporating ALARA, since the allowable releases under the EPA standard would already be so low as to eliminate any significant risk to public health and safety.

Based in part upon the standard recently proposed by EPA, the Commission considers it reasonable to anticipate that the permissible amounts of radioactivity in the general environment will be established at such a low level that efforts to reduce releases further would have little, if any, demonstrable value commensurate with their costs. Accordingly, the ability of a geologic repository to perform at levels superior to the EPA standard should not be the issue in licensing proceedings. The central issue with respect to the EPA standard is whether DOE's proposal, and the data presented in its support, will enable the Commission to determine with reasonable assurance that the established EPA standard will be met. The Commission may insist upon the adoption of a variety of design features, tests, or other measures in order to be able to conclude with confidence that the EPA standard is met. The result may be the same as if the Commission were to impose similar requirements in the name of keeping releases as low as reasonably achievable. But when the Commission finds that certain measures are needed to improve confidence in dealing with uncertainties, it is making a substantial safety judgment.

The same kinds of balancing that are undertaken in ALARA determinations may be appropriate. That is, if confidence in the performance of the geologic repository is sensitive to a particular source of uncertainty, it will be in order for the Commission to take into account both the significance of the factor involved and the costs of reducing or eliminating it.

In short, the Commission has concluded that the long-term performance requirements should not be tied to an ALARA principle, and the rule remains as it was when proposed. The Commission believes the concerns of the commenters in support of the ALARA approach will be largely accommodated in connection with its treatment of uncertainties in the course of the licensing process.[5]

2.6 Human Intrusion

The Commission observed, in the preamble of the proposed rule, that everything that is reasonable should be done to discourage people from intruding into the geologic repository. Those measures which it believed to be reasonable included directing site selection toward sites having little resource value and marking and documentation of the site. Beyond that, the Commission felt there would be no value in speculating on the "virtual infinity of human intrusion scenarios and whether they will or will not result in violation of the EPA standard." The Commission explained that inadvertent intrusion was highly improbable, at least for the first several hundred years during which time the wastes are most hazardous; and even if it should occur, it is logical to assume that the intruding society would have capability to assess the situation and mitigate consequences. The Commission recognized that deliberate intrusion to recover the resource potential of the wastes could result in elevated releases

[5]The proposed EPA standard calls for disposal systems to be selected and designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations. Proposed 40 CFR § 191.14(b). The Commission's rules will accommodate the underlying concerns of EPA, as they are articulated in the preamble to the Agency's proposed standards. There EPA explains that it is concerned, as is the Commission, with assuring confidence in complying with the numerical release limits. The Commission also notes that the definition of "generally applicable environmental standards" in Reorganization Plan No. 3 of 1970 refers to limits such as those contained in proposed § 191.13 and related definitions. Accordingly, the Commission would not contemplate making any revision to its rule even if EPA were to adopt a provision such as proposed § 191.14(b). Because of the measures that will be required to address the uncertainties, the Commission fully expects that actual releases are likely to be well below the upper bounds expressed in the EPA standard.

of radioactivity, but concluded that the acceptability of such releases was properly left to those making the decision to undertake resource recovery operations. It noted that comment on its proposal and alternative approaches would be welcome.

Commenters generally accepted the approach outlined. A number of commenters did emphasize the importance of intrusion scenarios as having the potential to lead to releases of radionuclides to the environment, but they suggested no alternative means for dealing with the prospect. One commenter correctly calls attention to the possibility of a third category of intrusion - that which is "intentional yet indifferent" - which was not covered in the earlier discussion of "inadvertent" or "deliberate" intrusion. This behavior presupposes knowledge (albeit imperfect) of the existence and nature of the geologic repository and a level of technology that could be applied to remedial action as well as to the intrusion itself, yet makes no judgment as to whether a societal decision has been made concerning the intrusion. The Commission has addressed this and other concerns in the revised language that is being adopted, as explained below.

Although the discussion accompanying the proposed rule indicated that intrusion scenarios need not be considered, the rule itself was not explicit on this point. The Commission considers it necessary to clarify its position and, in doing so, allows for examination of intrusion under appropriate bounding conditions. After careful consideration of the public comments received on questions relating to human intrusion, the Commission is of the view that while the passive control measures it is requiring will reduce significantly the likelihood of inadvertent intrusion into a geologic repository, occasional penetration of the geologic repository over the period of isolation cannot be ruled out, and some provision should be made in the final rule for consideration of intrusion should these measures fail. Its objective is to provide a means for evaluating events that are reasonably of concern, while at the same time excluding speculative scenarios that are inherently implausible. The Commission will not require this generation to design for fanciful events which the Commission has an abiding conviction will never occur; on the contrary, it will grant a license if it is satisfied that the risk to the health and safety of future generations is not unreasonable.

The rule now incorporates a definition of "unanticipated processes and events" which are reviewable in a licensing proceeding; such processes and events expressly include intrusion scenarios that have a sufficiently high likelihood and potentially adverse consequence to exceed the threshold for review. The scenarios must be "sufficiently credible to warrant consideration." The Commission is requiring that certain assumptions be made in assessing this likelihood. First, the monuments required by the rule are assumed to be sufficiently permanent to serve their intended purpose. The Commission takes this position because of its confidence that monuments can be built to survive. While it assumes that the monuments will last, it does not automatically assume that their significance will continue to be understood. Second, the Commission requires an assumption that the value to future generations of potential resources can be assessed adequately at this time. Consistent with its previously stated views, it thinks that the selection of a site with no foreseeably valuable resources could so reduce the likelihood of intrusion as to reduce, or eliminate, any further need for it to be considered. Third, the Commission requires the assumption that some functioning institutions - though not necessarily those undertaking the intrusion - understand the nature of radioactivity and appreciate its hazards. The extent of intergenerational transfer of knowledge is, of course, debatable; it is conservative, in the light of human history to date, to predict this minimal level of information and to take it into account in assessing the likelihood that intrusion will occur. Fourth, the Commission provides that relevant records are preserved, and remain accessible, for several hundred years after permanent closure. While perhaps this period could not be justified on the basis of historic precedents alone, the Commission considers the required deposit in land records and archives, together with current data handling technology, to provide a sufficient basis for assuming that information about the geologic repository will continue to be available for several hundred years.

The definition of "unanticipated processes and events" also implicitly bounds the consequences of intrusion scenarios. This is accomplished not only by the assumption of continued understanding of radioactivity and survival of records, but also by the further assumptions that if there are institutions that can cause intrusion at depth in the first place, there will also be institutions able to assess the risk and take remedial action. It need not be assumed that today's technology would be used - merely that a level of social organization and technological competence equivalent to that applied in initiating the processes or events concerned would be available to deal with the situation.

It was suggested that another way to reduce the likelihood of human intrusion would be to adopt additional design criteria for the waste form or waste package. These would prohibit, or at least discourage, the emplacement of materials which themselves might attract recovery operations - for example, operations to recover the residual energy resource value in spent fuel or scarce and expensive materials in the waste package. But, under the definition of "unanticipated processes and events" in the final rule, intrusion for such purposes would have to be reviewed in the licensing process if the particular circumstances are sufficiently credible to warrant consideration. This imposes a reasonable constraint. The Commission believes that any further limitation would unduly interfere with the flexibility of DOE as a designer and could, in the case of spent fuel disposal, conflict with other national objectives.

In summary, the Commission has retained the principle that highly speculative intrusion scenarios should not be allowed to become the driving force in license reviews, but has introduced some flexibility to permit consideration of intrusion on a case-by-case basis where circumstances warrant.

3.0 Other Principal Changes

3.1 Anticipated/Unanticipated Processes and Events

The proposed rule defined anticipated processes and events as "those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved and from which the design bases for the engineered system are derived." At the same time, the Commission was requiring that the facility be designed so as to assure that long-term releases conform to standards established by EPA. The statement of considerations pointed out that if the process or event is unlikely, the overall system must still limit the release consistent with the EPA standard as applied to such events. This created a contradiction because on the one hand it was stated that the design bases should be derived from anticipated processes and events while, on the other hand, the design was to meet an EPA standard as applied to what was unanticipated.

The Commission has resolved this conflict by eliminating the reference to design bases from the definition of "anticipated processes and events." It has also included a definition of "unanticipated processes and events." In the final rule, numerical performance objectives are established for particular barriers, assuming "anticipated processes and events." Such numerical criteria are not established for "unanticipated processes and events." Rather, additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

It should be noted that the distinction between anticipated and unanticipated processes and events relates solely to natural processes and events affecting the geologic setting. The Commission intends that a judgment whether a natural process or event is anticipated or unanticipated be based upon a careful review of the geologic record. Such processes or events would not be anticipated unless they were reasonably likely, assuming that processes operating in the geologic setting during the Quaternary Period were to continue to operate but with the perturbations caused by the presence of emplaced waste superimposed thereon. Unanticipated processes and events would include those that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which nevertheless are sufficiently credible to warrant consideration. These include processes and events which are not evidenced during the Quaternary Period or which, though evidenced during the Quaternary, are not likely to occur during the relevant time frame. Identification of anticipated and unanticipated processes and events for a particular site will require considerable judgment and will not be amenable to accurate quantification by statistical analysis, of their probability of occurrence.[6]

[6]The Commission views the proposed EPA standard as being directed to the evaluation of releases arising out of the categories that we have defined as "anticipated processes and events" and "unanticipated processes and events." As EPA itself recognizes, there can only be estimates rather than rigorous demonstrations of probabilities of occurrence. The Commission's translation of the EPA language into qualitative terms provides a clearer basis for judging, under the Atomic Energy Act, whether there is unreasonable risk to the health and safety of the public.

Because the design basis for the engineered barrier system will be derived from the identification of anticipated and unanticipated processes and events, such identification will have a pervasive effect on the basic structure of the licensing proceedings. The Commission therefore contemplates directing that rulings made in the course of construction authorization hearings on the scope of anticipated and unanticipated processes and events be separately identified by the presiding officers and certified to the Commission for interlocutory review, pursuant to 10 CFR 2.718(i).

The license review will thus need to include a determination whether the proposed activities will meet the EPA standard as applied to anticipated processes and events and as applied to such unanticipated processes and events, if any, as have been found to warrant consideration. Each determination will be made in the light of assessments which will involve interpretation of the geologic record and consideration of credible human-induced events as bounded by the assumptions set forth above. Worst-case scenarios would be analyzed to the extent they may be encompassed by the definition of unanticipated processes and events. Complex quantitative models will need to be employed, and a wide range of factors considered in arriving at a determination of whether there is reasonable assurance, making allowance for the time period and hazards involved, that the EPA standard will be met. There are two principal elements that will go into the Commission's application of this "reasonable assurance" concept. First, the performance assessment which has been performed must indicate that the likelihood of exceeding the EPA standard is low. Second, the Commission must be satisfied that the performance assessment is sufficiently conservative, and its limitations are sufficiently well understood, that the actual performance of the geologic repository will be within predicted limits.

3.2 Transuranic Waste (TRU)

The proposed rule included a definition of transuranic waste and performance objectives that would apply to the disposal of TRU in a licensed geologic repository. This was widely misconstrued as a requirement that radioactive material conforming to the definition must be disposed of in this manner. This was not the intention, nor in fact did the rule so specify. Rather, the Commission was merely indicating what performance objectives would apply <u>if</u> TRU were disposed of in a licensed geologic repository. Some commenters also took exception to the definition of TRU in the rule.

Whether or not a geologic repository is subject to licensing depends upon the applicability of Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974. (See definition of "HLW facility.") If a facility is licensed, then the Commission must consider the radiological hazards associated with whatever wastes may be emplaced. The Commission attempted, in the proposed rule, to address the requirements for one such kind of waste - TRU. But the Commission was too restrictive, in that its definition of TRU was too limited for present purposes and in that wastes other than HLW and TRU were not covered at all. For the time being, the Commission has concluded that the matter is best handled by eliminating all references to TRU. The remaining performance objectives provide adequate guidance to deal with TRU-related issues that may arise.

The Commission has also reviewed the waste package requirements, which as originally written would have applied to all emplaced radioactive waste. It is appropriate to include such requirements for HLW, which must necessarily be disposed of in a licensed facility. Since the Commission does not know what other radioactive wastes, if any, will also be emplaced, and what their chemical, radiological, thermal, and other characteristics may be, it has decided to leave pertinent waste package requirements to be determined on a case-by-case basis as the need arises.

3.3 Siting Criteria

Although provisions relating to site characteristics have been revised, the Commission has retained the same two basic concepts. First, a site should exhibit an appropriate combination of favorable conditions, so as to encourage the selection of a site that is among the best that reasonably can be found. By referring to a "combination" of conditions, it implies that the analysis must reflect the interactive nature of geologic systems. Second, any potentially adverse conditions should be assessed in order to assure that they will not compromise the ability of the geologic repository to meet the performance objectives. It is important to recognize that a site is not disqualified as a result of the absence of a favorable condition or the presence of a potentially adverse condition. The Commission emphasizes this point here because several commenters who characterized the siting criteria as unduly restrictive failed to appreciate that the presence of potentially adverse conditions would not exclude a site from further consideration while others mistakenly assumed that favorable conditions were requirements.

The changes do not reflect any departure from the Commission's original philosophy, but they are designed to express its purpose more clearly. Thus, its interest in specifying that the geologic setting shall have exhibited "stability" since the start of the Quaternary Period was to assure only that the processes be such as to enable the recent history to be interpreted and to permit near-term geologic changes to be projected over the relevant time period with relatively high confidence. This concept is best applied by identifying, as potentially adverse conditions, those factors which stand in the way of such interpretation and projection; this is the approach the Commission has chosen to follow.

One revison is the elimination of the classification of potentially adverse conditions into one set pertaining to the "geologic setting" (corresponding to "site" in the final rule) and one set pertaining to the "disturbed zone." The Commission has determined that by defining these conditions as potentially adverse only when they occur in the site or disturbed zone, respectively, some significant factors bearing upon waste isolation may not be assessed. The Commission has changed the siting criteria, therefore, so that the presence of any of the enumerated conditions is to be regarded as potentially adverse if it applies to the controlled area and, in addition, such a condition outside the controlled area is to be regarded as potentially adverse if it may affect isolation within the controlled area.

Another change, discussed under Single vs. Multiple Performance Standards, may have the effect of increasing the importance of the geological conditions. Under the final rule, the performance objectives for the engineered barrier system (§60.113(a)(1)) may be adjusted, on a case-by-case basis, if the overall system performance objective, as it relates to anticipated processes and events, is satisfied. This feature of the final rule may provide the designer additional incentive to select the site so as to maximize its isolation capabilities.

The Commission's review of the siting criteria, as modified, has led it to conclude that the isolation capabilities of the geologic repository will be given the emphasis that they merit. This review has included a consideration of suggestions that the rule require that the slate of sites be among the best that can be found on the basis of geological factors alone and that the geologic characteristics of the site provide the highest reasonably available degree of the site's isolation capabilities. These topics are discussed below, under the heading Geological Conditions.

A detailed review of the siting criteria is contained in the Section-by-Section Analysis.[7]

3.4 Containment

Several commenters took exception to the performance objective calling for a design of the waste packages to "contain all radionuclides" for a specified period after permanent closure. The objections were: first, that 100% performance cannot be expected in view of the very large number of containers that may be emplaced; second, that 100% performance cannot be justified as being needed in order to meet any likely EPA standard; and, third, that the adequacy of design to contain "all" radionuclides for long periods of time is not demonstrable. The commenters failed, in part, to recognize that under the specified standard of proof (see Reasonable Assurance, below), the applicant would not be forced to carry an impossible burden. Nevertheless, since the Commission does not expect proof that literally all radionuclides will be contained, the performance objective now requires design so that containment

[7]Under Section 112(a) of the Nuclear Waste Policy Act of 1982, DOE is required to develop guidelines for the recommendation of sites for repositories. Among other things, such guidelines are to "specify detailed geologic considerations that shall be primary criteria for the selection of sites in various geologic media." Issuance of these guidelines is subject to the concurrence of the Commission. The Commission has made no determination whether such guidelines, when issued, should in some manner be reflected in either the technical criteria or licensing procedures portions of 10 CFR Part 60.

of HLW within the high-level waste packages will be "substantially complete" for the specified period.

4.0 Terminology

Several commenters criticized, as vague or confusing, the terms used by the Commission to describe the various geographical locations that are addressed by the rule. There are many such locations--and there must be--because the Commission must deal with different concerns during site characterization, during operations, and after permanent closure. The Commission has nevertheless attempted to clarify the terms. In addition to the significant changes reviewed here, see also the discussion in the Section-by-Section Analysis.

4.1 Accessible Environment/Controlled Area

The isolation capability of a geologic repository is evaluated at a boundary which the Commission has referred to as the "accessible environment." Under the proposed rule, this was defined as "portions of the environment directly in contact with or readily available for use by human beings." Several commenters criticized this definition as being excessively vague; further, the definition failed to assure that the isolation capability of the rock surrounding the underground facility would be given appropriate weight in licensing reviews.

The Commission agrees with the criticism and has revised the definition in several respects--most importantly by excluding from the accessible environment that portion of the lithosphere that is inside what the Commission is calling, in the final rule, a "controlled area." This is an area marked with monuments designed to caution future generations against subsurface penetrations. The size and shape of the controlled area will depend upon the characteristics of the particular geologic repository, but it must be small enough to justify confidence that the monuments will effectively discourage subsurface disturbances. The Commission has therefore limited the size of the controlled area so that it extends no more than 10 kilometers from the emplaced waste. The term "accessible environment" also appears in the proposed EPA standard. The Commission has used the EPA language as a starting point - for example, in specifying the surface locations that are part of the accessible environment. But there is an important difference between the two definitions, in that EPA includes in the accessible environment only those parts of the lithosphere that are more than 10 kilometers from the emplaced waste, whereas NRC may include parts of the lithosphere that are less than 10 kilometers from the emplaced waste, depending on the extent of the "controlled area" for a geologic repository. In other words, the accessible environment may be larger under 10 CFR Part 60 than might be the case under the proposed EPA standard. The two definitions are nevertheless consistent in the sense that if the isolation requirements are satisfied at the boundary of the accessible environment specified by 10 CFR Part 60, they will necessarily be satisfied at the boundary defined by EPA as well.

Both technical and legal considerations have influenced the Commission's decision not to adopt an unqualifed 10-kilometer standard. The technical consideration is that uncertainties about activities that may be undertaken in the area outside the controlled area are so great that the Commission would not be warranted in giving credit to the isolation capability of the undisturbed lithosphere there. The legal consideration is that the standards established by EPA are to apply outside the boundaries of locations controlled by NRC licensees, and in the context of 10 CFR Part 60 this refers most appropriately to the "controlled area" as defined by the regulation. The Commission believes that the final rule is fully responsive to the concerns of the commenters while conforming as well to the policies underlying EPA's proposed standard.

4.2 <u>Geologic Setting</u>

The proposed rule limited this term to systems that provide isolation of the waste. This is too restrictive a definition to cover the wider region of interest which the Commission seeks to encompass by "geologic setting." The definition has accordingly been extended to include the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

4.3 Site

"Site" had been defined in the proposed rule as being equivalent to "geologic setting." This was appropriate where geologic setting referred to an area having isolation capability. In the final rule, isolation is to be provided within a controlled area rather than within the geologic setting and accordingly "site" now refers to the location of this controlled area.

4.4 Decommissioning

As used in the proposed technical criteria, the term "decommissioning" was intended to apply to that stage at which the underground facility was closed and shafts and boreholes were sealed. It was these activities that were addressed in § 60.51, "License amendment to decommission." This intention is better expressed by employing the term "permanent closure." Several commenters on the proposed rule expressed the opinion that including the requirement for dismantlement of all surface facilities in the definition of the term "decommissioning" may be unnecessary and overly restrictive. Upon consideration of these comments the Commission believes that where there is a need to refer to decontamination or dismantlement of surface facilities, this can readily be done without referring to "decommissioning."

Accordingly, references to "decommissioning" with one exception (see §60.132(e)), have been deleted from the rule, and the language now refers to "permanent closure" or to "decontamination or dismantlement of surface facilities," as appropriate.

4.5 Important to Safety

In past NRC usage, the term "important to safety" has only been defined qualitatively (e.g., 10 CFR Part 50, App. A). In response to public comments on Part 60, the NRC staff has adopted a numerical criterion for determining which structures, systems and components are important to safety. Structures, systems, and components are important to safety if, in the event they fail to perform their intended function, an accident could result which causes a dose commitment greater than 0.5 rem to the whole body or any organ of an individual in an unrestricted area. The value of 0.5 rem is equal to the annual dose to the whole body of an individual in an unrestricted area that would be permitted under 10 CFR Part 20 for normal operations. The definition that has been adopted defines as important to safety, therefore, any system, structure or component whose failure to operate as intended could result in an annual dose commitment to an individual in an unrestricted area in excess of what would be permitted for normal operations of certain other activities licensed by NRC. Such systems, structures, and components would be subject to additional design requirements and to a quality assurance program to ensure that they performed their intended functions. This conservative approach is possible because, as noted by several commenters, the materials received and possessed at a HLW facility will be in a form, and the operations that are carried out will be of a nature, that little potential exists for large releases of radioactive materials to unrestricted areas. The choice of 0.5 rem in this instance should not be construed as implying that it would be appropriate if applied to any other types of activities subject to regulation by the Commission.

The term "important to safety" has traditionally been linked to structures, systems, and components which must operate under accident conditions in a manner that will prevent serious offsite consequences. The proposed rule inappropriately referred to structures, systems, and components which must operate to meet the performance objectives--including those pertaining to long-term isolation under anticipated conditions--as being "important to safety." The effect of this was to extend accident-related design criteria to elements not subject to relevant kinds of accidents. Design criteria related to isolation are important, and are included, but not because the structures, systems, and components in question are "important to safety" in the traditional sense.

"Important to safety" is also important in defining the actions that are necessary elements of a quality assurance program. For a geologic repository, however, quality assurance must be extended to structures, systems, and components important to waste isolation. Since, for the reasons discussed above, these concerns are no longer encompassed by the term "important to safety," the quality assurance provisions have been amended to apply to structures, systems, and components "important to waste isolation" as well.

5.0 Other Principal Comments

These issues raised by commenters merit discussion here even though they have resulted in no change to the rule.

5.1 Comparative Safety Analyses

Several commenters took exception to the proposed requirement that the safety analysis report include a comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation, [now termed "important to waste isolation"], on the ground that a safety analysis should be directed at the specific design being proposed. As a general principle, the commenters are correct. In the context of licensing activities at a geologic repository operations area, however, the Commission thinks it is well within its discretion to seek the requested information. If the Commission finds, on the basis of its review, that the adoption of some alternative design feature would significantly increase its confidence that the performance objectives would be satisfied, and that the costs of such an approach are commensurate with the benefits, it should not hesitate to insist that the alternative be so adopted. This is consistent with the views expressed above in the discussion of the ALARA principle and, also, with the provisions of the revised performance objectives which contemplate that the performance objectives for particular barriers are subject to modification, on a case-by-case basis, as needed to satisfy applicable EPA standards.

5.2 Unsaturated Zone

The Commission had explained that the proposed criteria were developed for disposal in saturated media, and that additional or alternative criteria might need to be developed for regulating disposal in the unsaturated zone. Accordingly, the performance objective for the engineered barrier system (§60.113(a)(1)) was written so as to require the assumption of full or partial saturation of the underground facility and the favorable and potentially adverse conditions concerned only siting in the saturated zone.

This approach was criticized on the basis that disposal in the unsaturated zone was a viable alternative, and that since the criteria were generally applicable without regard to the possibility of saturation, their scope and applicability should not be unduly restricted. The Commission has reviewed the criteria in the light of the comments and find this criticism to be well-founded. Although the criteria as written are generally appropriate to disposal in both the saturated zone and the unsaturated zone, some distinctions do need to be made. Rather than promulgating the criteria which will apply to the unsaturated zone at this time, the Commission will shortly issue such criteria in proposed form so as to afford a further opportunity for public comment. However, those criteria that are uniquely applicable to the saturated zone are so indicated.

5.3 Geological Conditions

One commenter recommended that the rule should require that the slate of sites characterized by DOE be among the best that can reasonably be found on the basis of geological factors alone. The Commission did indicate, when it adopted licensing procedures, that the site characterization requirements will assure that DOE's preferred site will be chosen from a slate of sites that are among the best that reasonably could be found. The standard proposed by the commenter is quite different. The Commission intended that DOE should be able to take into account a variety of non-geological considerations in its screening process. It could properly exclude such locations as (1) areas, such as national parks and wilderness, devoted to other paramount uses, (2) locations which would be subject to unusually severe environmental and socioeconomic impacts, and (3) locations where necessary surface, mineral, and water rights may be obtainable only at great expense and with severe dislocating effects on residents. The Commission considers the rule, as written, properly conveys its meaning on this score.

The same commenter urged it to require a demonstration that the geologic characteristics of the chosen site provide the highest reasonably achievable degree of enhancement of the waste isolation capabilities of the geologic repository. Again, the Commission declines to accept the suggestion. In the first place, it anticipates that DOE would on its own initiative strive to maximize isolation capabilities in order to demonstrate more conclusively the facility's compliance with the performance objectives and other technical criteria. Beyond this, however, the Commission believes the proposal could have undesirable and unintended consequences. Maximizing isolation capabilities could dictate development at one particular location instead of at another a few miles away; this could result in the same kind of adverse environmental or other effects as were described above. Furthermore, adherence to the proposed standard could unduly interfere with, or increase the cost of, achievement of other goals, such as maintenance of retrievability, providing for worker safety, etc.

There were other related comments which argue that the Commission's approach places too great an emphasis on engineered barriers and provides insufficient incentive to select a site with optimal geologic and hydrologic characteristics. The Commission considers both engineered and natural barriers to be important, and it has structured the technical criteria in a manner that demands not only the use of advanced engineering methods, but also selection of a site with excellent isolation capabilities. As explained in the discussion of Reasonable Assurance, below, uncertainties in the models used in the analysis of repository performance must be considered in the Commission's deliberations on the issuance of a construction authorization or license. Selection of a site with favorable geologic conditions will greatly enhance the Commission's ability to make the prescribed findings. Moreover, since the final rule provides flexibility for the Commission to approve or specify performance objectives for the engineered barriers on a case-by-case basis, the applicant is afforded still a further incentive to pick a site in which the host rock has favorable geochemical characteristics or in which other particular sources of uncertainty about hydrogeologic conditions are substantially reduced. But in any event, the Commission anticipates that a high standard of engineering will be necessary--not only to compensate for geologic uncertainties at even the best reasonably available sites, but perhaps also to mitigate the consequences of unanticipated processes and events (including potential intrusion) during the years when fission product inventories remain high.

Although the Commission agrees with the underlying appraisal of the commenters that the isolation capabilities of the site play a key role in assuring that the performance objectives will be met, it finds no reason to change the rule's basic approach.

5.4 Reasonable Assurance

The proposed rule stated that with respect to the long-term objectives and criteria under consideration, "what is required is reasonable assurance, making allowance for the time period and hazards involved, that the outcome will be in conformance with those objectives and criteria." A number of commenters took exception to this formulation on the ground that it provides inadequate guidance as to the required level of proof. Others were concerned that "reasonable assurance" was too weak a test and that the Commission should not license DOE activities without a "high degree of confidence" that releases would be very small. Some commenters suggested that a statistical definition of acceptability should be employed. For the reasons set forth below, the Commission has not modified the language.

In the Commission's view, the "reasonable assurance" standard neither implies a lack of conservatism nor creates a standard which is impossible to meet. On the contrary, it parallels language which the Commission has applied in other contexts, such as the licensing of nuclear reactors, for many years. See 10 CFR 50.35(a) and 50.40(a). The reasonable assurance standard is derived from the finding the Commission is required to make under the Atomic Energy Act that the licensed activity provide "adequate protection" to the health and safety of the public; the standard has been approved by the Supreme Court. Power Reactor Development Co. v. Electrical Union, 367 U.S. 396, 407 (1961). This standard, in addition to being commonly used and accepted in the Commission's licensing activities, allows the flexibility necessary for the Commission to make judgmental distinctions with respect to quantitative data which may have large uncertainties (in the mathematical sense) associated with it.

The Commission has not modified the language, but has explained elsewhere (see Anticipated/Unanticipated Processes and Events, above) how the concept will be applied. The Commission expects that the information considered in a licensing proceeding will include probability distribution functions for the consequences from anticipated and unanticipated processes and events. Even if the calculated probability of meeting the Commission's standards is very high that would not be sufficient for the Commission to have "reasonable assurance"; the Commission would still have to assess uncertainties associated with the models and data that had been considered. This involves qualitative as well as quantitative assessments. The Commission would not issue a license unless it were to conclude, after such assessments, that there is reasonable assurance that the outcome will in fact conform to the relevant standards and criteria.

It is important to keep in mind this distinction between, first, a standard of performance and, second, the quality of the evidence that is available to support a finding that the standard of performance has been met. In principle, there is no reason why the first of these - the performance standard - cannot be expressed in quantitative terms. The rule does this in several places - notably, in including as performance objectives a designed containment period, a radionuclide release rate, and a pre-waste-emplacement groundwater travel time. Similarly, EPA's standard will establish limits on concentrations or quantities of radioactive material in the general environment.

Expressing a requisite level of confidence in quantitative terms is far more problematical. To be sure, measurement uncertainties are amenable to statistical analyses. Even though there may be practical limitations on the accuracy and precision of measurements of relevant properties, it is possible to make some quantitative statement as to how well these values are known. The licensing decisions which the Commission will be called upon to make involve additional uncertainties - those pertaining to the correctness of the models being used to describe the physical systems - which are not quantifiable by statistical methods. Conclusions as to the performance of the geologic repository and particular barriers over long periods of time must largely be based upon inference; there will be no opportunity to carry out test programs that simulate the full range of relevant conditions over the periods for which waste isolation must be maintained.

The validity of the necessary inferences cannot be reduced, by statistical methods, to quantitative expressions of the level of confidence in predictions of long-term repository performance. Similarly, the Commission will not be able to rigorously determine the probability of occurrence of an outcome that fails to satisfy the performance standards. It must use some other language, such as "reasonable assurance," to characterize the required confidence that the performance objectives will be met. In practice, this means that modeling uncertainties will be reduced by projecting behavior from well understood but simpler systems which conservatively approximate the systems in question. Available data must be evaluated in the light of accepted physical principles; but, having done so, the Commission must make a judgment whether it has reasonable assurance that the actual performance will conform to the standards the Commission has specified in this rule.

It should also be borne in mind that the factfinding process is an administrative task for which the terminology of law, not science, is appropriate. The degree of certainty implied by statistical definition has never characterized the administrative process. It is particularly inappropriate where evidence is "difficult to come by, uncertain or conflicting because it is on the frontiers of scientific knowledge." Ethyl Corp. v. EPA, 541 F.2d 1, 28 (D.C. Cir. 1976).

5.5 Population vs. Individual Dose

Some commenters noted that the performance objectives are derived from an assumed EPA standard that is based upon consideration of doses to populations as a whole rather than to the maximally exposed individual. Several other analyses of repository design have examined prospective requirements in terms of keeping individual doses below specified values, and as a consequence have led to different conclusions. The differences represent a source of potential uncertainty regarding the overall goal for safety performance. However, the resolution of this question is a matter within the province of EPA. The Commission has assumed that the EPA approach will be based upon population dose, since that is the direction reflected in its working documents and its recently proposed standard. The Commission's rule, especially as modified to allow performance objectives for particular barriers to be adapted in the light of the EPA standard, can be applied whether the overall safety goal is expressed in terms of total releases to the environment or in terms of maximum dose to an individual or maximum concentration at any place or time.

If EPA were to establish a standard based upon individual doses, the Commission would review the provisions dealing with the content of the license application (§ 60.21) so as to develop requirements for any additional analyses that might be needed to evaluate site-specific pathways for released radionuclides to reach humans.

5.6 Long-Term Post-Closure Monitoring

Several of the commenters suggested that the performance confirmation program be required to be continued for as long as one thousand years after permanent closure of the underground facility. The Commission considers such measures unnecessary and unlikely to provide useful information on the performance of a geologic repository. The multiple barrier approach the Commission has adopted will result in containment of substantially all of the radioactive materials within the waste packages for centuries after permanent closure, the feasibility of obtaining reliable data on subsurface conditions over a period of centuries is questionable, and the practicality of taking remedial action after sealing of the shafts is doubtful. Moreover, the emplacement of remote subsurface monitoring instruments and the provision of data transmission capabilities, could provide additional pathways for release that would make it more difficult to achieve isolation. Rather, the Commission has adopted an approach where the retrievability option is maintained until a performance confirmation program can be completed that will allow the Commission to decide, with reasonable assurance, that permanent closure of the facility with no further active human intervention with the emplaced wastes, will not cause an unreasonable risk to public health and safety. See also, Retrievability, above.

6.0 Section-by-Section Analysis

The final rule included numerous changes that reflect the considerations discussed above. Other changes, not involving significant policy issues, have also been incorporated in the final rule. The following section-by-section analysis identifies the changes from the proposed rule and includes an appropriate explanation for the revisions not previously discussed. Principal references are to the text of the final rule. Where the counterpart provision of the proposed (or procedural) rule appeared in a different place, that citation is given in brackets.

§ 60.2 Definitions

"Accessible environment." See Accessible Environment/Controlled Area, above.

"Anticipated processes and events." See Anticipated/Unanticipated Processes and Events, above.

"Candidate area." This term is unchanged, but will be considered again in connection with the Commission's review of the licensing procedures in the light of the Nuclear Waste Policy Act.

"Controlled area." New. See Accessible Environment/Controlled Area, above.

"Decommissioning." Deleted. See Decommissioning, above.

"Disposal." The undefined term "biosphere" has been changed to "accessible environment." As used in these rules, "isolation" refers specifically to radioactive materials entering the accessible environment. The definition here is related to the concept of isolation rather than to the concept of emplacement, as in Section 2(9) of the Nuclear Waste Policy Act; the Commission believes that in each instance the term is defined in a manner appropriate to its context, and that the differences in the definitions will not result in confusion or conflict.

"Disturbed zone." The term "disturbed zone" has been modified to relate changes in the physical or chemical properties of the controlled area to the performance of the geologic repository.

"Engineered barrier system." Formerly "engineered system." This clarifying change reflects the fact that shaft and borehole seals, though engineered, are not part of the system that is being referred to. The Commission considers this definition to be synonymous with the term "engineered barriers" which appears at Section 2(11) of the Nuclear Waste Policy Act of 1982.

"Far field." The term "far field" has been deleted from the rule. Therefore, the definition is no longer necessary.

"Floodplain." Deleted. This definition was taken from Executive Order 11988, which relates to environmental consequences of occupancy and modification of floodplains. Those effects need to be considered as part of the Commission's environmental review, but they do not implicate the radiological concerns that are addressed in Part 60. The term "floodplain" still appears in §60.122(c)(1). However, rather than establishing any particular frequency as the means for defining its extent, the Commission will allow the factors specified in §60.122(a)(3) to be used in assessing the significance of flooding, whenever it may occur.

"Geologic repository." Clarifying change, to bring the terminology into line with common usage. The new definition includes only that portion of the geologic setting that provides isolation - not the entire geologic setting. The term, as defined, is considered to be synonymous with "repository" as defined at Section 2(18) of the Nuclear Waste Policy Act.

"Geologic setting." See <u>Terminology</u>, above. The phrase "spatially distributed" was superfluous and has been deleted.

"High-level radioactive waste." The Nuclear Waste Policy Act distinguishes between "high-level radioactive waste" and "spent nuclear fuel." These technical criteria are applicable equally to both categories. Accordingly, no change in the definition of high-level radioactive waste is required at this time.

"Important to safety." See <u>"Important to Safety,"</u> above.

"Medium" or "geologic medium." Deleted. For the sake of clarity, the term "medium" is now replaced by "geologic medium" throughout the rule. Since the term "geologic medium" should be sufficiently clear to the professional community, it no longer appears necessary to define it.

"Overpack." This term has been deleted. Because the overpack could be a component of the waste package, it was included in the definition of the term "waste package." However, this term is not used in the final rule.

"Performance confirmation." The final rule's performance objective with respect to retrievability of the waste refers to the completion of a performance confirmation program and Commission review of the information obtained from such a program. The addition of this definition is intended to clarify the intended purpose of the performance confirmation program.

"Permanent closure." New. See Decommissioning, above.

"Restricted Area." New. See Important to Safety, above.

"Retrieval." New. See Retrievability, above.

"Saturated zone." New. Since the performance objectives in the final rule specifically refer to disposal in the saturated zone, a definition, derived from Water Supply Paper 1988 (U.S.G.S., 1972) has been included.

"Site." See Terminology, above.

"Stability." Deleted. See Siting Criteria, above. Also, Section by Section Analysis, §60.113, below.

"Subsurface facility." Deleted. Both "subsurface facility" and "underground facility" were defined in the proposed rule. The use of the two closely similar terms resulted in some confusion. "Subsurface facility" has been deleted and replaced (see definition of "Permanent closure") by explicit reference to shafts and boreholes, as well as the underground facility, where appropriate.

"Transuranic wastes." Deleted. See Transuranic Waste, above.

"Unanticipated processes and events." New. See Human Intrusion, above.

"Waste form." Clarifying change to bring terminology into line with common usage.

"Waste package." Revised. Commenters questioned the clarity of this proposed definition and one commenter suggested an alternative definition. One commenter misinterpreted the proposed definition to require that the outermost component of the waste package be an airtight, watertight, sealed container. The revised definition no longer uses the terms "discrete backfill" or "overpack," which were ambiguous. To the extent that absorbent materials or packing are placed around a container to protect it from corrosion by groundwater, or to retard the transport of radioactive material to the host rock, these materials would be considered part of the waste package. However, while the final rule no longer imposes a requirement for an airtight, watertight, sealed container as part of the waste package, the Commission believes it likely that DOE will incorporate such a component into the design of the waste package in order to meet the performance objectives for the engineered barrier system for the period following permanent closure. The related terms "disposal package" and "package," as defined at Section 2(10) of the Nuclear Waste Policy Act, include unspecified overpacks; for purposes of the Commission's rules, and specifically in connection with the performance objective set out at Section 60.113(a)(1)(ii)(A), a more precise definition is needed. The differences in the definitions will not, in the judgment of the Commission, result in confusion or conflict.

"Water table." New. Required because the term appears in the definition of "saturated zone". The definition is derived from Water Supply Paper 1988 (U.S.G.S., 1972).

§ 60.10 Site characterization.

One amendment clarifies the point that investigations shall be conducted in such a manner as to limit adverse effects; the original language could have been construed to mean that the purpose of the investigations was to limit such effects. The provision calling, as a minimum, for the selection of borehole locations to limit subsurface penetrations was said to be confusing; the

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

[(b)--Performance-of-the-geologic-repository-after-permanent-closure.

(1)-Overall-system-performance.]

§ 60.112 Overall system performance objectives for the geologic repository after permanent closure.

The geologic setting shall be selected and the engineered barrier system [subsurface-facility] and the shafts, boreholes and their seals shall be designed [so-as] to assure that [assuming-anticipated-processes-and events;] releases of radioactive materials [from-the-geologic-repository] to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

[(2)-Performance-of-the-engineered-system.

(i)--Containment-of-wastes.*--The-engineered-system-shall-be designed-so-that-even-if-full-or-partial-saturation-of-the-underground facility-were-to-occur,-and-assuming-anticipated-processes-and-events,-the waste-packages-will-contain-all-radionuclides-for-at-least-the-first-1,000 years-after-permanent-closure.--This-requirement-does-not-apply-to-TRU waste-unless-TRU-waste-is-emplaced-close-enough-to-HLW-that-the-TRU-release-rate-can-be-significantly-affected-by-the-heat-generated-by-the-HLW.]

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~~(ii) Control of releases.~~

[~~(A) For HLW, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the total annual curie release as prescribed by this paragraph.~~

~~(B) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be present in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the annual curie release as prescribed by this paragraph.~~]

§ 60.113 Performance of particular barriers after permanent closure.

(a) General provisions.

(1) Engineered barrier system.

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission

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product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete filling with groundwater of available void spaces in the underground facility shall be appropriately considered and analysed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in subsection 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

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[(3)--Performance-of-the-geologic-setting.

(i)--Containment-period.--During-the-containment-period,-the-geologic setting-shall-mitigate-the-impacts-of-premature-failure-of-the-engineered system.--The-ability-of-the-geologic-setting-to-isolate-wastes-during-the isolation-period,-in-accordance-with-paragraph-(b)(3)(ii)-of-this-section, shall-be-deemed-to-satisfy-this-requirement.]

[(ii)---Isolation-period.--Following-the-containment-period,-the-geologic-setting,-in-conjunction-with-the-engineered-system-as-long-as-that system-is-expected-to-function,-and-alone-thereafter,-shall-be-capable-of isolating-radioactive-waste-so-that-transport-of-radionuclides-to-the accessible-environment-shall-be-in-amounts-and-concentrations-that-conform-to-such-generally-applicable-environmental-standards-as-may-have-been-established-by-the-Environmental-Protection-Agency.--For-the-purpose of-this-paragraph,-the-evaluation-of-the-site-shall-be-based-upon-the assumption-that-those-processes-operating-on-the-site-are-those-which have-been-operating-on-it-during-the-Quaternary-Period,-with-perturbations caused-by-the-presence-of-emplaced-radioactive-wastes-superimposed-thereon.-]

[§60.112--Required-characteristics-of-the-geologic-setting.

(a)--The-geologic-setting-shall-have-exhibited-structural-and tectonic-stability-since-the-start-of-the-Quaternary-Period.

(b)--The-geologic-setting-shall-have-exhibited-hydrogeologic, geochemical,-and-geomorphic-stability-since-the-start-of-the-Quaternary Period.]

[(c)] (2) Geologic setting. The geologic repository shall be located so that pre-waste-emplacement groundwater travel time[s-through the-far-field] along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment [are] shall be at least

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1,000 years or such other travel time as may be approved or specified by the Commission.

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period, or pre-waste-emplacement groundwater travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are--

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and groundwater; and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

LAND OWNERSHIP AND CONTROL [OF-THE-GEOLOGIC-REPOSITORY-OPERATIONS-AREA-]

§ 60.121 Requirements for ownership and control of interests in land. [the-geologic-repository-operations-area.]

(a) Ownership of land. [the-geologic-repository-operations-area.]

(1) Both the geologic repository operations area and the controlled area shall be located in and on lands that are either acquired lands under

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the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use.

(2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) [(1)] rights arising under the general mining laws; (ii)[(2)] easements for right-of-way; and (iii)[(3)] all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) [Establishment-of] Additional controls.

Appropriate controls shall be established outside of the [geologic repository-operations] controlled area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the geologic repository's [site-or-engineered-system's] ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

(c) Water rights.

(1) DOE shall also have obtained such water rights as may be needed to accomplish the purpose of the geologic repository operations area.

(2) Water rights are included in the additional controls to be established under paragraph (b) of this section.

[ADDITIONAL-REQUIREMENTS-FOR-THE-GEOLOGIC-SETTING]

SITING CRITERIA

§ 60.122 Siting criteria [Favorable-conditions.]

(a)(1) [Each-of-the-following-conditions-may-contribute-to-the ability-of-the-geologic-setting-to-meet-the-performance-objectives

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relating-to-isolation-of-the-waste.] [In-addition-to-meeting-the mandatory-requirements-of-§-60.112,-a] A geologic setting shall exhibit an appropriate combination of [these] the conditions specified in paragraph (b) so that, together with the engineered barrier system, the favorable conditions present are sufficient to provide reasonable assurance that [such] the performance objectives relating to isolation of the waste will be met.

(2) If any of the potentially adverse conditions specified in paragraph (c) of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to isolation of the waste. In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository, the following must be demonstrated:

[60.124--Assessment-of-potentially-adverse-conditions.

In-order-to-show-that-a-potentially-adverse-condition-or-combination-of-conditions-cited-in-§-60.123-does-not-impair-significantly-the-ability-of-the-geologic-repository-to-isolate-the-radioactive-waste,-the-following-must-be-demonstrated.]

[(a)](i) The potentially adverse human activity or natural condition has been adequately investigated [characterized], including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

[(b)](ii) The effect of the potentially adverse human activity or natural condition on the site [geologic-setting] has been adequately evaluated using [conservative] analyses which are [and-assumptions,-and the-evaluation-used-is] sensitive to the potentially adverse human

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activity or natural condition and assumptions which are not likely to underestimate its effect; and

[(c)(1)](iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to [in] paragraph [b](2)(ii) of this section not to affect significantly the ability of the geologic repository [setting-to-isolate-waste,] to meet the performance objectives relating to isolation of the waste, or

[(c)(2)] (B) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics [cited-in-§-60.122,] so that the performance objectives relating to isolation of the waste are met, or

[(c)(3)] (C) The potentially adverse human activity or natural condition can be remedied.

[60.122(a)--The-nature-and-rates-of-tectonic-processes-that-have occurred-since-the-start-of-the-Quaternary-Period-are-such-that,-when projected,-they-would-not-affect-or-would-favorably-affect-the-ability of-the-geologic-repository-to-isolate-the-waste.

(b)--The-nature-and-rates-of-structural-processes-that-have-occurred since-the-start-of-the-Quaternary-Period-are-such-that,-when-projected, they-would-not-affect-or-would-favorably-affect-the-ability-of-the-geologic-repository-to-isolate-the-waste.

(c)--The-nature-and-rates-of-hydrogeological-processes-that-have occurred-since-the-start-of-the-Quaternary-Period-are-such-that,-when projected,-they-would-not-affect-or-would-favorably-affect-the-ability of-the-geologic-repository-to-isolate-the-waste.

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~~(d) The nature and rates of geochemical processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.~~

~~(e) The nature and rates of geomorphic processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.~~

~~(f) A host rock that provides the following ground water characteristics -- (1) low groundwater content, (2) inhibition of groundwater circulation in the host rock, (3) inhibition of groundwater flow between hydrogeologic units or along shafts, drifts, and boreholes, and (4) groundwater travel times, under pre-waste emplacement conditions, between the underground facility and the accessible environment that substantially exceed 1,000 years.]~~

(b) Favorable conditions.

(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(2) For disposal in the saturated zone, hydrogeologic conditions that provide --

(i) A host rock with low horizontal and vertical permeability;

(ii) Downward or dominantly horizontal hydraulic gradient in the host rock and in immediately surrounding hydrologeologic units; and

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(iii) Low vertical permeability and low hydraulic potential between the host rock and surrounding hydrogeologic units; or

(iv) Pre-waste emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years.

(3)[60.122(g)] Geochemical conditions that--(i)[(1)] Promote precipitation or sorption of radionuclides; (ii)[(2)] Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or [and] (iii)[(3)] Inhibit the transport of radionuclides by particulates, colloids, and complexes.

(4) [60.122(h)] Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

[(6)] (5) [60.122(i)] Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

[60.122(j)Any-local-condition-of-the-disturbed-zone-that-contributes to-isolation.]

(6) A low population density within the geologic setting and a controlled area that is remote from population centers.

[60.123] (c) Potentially adverse conditions.

The following conditions are potentially adverse conditions [The presence-of-any-such-conditions-may-compromise-site-suitability-and-will require-careful-analysis-and-such-measures-as-are-necessary-to-compensate-for-them-adequately-pursuant-to-§-60.124.] if they are characteristic of the controlled area or may affect isolation within the controlled area.

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(a)-Adverse-conditions-in-the-geologic-setting.]

(1)[60.123(a)(1)] Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments. [that-could-cause-flooding-of-the-geologic-repository operations-area.]

[(2)-Potential,-based-on-existing-geologic-and-hydrologic-conditions,-that-planned-construction-of-large-scale-surface-water-impoundments-may-significantly-affect-the-geologic-repository-through-changes in-the-regional-groundwater-flow-system.]

(2)[(3)] Potential for foreseeable human activity to adversely affect [significantly-the-geologic-repository-through-changes-in-the hydrogeology.--This-activity-includes,-but-is-not-limited-to-planned] the groundwater flow system such as, groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, [facilities,-or--underground] military activity or construction of large scale surface water impoundments.

[(5)-A-fault-in-the-geologic-setting-that-has-been-active-since-the start-of-the-Quaternary-Period-and-which-is-within-a-distance-of-the disturbed-zone-that-is-less-than-the-smallest-dimension-of-the-fault rupture-surface.]

[(6)--Potential-for-adverse-impacts-on-the-geologic-repository resulting-from-the-occupancy-and-modification-of-floodplains.]

(3)[(7)] Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could [affect-the-performance-of-the-geologic-repository-through-changes-in] change the regional

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groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4)[60.123(b)(8)] Structural deformation, such as uplift, subsidence, folding, or faulting, [and-fracturing-during-the-Quaternary-Period] that may adversely affect the regional groundwater flow system.

(5)[60.123(b)(12)] Potential for changes in hydrologic conditions that would [significantly] affect the migration of radionuclides to the accessible environment, such as [including-but-not-limited-to] changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6)[60.123(a)(8)-Expected-climatic-changes-that-would-have-an adverse-effect-on-the-geologic,-geochemical,-or-hydrologic-characteristics] Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(7)[60.123(b)(14)] Groundwater conditions in the host rock, including chemical composition, [but-not-limited-to] high ionic strength or ranges of Eh-pH, that could [affect] increase the solubility or [and] chemical reactivity of the engineered barrier system[s].

[60.123(b)--Adverse-conditions-in-the-disturbed-zone

For-the-purpose-of-determining-the-presence-of-the-following-conditions-within-the-investigations-should-extend-to-the-greater-of-either its-calculated-extent-or-a-horizontal-distance-of-2-km-from-the-limits of-the-underground-facility,-and-from-the-surface-to-a-depth-pathways for-radionuclide-of-500-meters-below-the-limits-of-the-repository excavation:]

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[~~60.123(b)(6)--The existence of a fault that has been active during the Quaternary Period.~~

~~(7)--Potential for creating new pathways for radionuclide migration due to presence of a fault or fracture zone irrespective of the age of last movement.~~]

[~~60.123(9)-More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.~~]

<u>(8)</u>[~~60.123(b)(15)~~] <u>Geochemical</u> [P] processes that would reduce sorption <u>of radionuclides</u>, result in degradation of the rock strength, or adversely affect the performance of the engineered <u>barrier</u> system.

<u>(9)</u>[~~60.123(b)(13)~~] <u>For disposal in the saturated zone, groundwater</u> [G] <u>c</u>onditions in the host rock that are not reducing [conditions].

<u>(10)</u>[~~60.123(b)(5)~~] Evidence of dissolutioning [~~of soluble rocks.~~] <u>such as breccia pipes, dissolution cavities, or brine pockets.</u>

<u>(11)</u>[~~60.123(b)(8)~~] Structural deformation such as uplift, subsidence, folding, <u>and faulting</u> [~~and fracturing~~] during ~~the Quaternary~~ Period.

<u>(12)</u>[~~60.123(a)(4)~~] Earthquakes which have occurred historically that if they were to be repeated could affect the [~~geologic repository~~] <u>site</u> significantly.

<u>(13)</u>[~~60.123(b)(16)~~] Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

<u>(14)</u>[~~60.123(b)(9)~~] More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

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(15)[60.123(b)(11)] Evidence of igneous activity since the start of the Quaternary Period.

(16)[60.123(b)(4)] Evidence of extreme erosion during the Quaternary Period.

(17)[60.123(b)(3)] [Resources-that-have-either] The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:

(i) economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(ii) such materials have greater gross value or net value[; or commercial potential] than the average for other [representative] areas of similar size that are representative of and located in the geologic setting.

(18)[60.123(b)(1)] Evidence of subsurface mining for resources within the site.

(19)[60.123(b)(2)] Evidence of drilling for any purpose within the site.

(20)[60.123(b)(16)] Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(21)[60.123(b)(17)] Geomechanical properties that do not permit design of [stable] underground openings [during construction, waste emplacement, or retrieval operations.] that will remain stable through permanent closure.

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DESIGN [AND-CONSTRUCTION-REQUIREMENTS] CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREAS

§60.130 Scope of [General] design criteria [requirements] for the geologic repository operations area.

[(a)] Sections [60.130] 60.131 through 60.134 specify minimum [requirements] criteria for the design of[;-and-construction-specifications-for;] the geologic repository operations area. [Requirements-for design-contained-in-§§60.131-through-60.133-must-be-considered-in-conjunction-with-the-requirements-for-construction-in-§60.134.--Sections-60.130 through-60.134-are-not-intended-to-contain-an-exhaustive-list-of] These design [and-construction-requirements] criteria are not intended to be exhaustive, however. Omissions in §§ [60.130] 60.131 through 60.134 do not relieve DOE from [providing] any obligation to provide such safety features in a specific facility needed to achieve the performance objectives. [contained-in-§§-60.111.] All design [and-construction-criteria-] bases must be consistent with the results of site characterization activities.

[(b)-Systems;-structures;-and-components-of-the-geologic-repository operations-area-shall-satisfy-the-following:]

§ 60.131 General design criteria for the geologic repository operations area.

(a)[60.130(b)(1)] Radiological protection.

The geologic respository operations area [structures;-systems;-and components-located-within-restricted-areas] shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air

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in [those] restricted areas within the limits specified in Part 20 of this chapter. [These-structures,-systems,-and-components] Design shall [be-designed-to] include--

(1)[(i)] Means to limit concentrations of radioactive material in air;

(2)[(ii)] Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and providing adequate space for ease of operation;

(3)[(iii)] Suitable shielding;

(4)[(iv)] Means to monitor and control the dispersal of radioactive contamination;

(5)[(v)] Means to control access to high radiation areas or airborne radioactivity areas; and

(6)[(vi)] A radiation alarm system to warn of significant increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with provisions for calibration and for testing its operability. [redundancy-and-in-situ-testing-capability.]

(b) Structures, systems, and components important to safety.

(1)[60.130(b)(2)] Protection against natural phenomena and environmental conditions.

[(i)-The-structures,-systems,-and-components-important-to-safety shall-be-designed-to-be-compatible-with-anticipated-site-characteristics and-to-accommodate-the-effects-of-environmental-conditions,-so-as-to prevent-interference-with-normal-operation,-maintenance-and-testing during-the-entire-period-of-construction-and-operations.]

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[(ii)] The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the [site] geologic repository operations area will not [result-in-any-relevant-time-period-in-failure-to-achieve-the-performance-objectives] interfere with necessary safety functions.

(2) [(3)] Protection against dynamic effects of equipment failure and similar events.

The structures, systems, and components important to safety shall be designed to withstand dynamic effects such as missile impacts that could result from equipment failure[;-such-as-missile-impacts], and similar events and conditions that could lead to loss of their safety functions.

(3) [(4)] Protection against fires and explosions.

(i) The structures, systems, and components important to safety shall be designed to perform their safety functions during and after credible fires or explosions in the geologic repository operations area.

(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat resistant materials.

(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.

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(4)[(5)] Emergency capability.

(i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency.

(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(5)[(6)] Utility services.

(i) Each utility service system that is important to safety shall be designed so that essential safety functions can be performed under both normal and [emergency] accident conditions.

(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

[(iii)-The-emergency-utility-services-shall-be-designed-to-permit testing-of-their-functional-operability-and-capacity.--This-will-include the-full-operational-sequence-of-each-system-when-transferring-between normal-and-emergency-supply-sources;-as-well-as-the-operation-of associated-safety-systems.]

(iii)[(iv)] Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and timely [continued] emergency power can be [is] provided to instruments, utility service systems, and operating systems, including alarm systems, important to safety. [This-emergency-power-shall-be-sufficient-to-allow-safe-condi-

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before emplacement or as a result of retrieval from the underground facility. [The-surface-facilities-shall-be-designed-so-as-to-permit inspection;-repair;-and-decontamination-of-such-wastes-and-their containers.--Surface-storage-capacity-is-not-required-for-all-emplaced waste.]

(b) Surface facility ventilation. Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in §60.111(a).

(c) Radiation control and monitoring.

(1) Effluent control. The surface facilities shall be designed to control the release of radioactive materials in effluents during normal [and-emergency] operations so as to meet the performance objectives of § 60.111(a). [The-facilities-shall-be-designed-to-provide-protection against-radiation-exposures-and-offsite-releases-as-provided-in-§60.111.]

(2) Effluent monitoring. The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) Waste treatment. Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

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(e) Consideration of decommissioning. The surface facility shall be designed to facilitate [decommissioning] decontamination or dismantlement to the same extent as would be required, under other parts of this chapter, with respect to equivalent activities licensed thereunder.

§ 60.133 [§-60.132] Additional subsurface design [requirements] criteria for the underground facility.

(a) General criteria for the underground facility.

[(1)--The-underground-facility-shall-be-designed-so-as-to-perform its-safety-functions-assuming-interactions-among-the-geologic-setting, the-underground-facility,-and-the-waste-package.]

[(2)--The-underground-facility-shall-be-designed-to-provide-for structural-stability,-control-of-groundwater-movement-and-control-of radionuclide-releases,-as-necessary-to-comply-with-the-performance objectives-of-§§60.111.]

(1) [(3)] The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the [enhance] containment and isolation of radionuclides [to-the-extent-practicable-at the-site].

(2) [(4)] The underground facility shall be designed so that the effects of credible disruptive events during the period of operations, such as [intrusions-of-gas,-or-water,-or] flooding, fires, and explosions, will not spread through the facility.

(b) Flexibility of design. The underground facility shall be designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

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[(c)--Separation-of-excavation-and-waste-emplacement-(modular-concept).
If-concurrent-excavation-and-emplacement-of-wastes-are-planned,-then:

(1)--The-design-shall-provide-for-such-separation-of-activities
into-discrete-areas-(modules)-as-may-be-necessary-to-assure-that
excavation-does-not-impair-waste-emplacement-or-retrieval-operations.

(2)--Each-module-shall-be-designed-to-permit-insulation-from-other
modules-if-an-accident-occurs.]

(c) [(d)] [Design-for] Retrieval of waste. The underground facility shall be designed to [(1)P-] permit retrieval of waste in accordance with the performance objectives of §60.111.

[(2)--Ensure-sufficient-structural-stability-of-openings-and-control
of-groundwater-to-permit-the-safe-conduct-of-waste-retrieval-operations;
and]

[(3)--Allow-removal-of-any-waste-packages-that-may-be-damaged-or
require-inspection-without-compromising-the-ability-of-the-geologic
repository-to-meet-the-performance-objectives-(§60.111).]

(d) [60.132(g)] Control of water and gas. [(1)--Water-and-gas
control-systems-shall-be-designed-to-be-of-sufficient-capability-and
capacity-to-reduce-the-potentially-adverse-effects-of-groundwater
intrusion,-service-water-intrusion,-or-gas-inflow-into-the-under-
ground-facility.] The design of the underground facility shall provide for control of water or gas intrusion.

[(2)-Water-and-gas-control-systems-shall-be-designed-to-control-the
quantity-of-water-or-gas-flowing-into-or-from-the-underground-facility;
monitor-the-composition-of-gases,-and-permit-sampling-of-liquids.

(3)--Systems-shall-be-designed-to-provide-control-of-water-and-gas
in-both-waste-emplacement-areas-and-excavation-areas.

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(4) Water control systems shall be designed to include storage capability and modular layouts that ensure that unexpected inrush or flooding can be controlled and contained.

(5) If the intersection of aquifers or water bearing geologic structures is anticipated during construction, the design of the underground facility shall include plans for cutoff or control of water in advance of the excavation.

(6) If linings are required, the contact between the lining and the rock surrounding subsurface excavations shall be designed so as to avoid the creation of any preferential pathway for groundwater or radionuclide migration.]

(e) [Design of subsurface] Underground openings.

(1) [Subsurface] Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained. [to maintain stability throughout the construction and operation periods. If structural support is required for stability, it shall be designed to be compatible with long term deformation, hydrologic, geochemical, and thermomechanical characteristics of the rock and to allow subsequent placement of backfill.]

(2) Structures required for temporary support of zones of weak or highly fractured rock shall be designed so as not to impair the placement of permanent structures or the capability to seal excavated areas used for the containment of wastes.

(2)[(3)] [Subsurface o]Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock. [over the long term. The size, shape, orientation, and spacing of openings and the design of

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engineered-support-systems-shall-take-the-following-conditions-into considerations--

(i)--natural-stress-conditions;

(ii)--deformation-characteristics-of-the-host-rock-under-normal conditions-and-thermal-loading;

(iii)--the-kinds-of-weaknesses-or-structural-discontinuities-found-at various-locations-in-the-geologic-repository;

(iv)--equipment-requirements;-and:

(v)--the-ability-to-construct-the-underground-facility-as-designed so-that-stability-of-the-rock-is-enhanced.

(f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment. [damage-to-and-fracturing-of-rock.] (NOTE: The modified text for 60.132(g) Control of water and gas is now found at § 60.133(d)).

(g) [60.132(h)] [Subsurface] Underground facility ventilation. The ventilation system shall be designed to--

(1) Control the transport of radioactive particulates and gases within and releases from the underground [subsurface-] facility in accordance with the performance objectives of [(]§60.111(a)[)].

[(2)-Permit-continuous-occupancy-of-all-excavated-areas-during normal-operations-through-the-time-of-permanent-closure;

(3)--Accommodate-changes-in-operating-conditions-such-as-variations in-temperature-and-humidity-in-the-underground-facility;

(4)--Include-redundant-equipment-and-fail-safe-control-systems-as may-be-needed-to]

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(2) [a] Assure continued function during [under] normal operations and under accident conditions; and

(3)[(5)] Separate the ventilation of excavation and waste emplacement areas.

(h)[(i)] Engineered barriers.

Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.

[(1)--Barriers-shall-be-located-where-shafts-could-allow-access-for groundwater-to-enter-or-leave-the-underground-facility.

(2)--Barriers-shall-create-a-waste-package-environment-which favorably-controls-chemical-reactions-affecting-the-performance-of-the waste-package.

(3)--Backfill-placed-in-the-underground-facility-shall-be-designed as-a-barrier.

(i)--Backfill-placed-in-the-underground-facility-shall-perform-its functions-assuming-anticipated-changes-in-the-geologic-setting.

(ii)-Backfill-placed-in-the-underground-facility-shall-serve-the following-functions:

(A)--It-shall-provide-a-barrier-to-groundwater-movement-into-and from-the-underground-facility.

(B)--It-shall-reduce-creep-deformation-of-the-host-rock-that-may adversely-affect-(1)-waste-package-performance-or-(2)-the-local hydrological-system.

(C)--It-shall-reduce-and-control-groundwater-movement-within-the underground-facility.

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(B)--It-shall-retard-radionuclide-migration.

(iii)--Backfill-placed-in-the-underground-facility-shall-be-selected to-allow-for-adequate-placement-and-compaction-in-underground-openings.

(j)--Waste-handling-and-emplacement.

(1)--The-systems-used-for-handling,-transporting,-and-emplacing radioactive-wastes-shall-be-designed-to-have-positive,-fail-safe-designs to-protect-workers-and-to-prevent-damage-to-waste-packages.

(2)--The-handling-systems-for-emplacement-and-retrieval-operations shall-be-designed-to-minimize-the-potential-for-operator-error.]

(i) [60.132(k)] [Design-for] Thermal loads. [(1)] The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, surrounding strata, and groundwater system. [will-not degrade-significantly-the-performance-of-the-repository-or-the-ability of-the-natural-or-engineered-barriers-to-retard-radionuclide-migration.

[(2)-The-design-of-waste-loading-and-waste-spacings-shall-take-into consideration--

(i)--Effects-of-the-design-of-the-underground-facility-on-the thermal-and-thermomechanical-response-of-the-host-rock-and-the-groundwater-system;

(ii)--Features-of-the-host-rock-and-geologic-setting-that-affect-the thermomechanical-response-of-the-underground-facility-and-barriers, including-but-not-limited-to,-behavior-and-deformational-characteristics of-the-host-rock,-the-presence-of-insulating-layers,-aquifers,-faults, orientation-of-bedding-planes,-and-the-presence-of-discontinuities-in the-host-rock,-and

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(iii)--The-extent-to-which-fracturing-of-the-host-rock-is-influenced by-cycles-of-temperature-increase-and-decrease.]

§ 60.134[60.133] Design of [shafts-and] seals for shafts and boreholes.

(a) General design criterion. [Shaft-design] Seals for [S] shafts and boreholes shall be designed so that they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure. [as-not-to-create-a-preferential-pathway-for-migration-of-groundwater and-so-as-not-to-increase-the-potential-for-migration-through-existing pathways.]

(b) Selection of materials and placement methods. Materials and placement methods for seals shall be selected to reduce, to the extent practicable, (1) the potential for creating a preferential pathway for groundwater or (2) radioactive waste migration through existing pathways.

[60.133(b)--Shaft-and-borehole-seals.

Shaft-and-borehole-seals-shall-be-designed-so-that.

(1)--Shafts-and-boreholes-will-be-sealed-as-soon-as-possible-after they-have-served-their-operational-purpose.

(2)--At-the-time-of-permanent-closure-sealed-shafts-and-boreholes will-inhibit-transport-of-radionuclides-to-at-least-the-same-degree-as the-undisturbed-units-of-rock-through-which-the-shafts-or-boreholes-pass. In-the-case-of-soluble-rocks,-the-borehole-and-shaft-seals-shall-also-be designed-to-prevent-groundwater-circulation-that-would-result-in dissolution.

(3)--Contact-between-shaft-and-borehole-seals-and-the-adjacent-rock does-not-become-a-preferential-pathway-for-water.

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(4)--Shaft-and-borehole-seals-can-accommodate-potential-variations of-stress;-temperature;-and-moisture.

(5)--The-materials-used-to-construct-the-seals-are-appropriate-in view-of-the-geochemistry-of-the-rock-and-groundwater-system;-anticipated deformations-of-the-rock;-and-other-in-situ-conditions.

[§60.134--Construction-specifications-for-surface-and-subsurface-facilities.

(a)--General-requirement.--Specifications-for-construction-shall conform-to-the-objectives-and-technical-requirements-of-§§60.130-through 60.133.

(b)--Construction-management-program.--The-construction-specifications-shall-facilitate-the-conduct-of-a-construction-management-program that-will-ensure-that-construction-activities-do-not-adversely-affect the-suitability-of-the-site-to-isolate-the-waste-or-jeopardize-the-isolation-capabilities-of-the-underground-facility;-boreholes;-shaft;-and seals;-and-that-the-underground-facility-is-constructed-as-designed.

(NOTE: What was 60.134(c) is now found in modified form at § 60.72.)

(d)--[60.134(d)]--Rock-excavation.--The-methods-used-for-excavation shall-be-selected-to-reduce-to-the-extent-practicable-the-potential-to create-a-preferential-pathway-for-groundwater-or-radioactive-waste-migration-or-increase-migration-through-existing-pathways.

(e)--Control-of-explosives.--If-explosives-are-used;-the-provisions of-30-CFR-57.6-(Explosives)-issued-by-the-Mine-Safety-and-Health-Administration;-Department-of-Labor;-shall-be-met;-as-minimum-safety-requirements-for-storage;-use-and-transport-at-the-geologic-repository-operations-area.

(f)--Water-control.--The-construction-specifications-shall-provide that-water-encountered-in-excavations-shall-be-removed-to-the-surface

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and-controlled-in-accordance-with-design-requirements-for-radiation-control-and-monitoring-(§60.131(c)).

(g)--Waste-handling-and-emplacement.--The-construction-specifications shall-provide-for-demonstration-of-the-effectiveness-of-handling-equipment and-systems-for-emplacement-and-retrieval-operations,-under-operating conditions.]

DESIGN CRITERIA FOR THE WASTE PACKAGE [REQUIREMENTS]

§ 60.135 [Requirements] Criteria for the waste package and its components.

(a) [General-requirements-of-design] High-level-waste package design in general.

[The-design-of-the-waste-package-shall-include-the-following elements:

(1) [Effect-of-the-site-on-the-waste-package.--The-waste] [p] Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

[(2)--Effect-of-the-waste-package-on-the-underground-facility-and the-natural-barriers-of-the-geologic-setting.--The-waste-package-shall-be

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designed-so-that-the-in-situ-chemical;-physical;-and-nuclear-properties of-the-waste-package-and-its-interactions-with-the-emplacement-environment-do-not-compromise-the-performance-of-the-underground-facility-or-the geologic-setting.--The-design-shall-include-but-not-be-limited-to-consideration-of-the-following-factors:--solubility;-oxidation/reduction reactions;-corrosion;-hydriding;-gas-generation;-thermal-effects;-mechanical-strength;-mechanical-stress;-radiolysis;-radiation-damage;-radionuclide-retardation;-leaching;-fire-and-explosion-hazards;-thermal-loads; and-synergistic-interactions.]

(b) [(c)] Specific criteria for HLW package design.

[The-HLW-waste-package-design-shall-meet-the-following-requirements:]

(1) Explosive, pyrophoric, and chemically reactive materials. The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials in an amount that could [interfere-with operations-in] compromise the ability of the underground facility [or compromise] to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives.

(2) Free liquids. The waste package shall not contain free liquids in an amount that could compromise the ability [impair-the-structural integrity] of the waste packages [components] to achieve the performance objectives relating to containment of HLW (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of waste package perforation during the period through permanent closure.

(3) Handling. Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

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(4) Unique identification. A label or other means of identification shall be provided for each waste package. The identification shall not impair the integrity of the waste package and shall be applied in such a way that the information shall be legible at least to the end of the [retrievable-storage] period of retrievability. Each waste package identification shall be consistent with the waste package's permanent written records.

(c)[60.135(b)] Waste form [requirements] criteria for HLW.

High-level [R]radioactive waste that is emplaced in the underground facility shall be designed to meet the following [requirements] criteria:

(1) Solidification. All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) Consolidation. Particulate waste forms shall be [have-been] consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) Combustibles. All combustible radioactive wastes shall be [must-have-been] reduced to a noncombustible form unless it can be demonstrated that a fire involving [a-single] the waste packages containing combustibles will not [neither] compromise the integrity of other waste packages, [nor] adversely affect any [safety-related] structures, systems, or components important to safety, or compromise the ability of the underground facility to contribute to waste isolation.

(d) Design criteria for other radioactive wastes.

Design criteria for waste types other than HLW will be addressed on an individual basis if and when they are proposed for disposal in a geologic repository.

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PERFORMANCE CONFIRMATION REQUIREMENTS

§ 60.137 General requirements for performance confirmation.

The geologic repository operations area shall be designed so as to permit implementation of a performance confirmation program that meets the requirements of Subpart F of this part.

SUBPART F - PERFORMANCE CONFIRMATION PROGRAM

§ 60.140 General requirements.

(a) The performance confirmation program shall provide data which indicates, where practicable [ascertain] whether--

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

(b) The program shall have been started during site characterization and it will continue until permanent closure.

(c) The program [will] shall include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The [confirmation] program shall be implemented so that:

(1) It does not adversely affect the ability of the natural and engineered elements of the geologic repository to meet the performance objectives.

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(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§ 60.141 Confirmation of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered.

(b) Subsurface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into subsurface areas, changes in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases

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and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

§ 60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

§ 60.143 Monitoring and testing waste packages.

(a) A program shall be established at the geologic repository operations area for monitoring the condition of the waste packages. Waste [P] packages chosen for the program shall be representative of those to be emplaced in the [repository.] underground facility.

(b) Consistent with safe operation [of] at the geologic repository operations area, the environment of the waste packages selected for the

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waste package monitoring program shall be representative of the [emplaced] environment in which the wastes are to be emplaced.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the [repository] underground facility during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

SUBPART G - QUALITY ASSURANCE

§ 60.150 Scope.

[(a)] As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that the geologic repository and its subsystems or components will perform satisfactorily in service. [b] Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements. [is-a-multi-disciplinary-system-of-management-controls-which-address-safety,-reliability,-maintainability,-performance,-and-other-technical-disciplines.]

§ 60.151 Applicability.

The quality assurance program applies to all systems, structures and components important to safety, to design and characterization of barriers important to waste isolation, and to activities related thereto. [which

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~~Enclosure C~~

would-prevent-or-mitigate-events-that-could-cause-an-undue-risk-to-the health-and-safety-of-the-public.] These activities include: site characterization, facility and equipment construction, facility operation, [exploring;-selecting;-designing;-fabricating;-purchasing;-handling; storing;-cleaning;-erecting;-installing;-emplacing;-inspecting;-testing operating;-maintaining;-monitoring;-repairing;-modifying;-and decommissioning] performance confirmation, permanent closure, and decontamination and dismantling of surface facilities.

§ 60.152 Implementation.

DOE shall implement a quality assurance program based on the criteria of Appendix B of 10 CFR Part 50 as applicable, and appropriately supplemented by additional criteria as required by § 60.151.

[§-60.153--Quality-assurance-for-performance-confirmation.

The-quality-assurance-program-shall-include-the-program-of-tests, experiments-and-analyses-essential-to-achieving-adequate-confidence that-the-emplaced-wastes-will-remain-isolated-from-the-accessible environment.]

SUBPART H - TRAINING AND CERTIFICATION OF PERSONNEL

§ 60.160 General requirements.

Operations of systems and components that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct

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operations that are important to safety must also be certified in such operations.

§ 60.161 Training and certification program.

[The] DOE shall establish a program for training, proficiency testing, certification and requalification of operating and supervisory personnel.

§ 60.162 Physical requirements.

The physical condition and the general health of personnel certified for operations that are important to safety shall not be such as might cause operational errors that could endanger the public health and safety. Any condition which might cause impaired judgment or motor coordination must be considered in the selection of personnel for activities that are important to safety. These conditions need not categorically disqualify a person, so long as appropriate provisions are made to accommodate such [defect] conditions.

SUBPART I - EMERGENCY PLANNING CRITERIA

[RESERVED]

Dated at Washington, D.C. this ______________ day of _____, 1983.

For the U.S. Nuclear Regulatory Commission.

____
Samuel J. Chilk
Secretary of the Commission

Appendix B

RATIONALE FOR THE PERFORMANCE OBJECTIVES IN 10 CFR PART 60

DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTE IN GEOLOGIC REPOSITORIES

TABLE OF CONTENTS

I. INTRODUCTION

On July 8, 1981, the Nuclear Regulatory Commission (NRC) proposed technical criteria (46 FR 35280) which would be used in the evaluation of license applications under procedural rules established by the Commission for licensing of geological disposal by the U.S. Department of Energy (DOE) of high-level radioactive waste (HLW), 46 FR 13971. NRC received 86 comment letters on these proposed technical criteria. Many commenters focused their commentary on the proposed numerical performance objectives, among other things, and identified the issues related to them that are the subject of this rationale. In particular, the rationale shows how the numerical performance objectives for individual sub-systems of the geologic repository, as revised in consideration of the public comment received, contribute to meeting the overall system performance objective, which is whatever generally applicable environmental standard as may have been established by the Environmental Protection Agency (EPA), and which for purposes of this analysis is assumed to be the working draft of the EPA standard found in Appendix C of NUREG-0806, of which this rationale is a part.

This chapter briefly delineates the authority of the three federal agencies mentioned above as involved in disposal of high-level radioactive wastes -- NRC, DOE, and EPA. Chapter II describes the nature of the high-level waste problem, including the inventories, hazards, and heat generation rates associated with various types of HLW, and how they change with time. Chapter III briefly discusses the functions which a repository must perform to protect public health and safety in light of the hazards discussed in Chapter II, and Chapter IV describes both the engineered and geologic features of a repository which must be considered in evaluating those functions. Chapter V contains a discussion of the uncertainties associated with assessing the performance of the features of a repository described in Chapter IV. Chapter VI discusses how the uncertainties discussed in Chapter V affect the alternatives considered in selecting a regulatory approach and the rationale for the approach selected. Chapter VII describes an assumed environmental standard for the allowable releases from a HLW repository and a model which both relates this standard to the numerical criteria for the performance objectives in the rule and reflects the uncertainties mentioned in Chapter V. Chapter VII also discusses the results of this model for the routine long term performance of the repository. Chapter VIII applies the model to two failure scenarios for long term repository performance, and describes the impact of the numerical criteria on whether the assumed environmental standard is met. Chapter IX describes the rationale for requiring the repository to be designed so that the option to retrieve the wastes is preserved. Chapter IX also contains the basis for the numerical value selected for the design period during which the retrieval option is to be preserved.

Three Federal agencies have major roles in the national program for disposal of high-level radioactive wastes. The EPA is responsible for developing a generally applicable environmental standard which will serve as the overall performance objective for releases from high-level waste disposal. The NRC will develop and issue regulations which cover all aspects of high-level waste disposal, and which will implement the EPA standard. The NRC will then consider license applications for HLW disposal to determine whether the proposal will conform to the regulation. The DOE has lead responsibility for formulating national policy for disposal of HLW, and has determined that national policy should focus on disposal of HLW in mined geologic repositories (Ref. 1-1). Further, DOE is responsible for constructing and operating a waste disposal facility in accordance with NRC regulations.

Disposal of high-level radioactive waste in a manner that will assure safety for many thousands of years represents a unique problem not previously dealt with in other NRC or EPA standards. Throughout the rulemaking process for the technical criteria, the NRC staff has considered several approaches that might be applied to this unusual regulatory problem. The remainder of this report provides the bases for the approach selected for siting and design of the repository to assure effective long-term isolation of the wastes.

II. NATURE OF THE HIGH-LEVEL WASTE PROBLEM

In this chapter we describe the types and quantities of high-level wastes, and their properties, such as radioactivity and heat generation rates, that could affect the design and performance of a HLW facility. For perspective, we compare the hazard of the HLW, as a function of time, with the hazard of the natural uranium ore that was mined to make the fuel that produced the wastes. From these considerations we attempt to draw some inferences about the relevant time periods for isolation of HLW.

Types and Quantities of Wastes

HLW may be disposed of in two basic forms: spent fuel discharged from nuclear power plants (if it is disposed of as a waste), and the residue resulting from reprocessing spent fuel for recovery of uranium and/or plutonium.

Substantial quantities of HLW currently exist in the United States as a result of both U.S. defense programs and commercial nuclear power operations, and additional quantities of wastes are projected to be generated in the future by both programs. The amount of radioactivity in defense wastes is less than 10% of that in the commercial wastes which are expected to be generated by the time a repository is constructed and in operation; the following discussion is therefore limited to commercial waste inventories. It should be recognized that defense wastes will add a small but significant increment to the total HLW inventory, and that commercial wastes represent an upper bound with respect to heat generation rates and concentrations of radioactivity.

Commercial light-water reactors of the type currently in use in the U.S. generate spent fuel at a rate of about 35 metric tons of heavy metal (MTHM) per GWe-yr* of electrical energy production. Currently operating

* GWe-yr means the amount of electrical energy, in billions of watts, produced in a year of continuous operation.

nuclear power plants have a generating capacity of about 55 GWe, and additional plants which are planned or under construction could increase the total generating capacity to about 130-150 GWe.

Depending on the rate at which new plants are placed in service, the cumulative year 2000 inventory of spent fuel is likely to lie in the range from about 45,000 to 72,000 MTHM* (Ref. 2-1), or about the capacity of a single repository (Ref. 2-2). By the year 2040, 1 to 3 additional repositories would be required depending on the growth rate of nuclear power generation, whether or not the waste is reprocessed, and the geologic media selected for disposal.

Waste Characteristics

As nuclear fuel is irradiated in a nuclear reactor, three types of radioactive products are formed. Fission products are generated by fissioning uranium and plutonium isotopes and, with a few exceptions, are characterized by relatively short half-lives and low radiotoxicity. Actinides are radionuclides with atomic numbers greater than 88, and result from non-fission neutron absorptions in uranium. The actinides typically have longer half-lives and higher radiotoxicities than the fission products. Small quantities of additional radionuclides, called activation products, are produced by neutron absorption in the structural materials which support and contain the fuel in a reactor. The activation products make only a minor contribution to the overall radiotoxicity of HLW, and will not be discussed further.

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* The small current inventories of commercially generated reprocessing wastes are insignificant.

Figure 1 presents the radioactivity of pressurized water reactor (PWR) spent fuel as a function of time after removal from a reactor, while Figures 2 and 3 present the same information for the wastes which would result from reprocessing the spent fuel from the uranium recycle and mixed oxide fuel cycles, respectively.* (Figures 1-3 as well as subsequent figures and tables in this chapter are all normalized on the basis of one metric tonne of heavy metal (MTHM) initially charged to a reactor.)

In all three fuel cycles, the fission product radioactivity decreases by 5 orders of magnitude during the first thousand years and then stays relatively constant until about 100,000 years after disposal. Much of this change (about 99.9 % or more) occurs within the first few hundred years, primarily because of decay of Sr-90, Cs-137 and other short-lived fission products. Some of the shorter-lived actinides such as Pu-238 also decay significantly during the first few hundred years.

Figures 4, 5 and 6 display the decay heat generation for spent fuel and reprocessing wastes from these same fuel cycles. In all three fuel cycles, the fission product decay heat generation rate decreases by almost 6 orders of magnitude during the first 1000 years and stays relatively constant for the next 100,000 years. The rate at which total heat is generated by the waste decreases less rapidly than the total radioactivity, but at least

*In the uranium recycle fuel cycle, it has been assumed that 99.5% of the plutonium in spent fuel is recovered and placed in storage, while the recovered uranium is returned to the fuel cycle. In the mixed oxide fuel cycle, both plutonium and uranium are returned to the fuel cycle. Reference 2-3 discusses additional assumptions.

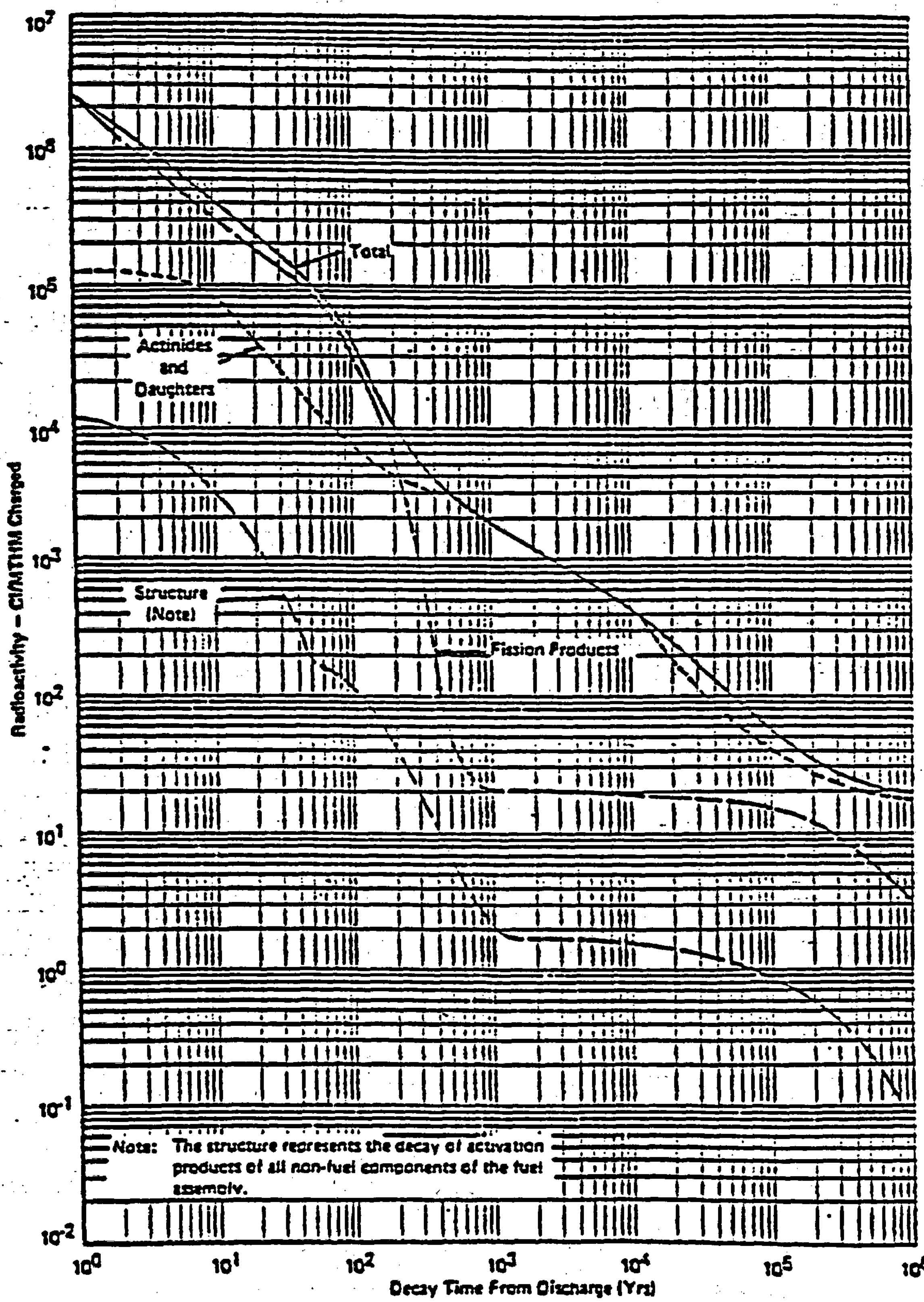


FIGURE 1. PWR SPENT FUEL -- RADIOACTIVITY
(Ref. 2-3)

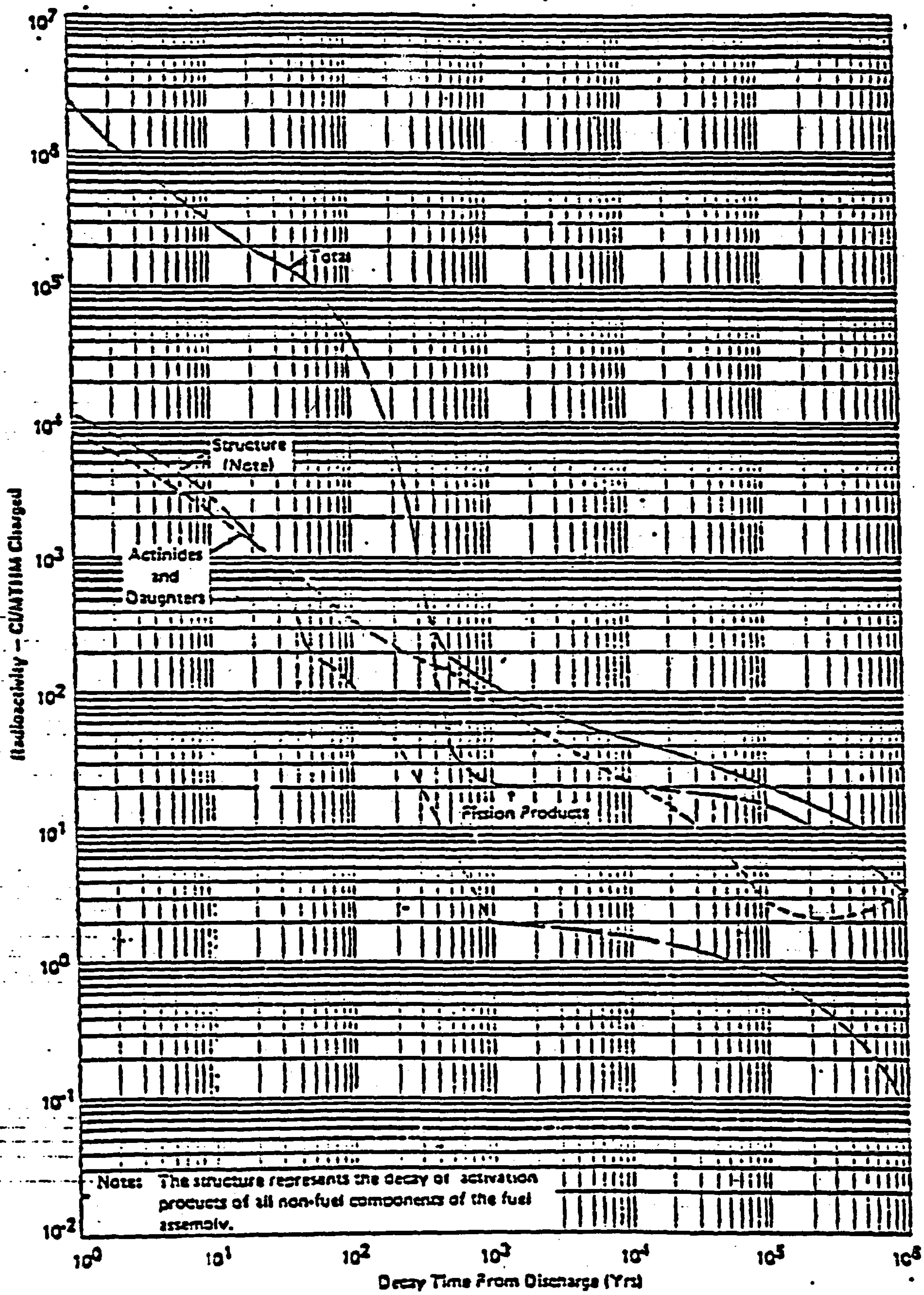


FIGURE 2. URANIUM RECYCLE REPROCESSING WASTE -- RADIOACTIVITY (Ref. 2-3)

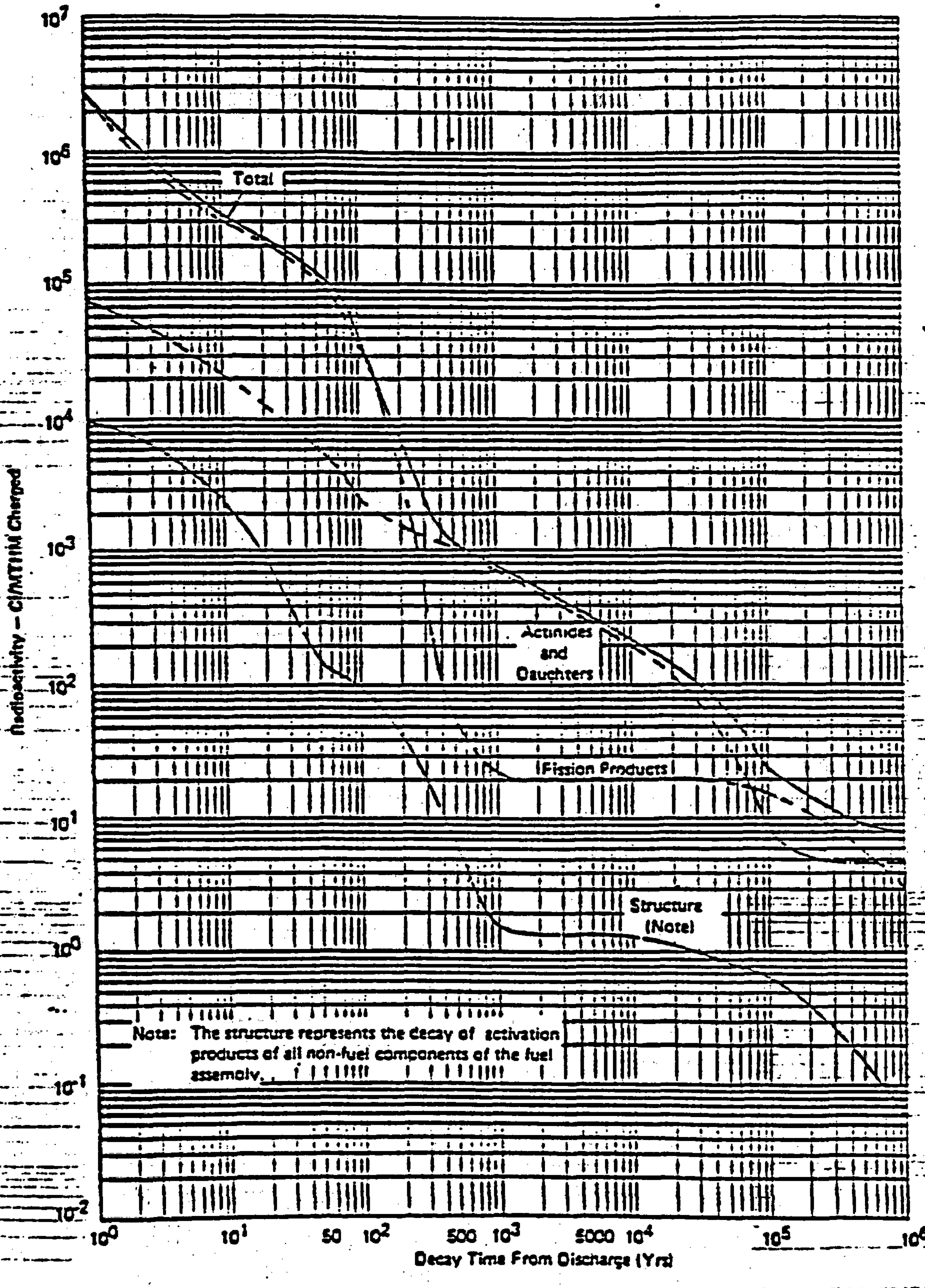


FIGURE 3. MIXED OXIDE REPROCESSING WASTE -- RADIOACTIVITY (Ref. 2-3)

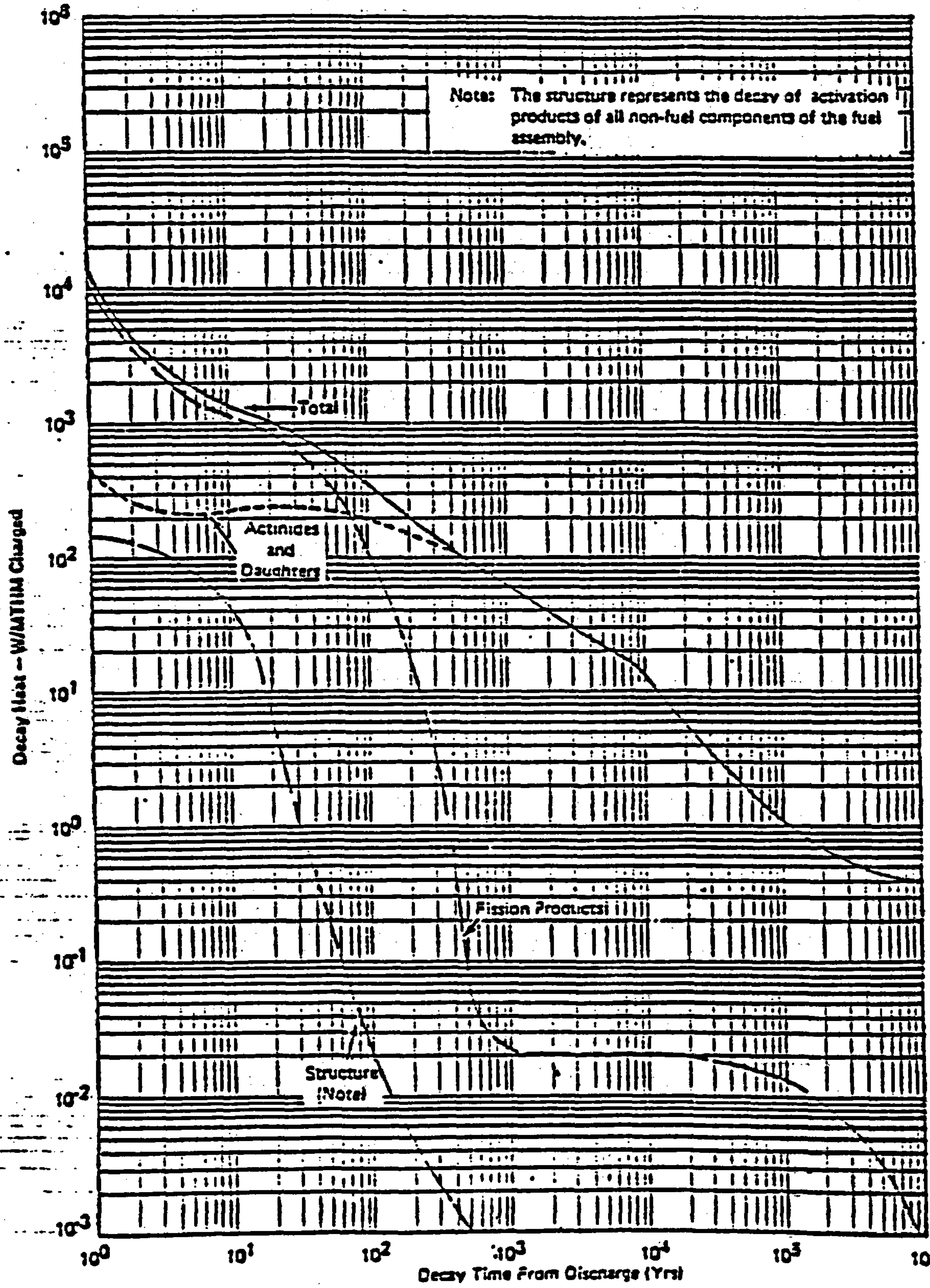


FIGURE 4. PWR SPENT FUEL -- DECAY HEAT GENERATION (Ref. 2-3)

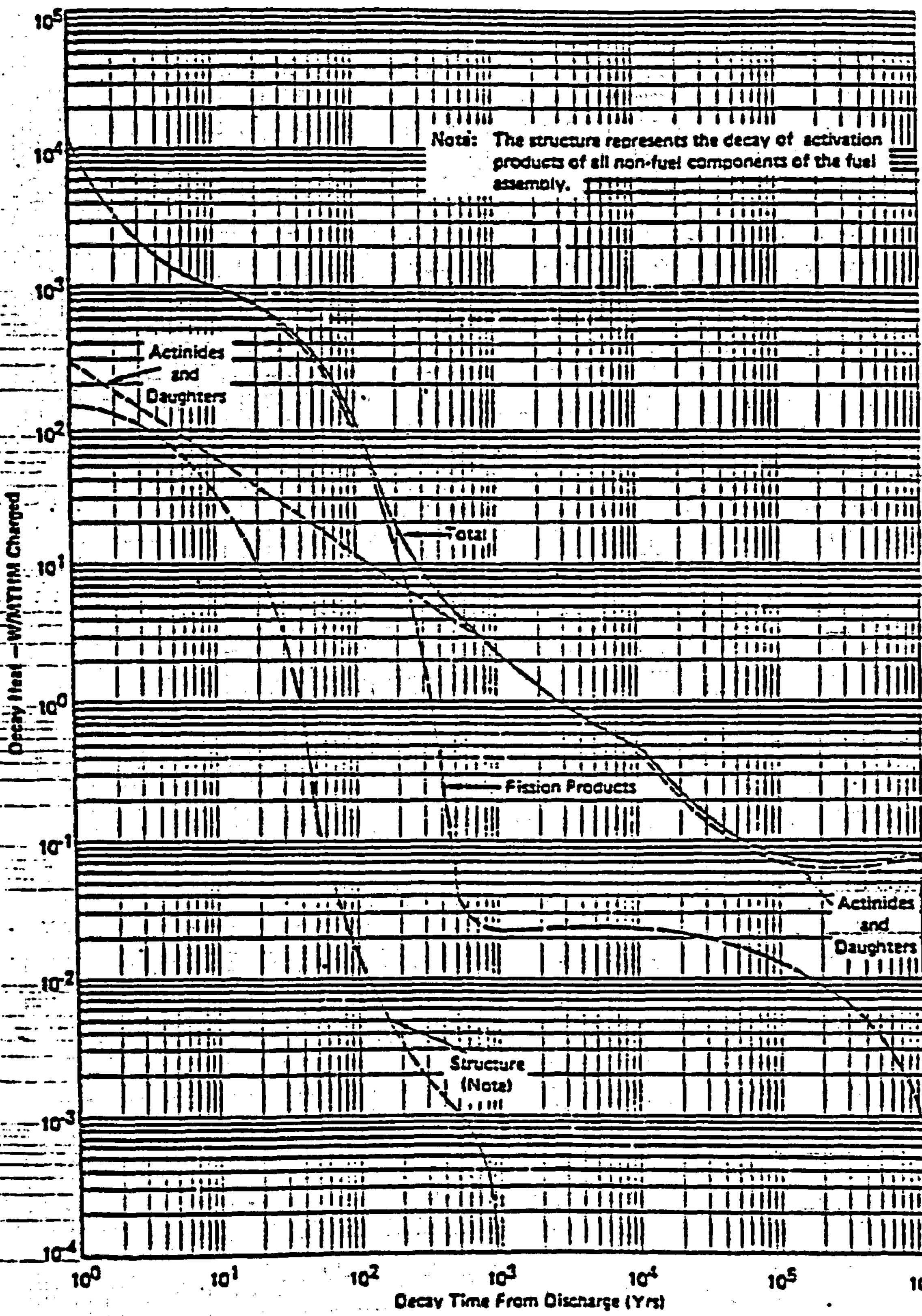


FIGURE 5. URANIUM RECYCLE REPROCESSING WASTE -- DECAY HEAT GENERATION (Ref. 2-3)

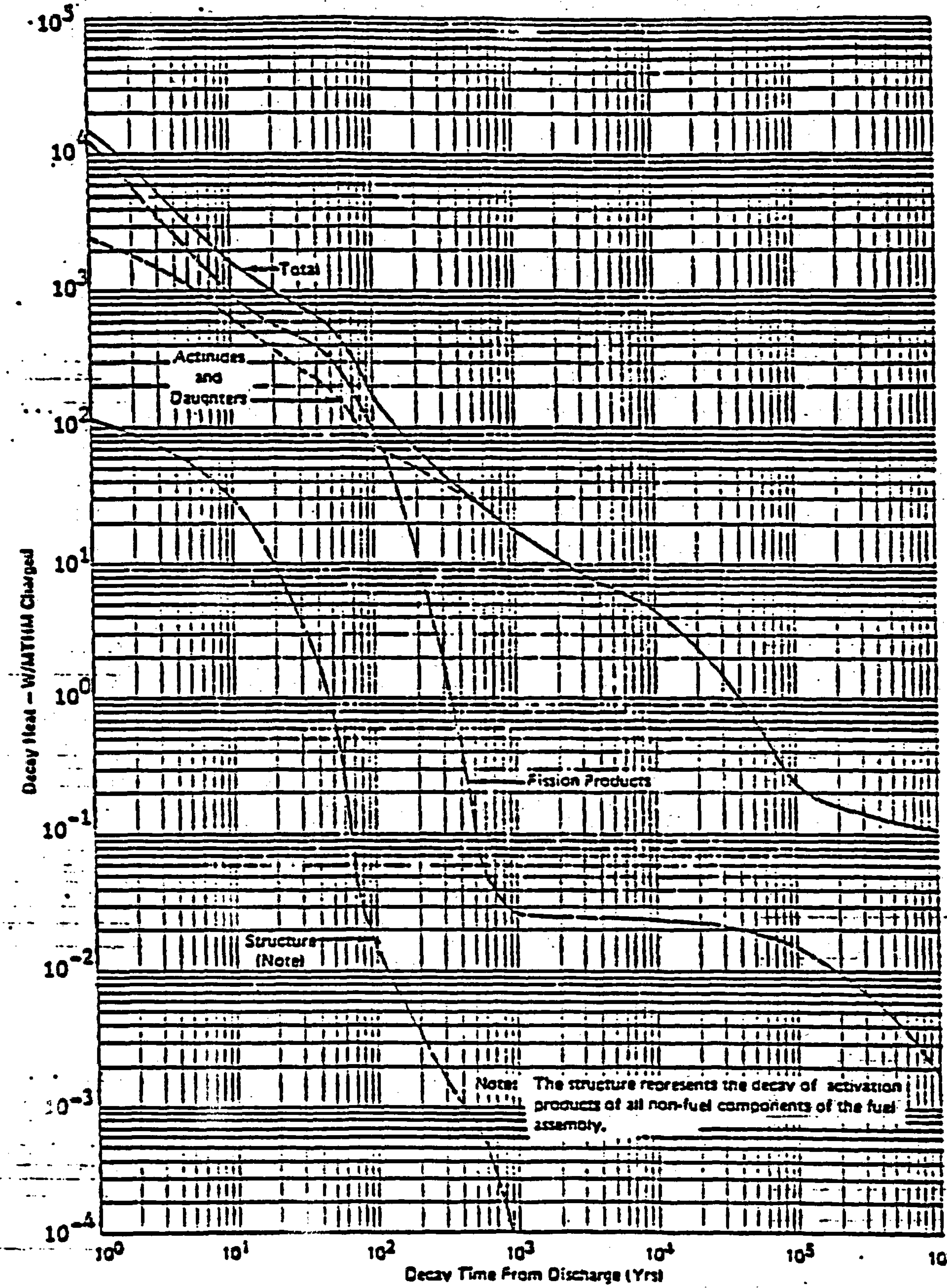


FIGURE 6. MIXED OXIDE REPROCESSING WASTE — DECAY HEAT GENERATION (Ref. 2-3)

a 99% reduction in heat generation rate is achieved within the first few hundred years for each of the waste types.

The preceding discussion does not address the differing radiotoxicities of the nuclides present in HLW. A rough estimate of the intrinsic hazard of a radioactive waste material can be obtained by calculating the "hazard index" or "untreated dilution index" (UDI) defined by:

$$UDI = \sum_i \frac{Qi}{MPC_i}$$

where Qi is the activity of nuclide i in the waste and MPC_i is the concentration limit for the nuclide in effluents as presented in 10 CFR 20. This "untreated dilution index" then represents the quantity of water (in cubic meters) which would be required to dilute the waste to meet the effluent concentration limits of Part 20. Figures 7, 8 and 9 present this index as a function of time for spent fuel and reprocessing wastes. These figures also include, for perspective, the "untreated dilution index" for an equivalent amount of unmined uranium ore.

Recent revisions in the ICRP's recommendations for dosimetry calculations (Ref. 2-4) would cause some significant changes in this measurement of the relative hazard of HLW as a function of time. This effect has been noted recently in the scientific literature by a number of authors (Ref. 2-5, 2-6 and 2-7). Revised curves, based on the more recent ICRP recommendations (ICRP-30), are displayed in Figures 10, 11 and 12 for spent fuel and reprocessing wastes. The most significant results of the ICRP revisions are:

1) the hazard of some of the fission products (primarily Sr-90) is reduced,

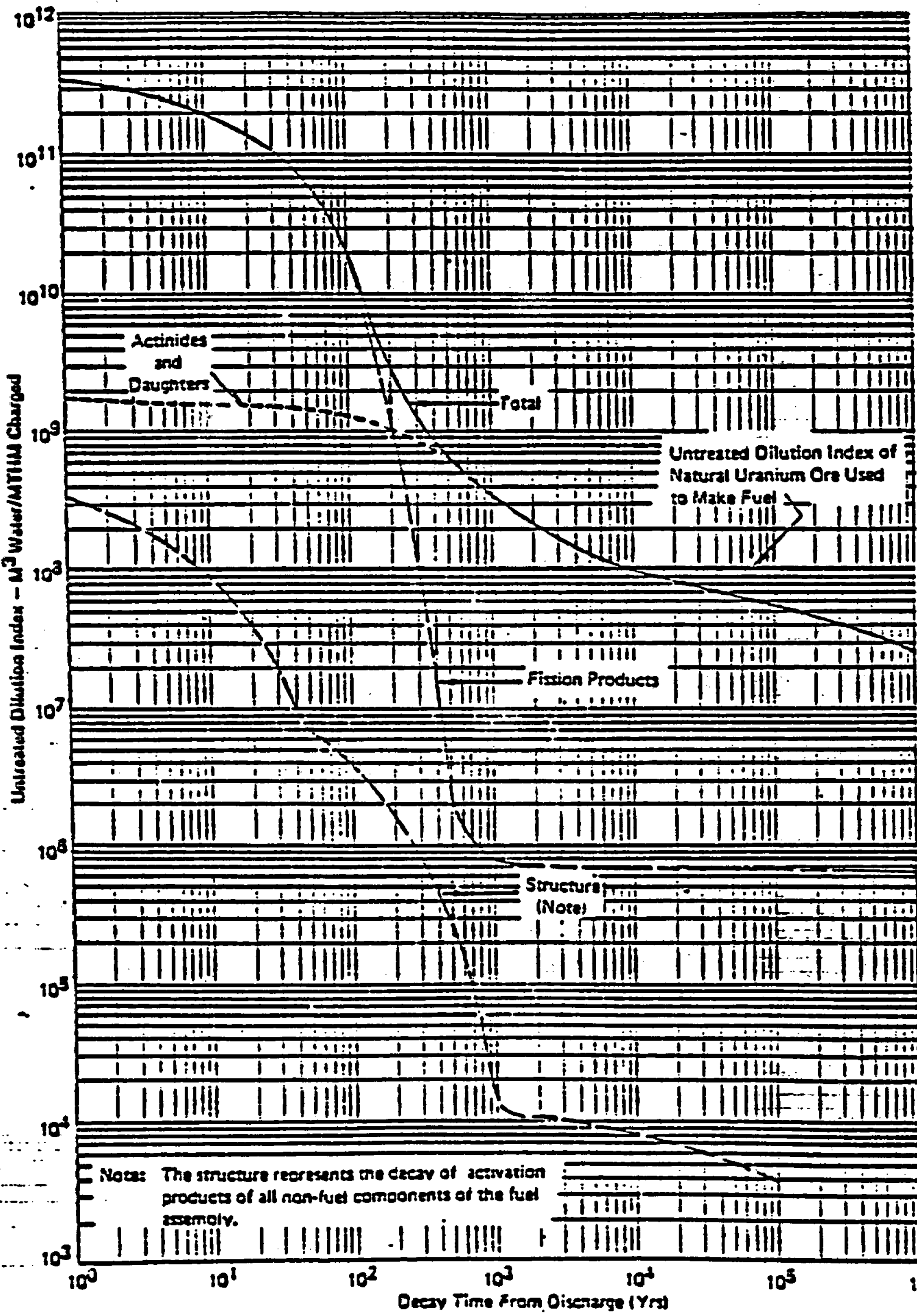


FIGURE 7. PWR SPENT FUEL -- UNTREATED DILUTION INDEX (Ref. 2-3)

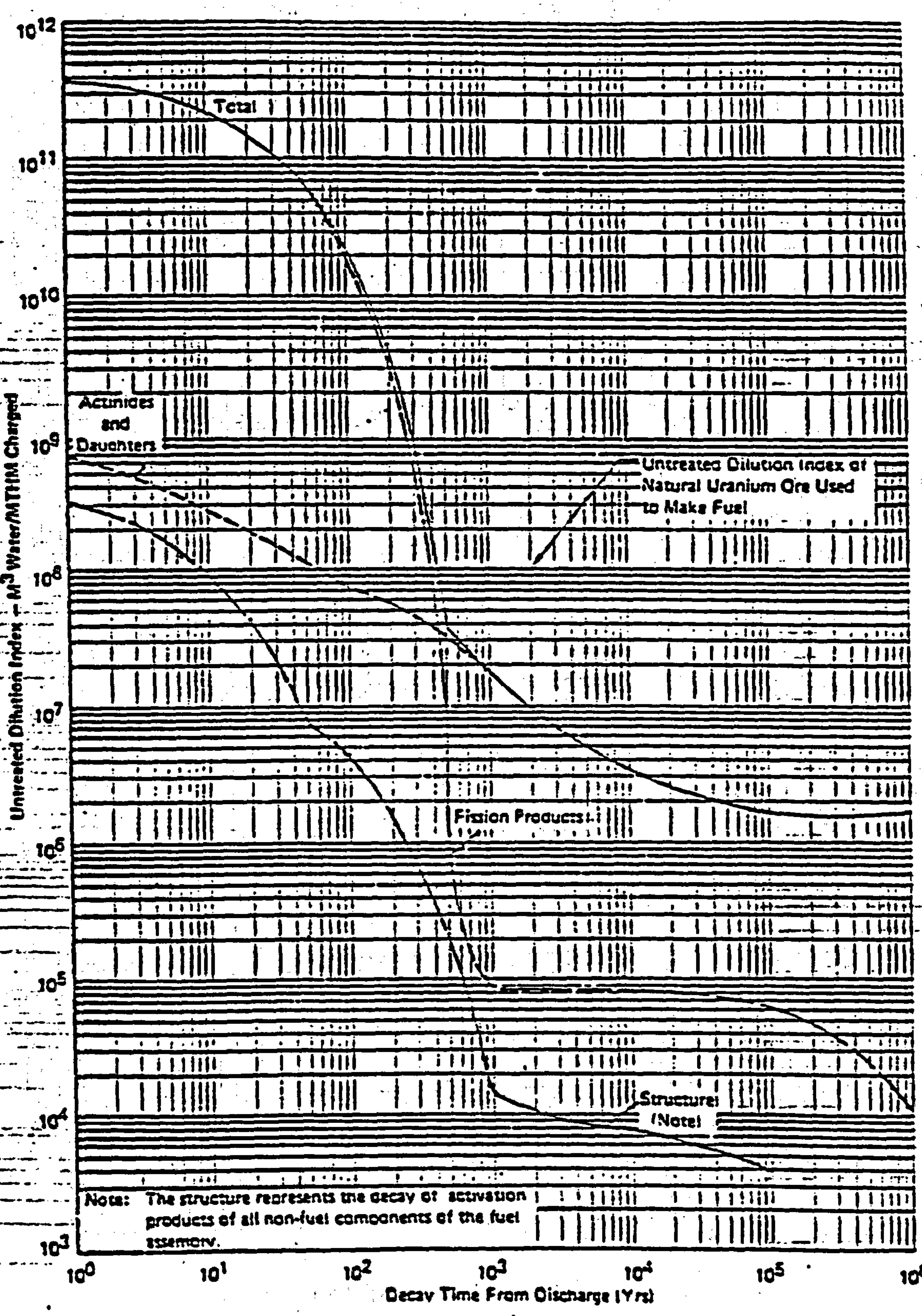
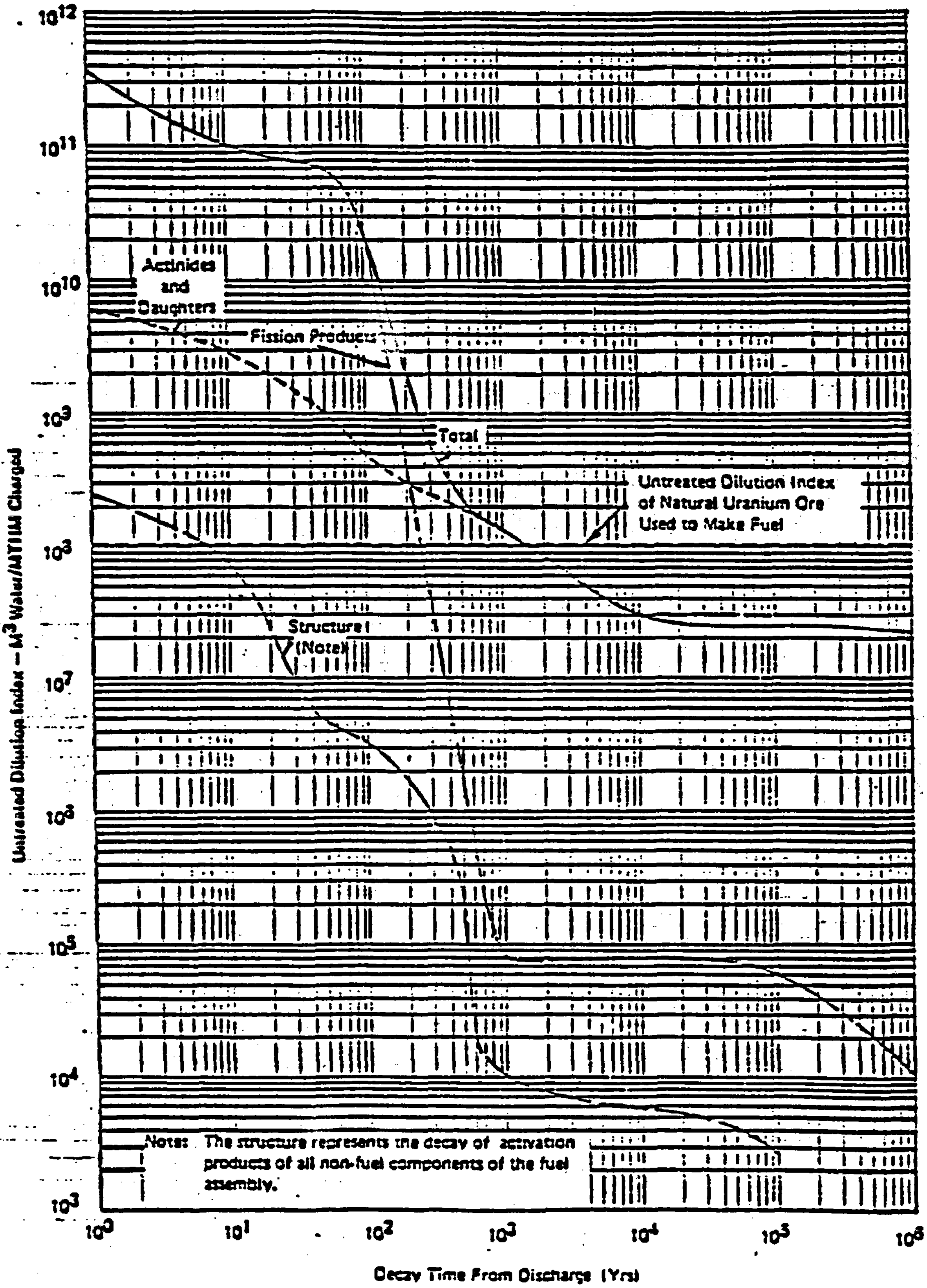


FIGURE 8. URANIUM RECYCLE REPROCESSING WASTE -- UNTREATED DILUTION INDEX (Ref. 2-3)



FI~~RE 9. MIXED OXIDE REPROCESSING WASTE -- UNTREATED DILUTION INDEX (Ref. 2-3)

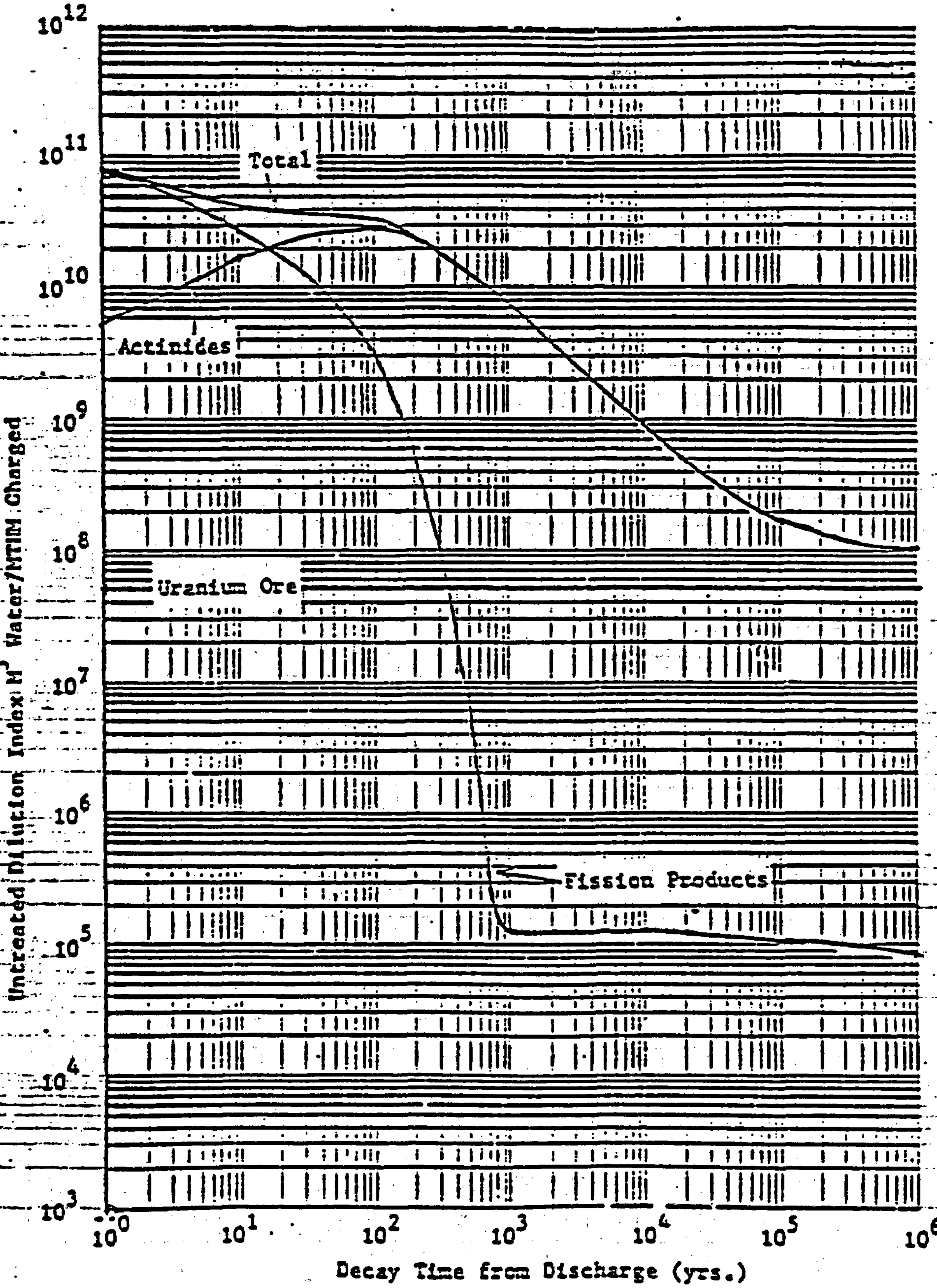


Figure 10. PWR Throwaway Cycle - Untreated Dilution Index Based on ICRP-30 Dosimetry.

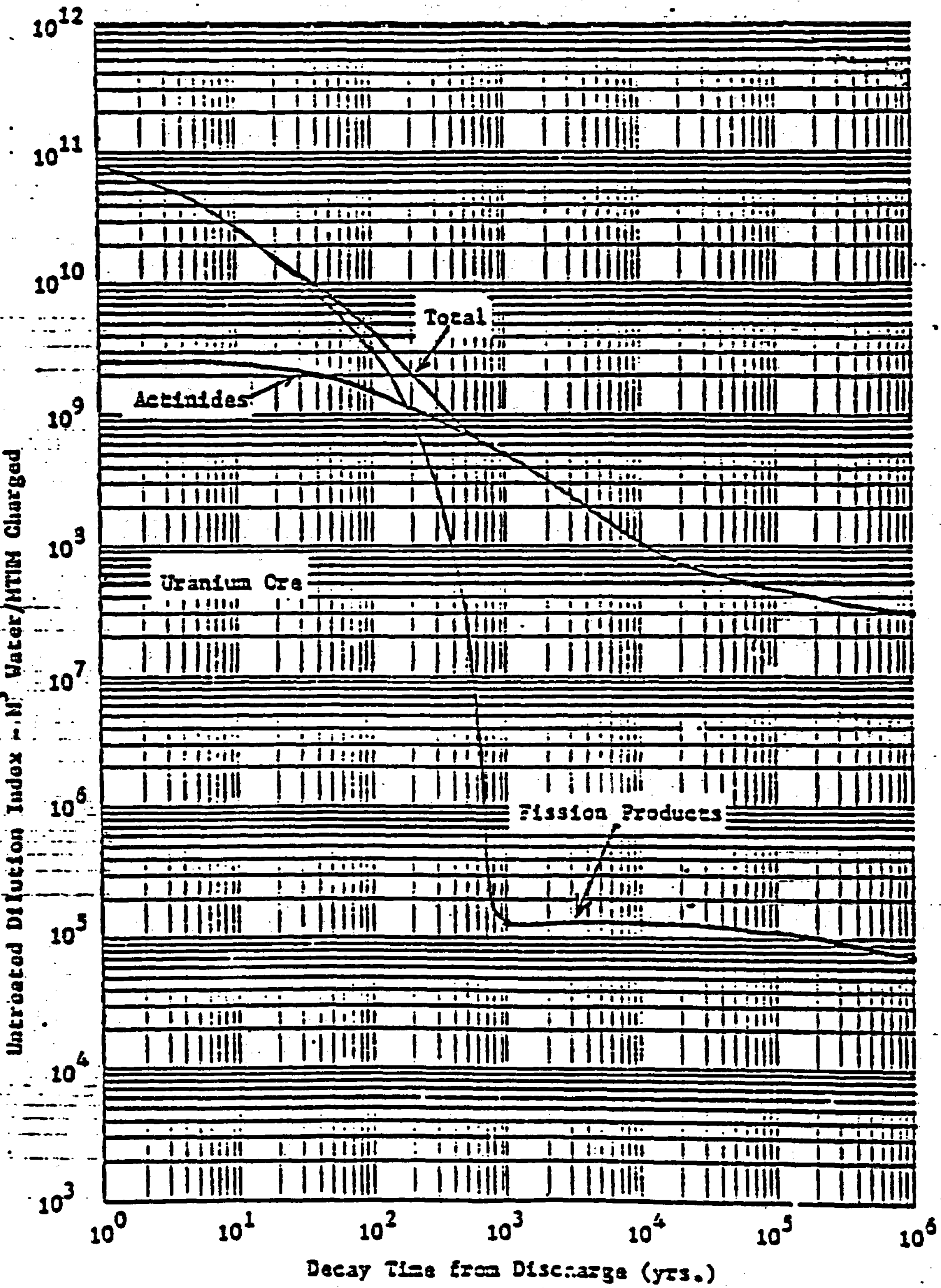


Figure 11. Reprocessed Waste - Untreated Dilution Index Based on ICRP-30 Dosimetry.

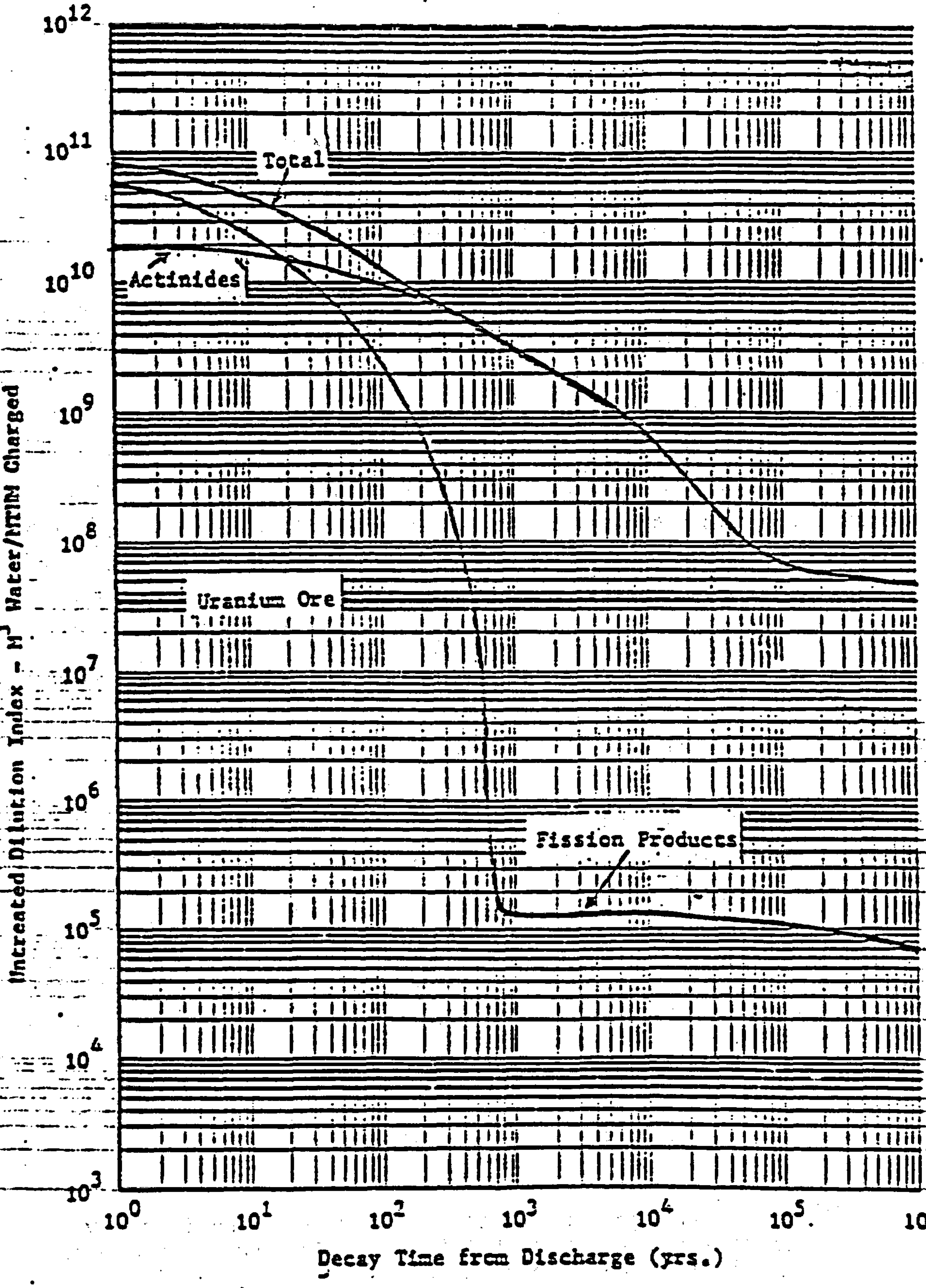


Figure 12. Mixed Oxide Reprocessing Waste - Untreated Dilution Index Based on ICRP-30 Dosimetry.

2) the hazard of several of the long-lived actinides is increased (especially Am-241, Am-243 and Np-237), and

3) the hazard of Ra-226 is reduced and, as a result, the hazard of the original uranium ore is reduced.

The UDI curves of Figures 7-12 indicate that the toxicity decreases substantially (90% - 99.9%) during the first 1000 years for all three waste types and for both dosimetry approaches considered. The toxicity of the fission products decreases by more than five orders of magnitude during the first 1,000 years and then remains essentially constant for the next 100,000 years. Table 1 lists the nuclides and their inventories which dominate the UDI curves using the revised ICRP-30 calculational procedure. (The NRC has not formally adopted ICRP-30, but the procedures described in it have been used here because it is the most current ICRP publication on internal dosimetry available.)

The "untreated dilution index" can provide some perspective regarding the intrinsic toxicity of a radioactive material, but is subject to the following limitations:

- The UDI does not consider the physical or chemical form of the radioactive material. Properties such as solubility or leachability may significantly affect the true hazard to human health.

- The location of the material and the pathways through which it could reach humans are not considered.

- There is considerable uncertainty inherent in the dosimetry parameters upon which the UDI is based, leading to considerable uncertainty in the index itself.

Despite these limitations, the UDI and the comparison with uranium ore are useful in understanding the magnitude of the hazard associated with HLW and how this hazard changes with time. In order to gain further

TABLE 1 - Dominant Nuclides* in Spent Fuel

Nuclide	Curies/ MTHM	UDI (m^3/ MTHM)	Percent of Total UDI
	10 Years		
Sr-90	6.0E4	2.0E10	43
Am-241	1.7E3	1.1E10	24
Cs-137	8.6E4	7.2E9	16
Pu-241	8.0E4	2.7E9	6
Pu-238	2.2E3	2.5E9	5
Cm-244	1.4E3	5.2E8	1
	1000 Years		
Am-241	9.2E2	6.1E9	80
Pu-240	4.4E2	7.5E8	10
Pu-239	3.2E2	5.4E8	7
Np-237	1.0E0	1.1E8	1
Am-243	1.6E1	1.1E8	1
I-129	3.8E-2	6.4E4	—
Tc-99	1.4E1	4.7E4	—
	100,000 Years		
Np-237	1.2E0	1.4E8	78
Pu-239	2.0E1	3.4E7	19
Ra-226	9.8E-1	4.7E6	3
I-129	3.8E-2	6.4E4	—
Tc-99	1.0E1	3.3E4	—

*Tc-99 and I-129 are included because of their mobility in geohydrologic systems.

understanding of the potential impacts of disposal of high level wastes, it is necessary to consider the rate of releases of the radioactive materials from the location where the wastes are emplaced and the physical and chemical processes that transport the radioactivity back to parts of the environment where it can be contacted by humans. These rates and processes are addressed in detail in the following chapters.

III FUNCTION OF A GEOLOGIC REPOSITORY

At present, national policy is focusing on disposal of HLW in mined geologic repositories (Ref. 3-1). The primary function of a mined geologic repository is to isolate the waste so that only small quantities of the wastes would return to the environment over such long times that disposal would not constitute an unreasonable risk to public health and safety. The principal mechanism by which radioactive material is anticipated to be released to the environment from a geologic repository is by contamination of groundwater (Ref. 3-2) that contacts the emplaced waste and transports the radioactive materials from the repository to locations in the environment where they can be ingested or contacted by humans. Thus, the assessment of how well a repository performs its isolation function involves consideration of the time when groundwater initially contacts the waste, the rates at which groundwater can contact the waste, the quantities and concentrations of radioactive materials which may be transported away from the disposal facility, and the rates of transport of the radionuclides through the geologic, hydrologic and geochemical systems to the accessible environment.

In order to emplace the wastes, the repository must be open for a period of years during which wastes would be received and handled in surface facilities, transported to the underground facility and placed in disposal locations. After this period of operation, the repository would be sealed and permanently closed. Until the time of permanent closure, handling of the radioactive materials would be carried out so that the public and workers would be protected from excessive exposure to radiation. The measures taken to protect the public and workers during the pre-closure period would be similar to those taken for radiation protection at other nuclear facilities and are not discussed further.

In light of the hazards of the radioactive materials in the HLW and the time periods involved, the measures required to achieve successful isolation of HLW are unique. As discussed in Chapter II, there are substantial uncertainties involved in estimating the toxicity of the waste material itself, and these uncertainties are compounded by uncertainties in such factors as the release rate of wastes from a repository and the pathways by which the wastes might reach the environment. These uncertainties will be discussed in more detail in the following chapters.

IV DESCRIPTION OF A GEOLOGIC REPOSITORY

A mined geologic repository is a facility which achieves isolation (limiting the rate of waste release to the accessible environment to acceptable levels) by means of two major subsystems. These are the geologic setting itself, which is selected for geologic, hydrologic and geochemical attributes which can contribute to isolation; and the engineered system consisting principally of waste packages and materials used to backfill and seal the underground facility, boreholes and shafts. The geologic setting and the engineered system differ both in their contributions to isolation and in the degree of confidence which can be placed on predictions of their long-term performance. Any mined geologic repository will contain some combination of these engineered and natural barriers which together must provide isolation. This is commonly called the multiple-barrier or the defense-in-depth approach. A major issue the Commission has had to deal with in promulgating technical criteria for geologic disposal of HLW is "how do the components of these two subsystems contribute to isolation and what confidence can be placed on their relative contributions to overall system performance?" To answer this question, the staff considered what the respective contributions of the geologic setting and the engineered system to overall performance should be so that the Commission can determine that there is reasonable assurance that a particular repository can isolate wastes.

ENGINEERED BARRIER SYSTEM

As currently envisioned by DOE in its GEIS on Commercial Waste Management (Ref. 4-1), wastes placed in a geologic repository will be in solid form and will be in a container or canister which, as a minimum, is needed to facilitate shipping and handling. Packages can be made of long-lived corrosion resistant materials, and special low permeability and absorbent materials can be placed around the canisters and in the underground facility to contribute to isolation. In fact DOE, in its GEIS, states that one of the functions of the waste package is to contain the waste for periods sufficient to allow most of the fission products to decay to very low levels. This action protects the waste from groundwater contact until the temperature and radiation levels have decreased to the point where technically supportable predictions of radionuclide release rates to the host rock can be made. It is expected that, at the end of repository decommissioning, the underground facility will have been backfilled and the boreholes and shafts which connect the underground facility with the ground surface will have been sealed with low permeability materials. The combination of waste packages and the underground facility we have called the engineered barrier system. The engineered barrier system can contribute to isolation first by controlling the release rate of radioactive materials to the geologic setting, thereby reducing the contribution which the geologic setting must make, and second, by providing a source of isolation which is relatively independent of the geologic setting and which can therefore mitigate the consequences of unforeseen failure of that setting.

This control of the source term can be achieved in several ways. First, the engineered barrier system can be designed of materials that limit the rate at which groundwater can contact the wastes. Second, the waste form itself can be comprised of, or encapsulated in, leach resistant materials. Third, materials which can retard migration once leaching has occurred can be placed in the underground facility and around the canisters to further control release of radioactive materials to the geologic setting.

One means by which waste-groundwater contact can be limited is by containment. In this context, containment means confining the wastes within a sealed boundary, such as a metal or ceramic container or canister, to protect the waste form from groundwater and to delay the onset of leaching and migration until the containment boundary is breached. Such a container can protect the waste form from water during the period when radiation and temperatures are high and release rate predictions are difficult. Even after an initial breach of a canister, which may only be a small pinhole or crack, the waste package may continue to contribute substantially to control of release for decades or centuries by limiting the amount of water which may contact the waste form.

Use of a long lived package to achieve containment is a means, therefore, to compensate for, and to an extent avoid, uncertainties in the prediction of rates of release and migration of the individual radionuclides, particularly during the critical period when the hazard of the wastes is greatest and the heat generation rates are the highest. This is important, because, as explained in Chapter V, temperature is one of the principal factors in calculating what the source term to the geologic setting is. During this critical period the uncertainties in predicting release rates are very great. Even if we did understand the mechanisms completely, the data scatter increases with temperature so that test programs to gather the data to narrow the uncertainties to reasonable bounds are very cumbersome (Ref. 4-2).

THE GEOLOGIC SETTING

Following release of the radioactive materials from the engineered barrier system, the geologic setting alone must provide whatever additional isolation is needed to keep radioactive materials entering the accessible environment to acceptable levels. The geologic setting can provide the needed isolation by two principal means. First, the geologic setting can exhibit hydrologic conditions which result in low groundwater velocities and long groundwater travel times to the accessible environment. Second, the geologic setting can be comprised of materials that chemically inhibit transport of radionuclides by groundwater by, for example, ion-exchange or precipitation reactions. The objective is for the geologic setting, through long groundwater travel times and geochemical retardation, to delay the arrival time of radionuclides at the accessible environment for many thousands of years. During this time additional radioactive decay will take place, so that only a small fraction of the material released from the engineered barrier system will enter the accessible environment, and then only very far in the future.

V. UNCERTAINTIES ASSOCIATED WITH GEOLOGIC DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES

In the two previous chapters we discussed the function of geologic disposal of HLW (Chapter III) and gave a brief description of current concepts for a geologic repository (Chapter IV). Assessments of the long-term performance of such a HLW repository require the use of quantitative models, and substantial uncertainties are associated with both the models themselves and with the input data necessary for their use. In this chapter we discuss the uncertainties associated with long-term performance assessments, the effects of those uncertainties on the confidence that can be placed in such assessments, and the means by which these uncertainties may be reduced or compensated for.

In Section 1 of this chapter, we begin by reviewing the functions of engineered barriers for isolating HLW, noting specific processes which control or determine these functions. For each process, we cite 1) the properties important in the process, 2) the methods available to measure those properties, 3) ways to determine whether the function is achieved, and 4) the uncertainties associated with those determinations. In Section 2, we treat the key elements of the geologic setting in a similar manner. Finally, we discuss the implications of the uncertainties with respect to confidence that the wastes will continue to remain isolated long into the future.

The specific processes discussed are chosen to follow current concepts of a geologic repository. A canister containing a leach-resistant waste form is emplaced within a backfilled underground facility. Hence, in Section 1 we discuss the engineering by focusing upon the containment properties of a canister, leach properties of waste forms, and sorption/chemical/mechanical properties of backfill. The processes discussed (corrosion, leaching, etc.) would be relevant to any engineering scheme which might be proposed to control release of radionuclides to the geologic setting. Similarly, groundwater flow, geochemical retardation, and the general suitability of a location to host a geologic repository are discussed in Section 2.

1. Uncertainties in the control of radionuclide release to the geologic setting through engineering.

If an engineered barrier system is used to control the release of radionuclides to the geologic setting by methods such as containing the wastes for some period or controlling the rate at which the nuclides are released, then there must be some level of confidence that the materials will perform as planned. This section discusses those processes which determine how engineered materials will behave and affect containment or release of radionuclides, methods for determining and projecting the performance of engineered materials and the uncertainties associated with projecting barrier performance.

To assess the performance of barrier materials it is necessary to understand the environment which they experience, as altered by the effects of these materials on that environment. The central feature of the environment will be groundwater, whose naturally occurring properties such as chemistry and temperature will be altered by thermal and radiation effects of the waste, as well as by chemical interactions with the barrier materials. The complexity of these interactions will result in an uncertainty in the understanding of the environment experienced by the barrier materials which will contribute to the uncertainties in the prediction of their performance.

a) Leach-resistant waste forms

(i) Properties

Leach-resistant waste forms can control releases of radionuclides to the geologic setting in two ways. First, the rate at which nuclides are released can be reduced, reducing nuclide concentrations in groundwater. Second, retention of radionuclides in the waste form allows time for decay, reducing the total quantity of radioactivity ultimately released to the geologic setting.

Leaching will depend on parameters associated with the ground (or repository) water contacting the waste form, such as composition, pH and Eh; parameters pertinent to the waste form itself, such as surface area and structure; and parameters which affect properties of both the water and the waste form, such as temperature and radiation. (Ref. 5-1, 5-2 and 5-3).

(ii) Determination of leach rate

Leaching of a waste form by groundwater is a very complex process. There is as yet no rigorous, well determined rate expression available to describe the leaching of a waste form and its dependence on all the physical, chemical and geometric properties that are known to affect it. Moreover, much of the data available indicate a complex interplay between leach rates and parameters such as pH, Eh, flow rates, leachant chemistry and how these parameters may change with temperature. As a result the models presently available to estimate the rate of leaching generally reflect empirical correlations rather than theoretical principles.

Experimental measurements can be conducted under conditions intended to represent the expected leacning environment (Ref. 5-4 and 5-5).

Controlled perturbations of leach rate experiments may lead to a broader understanding of fundamental leach rate phenomena (e.g., the influence of temperature and pH on leaching) and, in principle, can aid in the development of and improve the validity of the models. However, in all cases, predictions of long term performance will be based on the results of tests and analyses of those results. From such analyses, it is known that certain parameters such as temperature and radiation alter the measured leach rates significantly (Ref. 5-6 and 5-7). As the temperature increases the mechanism of leaching may change, the nature of the leaching medium may change, and the ability to precisely and reproducibly determine the leach rate may be hampered. Radiation will alter characteristics of the leaching medium, such as, its pH (Ref. 5-8), and thus will alter measured leach rates. The combined effects of increased temperature and radiation can potentially increase the uncertainties in the leach performance of the waste form to a point where they may not easily be quantifiable.

Further, there will always remain the question as to whether the conditions by which leach rates are determined in the laboratory are the same as those which will be encountered by the waste form in the repository. Uncertainties in measurements of current hydrologic characteristics (e.g., flow rates) and, particularly, in predictions of future hydrologic conditions (Ref. 5-9), place limits on the reliability of long-term leaching extrapolations.

(iii) Implications

Several conditions must be met if a leach resistant waste form is to serve as a major barrier to waste release:

1) The influence of significant parameters (e.g., temperature, groundwater chemistry) must be thoroughly investigated. An understanding of the influence of these parameters may require that the waste form be contained to prevent the initiation of leaching until temperature and radiation levels are low enough that a greater degree of confidence can be placed on the long term leach behavior.

2) Predictions of the repository environment far into the future must be bounded, including changes in the environment between closure and resaturation of the underground facility. Such predictions need not be precise, but the bounds must lie within the range of conditions for which the waste form has been experimentally tested.

3) Manufacturing quality control must be adequate to assure that the properties of "production line" waste forms do not deviate significantly from the properties of the waste forms evaluated in the laboratory.

If these conditions are met, leach rates may be extrapolated with less uncertainty. Furthermore, long-term leach rates can probably be predicted with more confidence than can near-term leach rates because of the elevated temperature conditions shortly after waste emplacement. A low leach rate waste form can therefore serve as a high performance engineered barrier over the long-term after thermal and radiation effects have decreased. The level of confidence would probably be lower in the short-term (hundreds of years) when elevated temperatures and radiation may cause extreme repository conditions.

The waste form testing, groundwater measurement and manufacturing quality control conditions discussed above seem reasonable in light of the degree of confidence which could be placed on a low-leach rate waste form as an engineered barrier. A numerical limit for the leach rate to be achieved by such a waste form will be discussed in a later chapter.

(b) Canister

(i) Properties

The use of a canister to contain the wastes can overcome some of the difficulties with predicting leach rate and radionuclide sorption (to be discussed in section (c)) at the elevated temperatures and radiation levels likely to be present during the first few centuries following closure. Containment can delay the onset of the leaching process until temperatures have fallen to a level where the leach rate is predictable with a higher degree of confidence.

The mechanism of containment functions not so much to keep wastes within a specified volume (e.g., the canister), but to keep the groundwater from contacting the waste-form until temperature and radiation levels are within the range where laboratory data can be relied on to predict long term performance with reasonable assurance. Hence, the process of concern is deterioration of the canister. Some of the physical and chemical parameters which determine corrosion rates are the same as those which determine leach rates. Principal among these are groundwater chemistry (Eh, pH and chemical composition), temperature and radiation (Ref. 5-10).

(ii) Determination of expected containment time

Actual containment time can not be observed directly because of the long periods involved. Rather, the expected containment time must be inferred from extrapolation of experiments, noting both the modes and rates of deterioration and failure. Typically, specimens of the material to be used, including weldments, will be subjected to conditions simulating the groundwater and, possibly, the radiation environment expected to be present.

(iii) Implications

The principal advantage of containment is that it permits the system to be simplified by separating the waste from the groundwater until such time as temperature and radiation effects decrease to where laboratory tests can better simulate repository conditions.

Container degradation or failure can be experimentally measured over a wide range of anticipated repository conditions (e.g., typical repository water chemistries, temperatures and radiation fields). As with leaching from a waste form, corrosion of a metallic barrier is a complex kinetic process which may be difficult to predict. At higher temperatures, new mechanisms may arise and the uncertainties in the data may increase. However, failure rates for some processes, or the conditions under which a specific process can cause failure, may be investigated. Failure rates under the range of conditions expected in the repository can be estimated and their accompanying uncertainties bounded. These can then be used to assess the performance of canister materials and to bound the confidence in that assessment.

The conditions previously discussed for leach rate predictions (predictions of groundwater conditions, testing that bounds these conditions, and manufacturing quality control) also apply to containment time predictions. If these conditions are met, containment times may be extrapolated with confidence. A numerical limit for the containment time to be achieved will be discussed in a later chapter.

(c) Backfill

(i) Properties

Backfill materials can serve a number of purposes. They can retard migration from the underground facility of radionuclides leached from the waste form, can condition groundwater within the underground facility both to slow corrosion of canisters and to lower leach rates, and can physically limit the rate of groundwater contact with a canister or waste form (Ref. 5-11). The chemical, thermal, and mechanical (physical) properties of the backfill and its interaction with the groundwater determine its performance. When groundwater interacts with a canister or a waste form, the chemical composition of the resultant solutions must be considered if backfill is used to retard radionuclide migration, limit leach rates or reduce solubility limits. Further, for backfill to be a useful agent for conditioning groundwater or retarding radionuclide movement it must contact the groundwater effectively. That is, the backfill must be emplaced in such a way that there are no extensive voids or channels that would permit the groundwater to bypass the backfill materials. In addition, the backfill must be able to perform its function in the changing thermal, chemical, and radiation environment of the repository.

(ii) Determination of backfill performance

Standard engineering tests for compaction, permeability, homogeneity, and gradation can be performed on backfill emplaced within an underground facility to assure the proper mechanical properties for its intended function. Groundwater conditioning and radionuclide retardation properties can be determined by laboratory tests which focus on the chemical properties of the backfill. Backfill materials can be tested in the laboratory and in-situ to determine their behavior in the repository environment (Ref. 5-11 and 5-12).

(iii) Implications

The functions of a backfill material can be considered to be of two basic types:

(1) An adjunct to other barriers. A backfill can condition groundwater to increase containment times and reduce leach rates, and can limit the rate of groundwater contact with a canister or waste form.

(2) A barrier in its own right. A backfill can retard movement of nuclides away from their location of emplacement.

The uncertainty in the performance of a backfill material probably cannot be quantified very precisely. Rather, the backfill serves largely to reduce the uncertainty in the performance of the other barriers. (For example, by controlling the pH of the groundwater, uncertainty in the corrosion rate of a canister may be reduced.) The backfill can, nevertheless, serve an important function in overall repository performance, and can be instrumental in predicting the performance of the other engineered barriers.

2. Uncertainties with respect to transport of radionuclides through the geologic setting.

Regardless of the extent to which engineering is used to contain wastes or control the release of radionuclides, the geologic setting determines the environment in which the engineering must perform its intended function. Hence, the geologic setting must be characterized and understood at least with respect to the design parameters of the engineering. Moreover, to the extent that the geologic setting is used to isolate the wastes from the accessible environment, or that it is relied upon to mitigate the consequences of premature or unanticipated failure of the engineering, it must be characterized and understood with respect to its ability to control the movement of radionuclides to the accessible environment. In this section we discuss the parameters which describe the processes and characteristics of the geologic setting relevant to the functions described above.

(a) Groundwater Hydrology

(i) Properties

The groundwater is the likely means by which radionuclides would be transported from a geologic repository to the accessible environment. Hence a long groundwater flow time between the underground facility and the accessible environment is a highly favorable condition for waste isolation. Further, our confidence in the ability of a geologic repository to isolate wastes is directly dependent upon an understanding of the groundwater flow between the repository and the accessible environment. The characteristics by which we describe the groundwater flow through porous media typically are those by which any fluid system is described: hydraulic gradient, porosity, permeability, temperature, density, viscosity, and the geometry of the system. For flow in fractured media, an effective porosity and an effective permeability can be developed based on average fracture size and length and the porosity and permeability of the unfractured rock. (The chemical properties of the groundwater also are important to the design of the engineering used to contribute to the isolation of the wastes. The measurements of the chemical properties relevant to engineering, and their associated uncertainties were discussed in the previous section.)

(ii) Determination of groundwater flow

The hydraulic properties of the groundwater system particularly important to isolation of radioactive wastes are related to groundwater flow (rate, quantity, direction, and, in the saturated zone, time for resaturation of the underground facility). Groundwater flow can be measured directly for simple aquifers with rapid groundwater flow. However, the underground facility is likely to be constructed in an aquitard or aquiclude, nearby groundwaters are likely to be very slow flowing, and flow paths may be complex and fractured. Such slow flow or complex heterogeneous conditions make direct measurement of groundwater flow difficult. Fluid systems models that incorporate the properties described in the preceding section can be used in place of direct measurement to estimate groundwater flow. Such models have been developed, but have not been validated, for estimating groundwater flow in the slow-flow conditions expected in the stratum in which an underground facility would be constructed. Moreover fracture-flow will likely be of importance in many host rocks, but the development of fracture-flow models is in its infancy and the utility of these models for predictive purposes has not yet been demonstrated (Ref. 5-13 through 5-16).

Groundwater dating is an alternative to direct measurement for estimating groundwater flow, and does not require measurement of all the properties which determine groundwater flow. Hence, groundwater dating can provide a semi-independent check on groundwater flow estimates (Ref. 5-17). Groundwater dating involves uncertainties which are potentially important, however. Among these are uncertainties in initial isotope ratios, chemical or physical processes which could alter isotope ratios or concentrations along the flow-path, and mixing with groundwaters from other sources between measurement locations. At present, groundwater dating techniques applicable to waste repositories are mostly in the early stages of development, except for methods using C-14 (Ref. 5-18).

(iii) Implications

Some of the uncertainties associated with estimates of groundwater flow for repository performance can be assessed quantitatively by means of parameter sensitivity analyses and statistical sampling techniques (Ref. 5-19, 5-20 and 5-21). However, the utility of uncertainties estimated in this way is limited with regard to actual flow at a repository site for several reasons. Validation is lacking for flow estimates under slow-flow and fracture-flow conditions. Also, the models used to make the estimates may not properly account for (1) the diverse and heterogeneous geologic environments which are likely to be encountered over the distance of groundwater travel from the underground facility to the accessible environment, and (2) the effects of natural geologic processes, as well as the thermomechanical perturbations caused by the wastes themselves, which may significantly alter groundwater flow patterns over the time period required for waste isolation.

(b) Geochemistry

(i) Properties

Favorable geochemistry would tend to retard the movement of radionuclides with the groundwater. The movement of radionuclides typically is described by the groundwater flow rate and the empirical retardation factor. The latter is a shorthand for the complex geochemical processes which affect radionuclide transport in groundwater. The retardation factor is described in terms of characteristics of the geologic medium (e.g., bulk density and porosity for porous-medium flow) and the radionuclide distribution coefficient, Kd, which accounts for the chemical interactions among a radionuclide, the constituents of the groundwater, and the host rock/aquifer of concern.

Solubility limits may also be important, particularly for the actinide elements. If the rate of groundwater contact with a waste form is very low (e.g., because of favorable backfill material properties), or if the solubility limit of an element is very low, the apparent "leach rate" of a waste form will be reduced independent of the inherent leaching characteristics of that material. Solubility limits are dependent primarily on the groundwater chemistry (for a given element). Thus, a combination of a favorable groundwater chemistry and a low rate of groundwater contact with a waste form (e.g., good backfill properties) could substantially reduce nuclide dissolution rates from a waste form.

(ii) Determination of geochemistry conditions

The relevant processes which must be measured or inferred to predict geochemical retardation of radionuclides include, among others, precipitation/dissolution (controlled by solubility), the chemical forms of nuclides in solution, sorption/desorption interactions, and colloid transport and ultrafiltration. Generally, the limiting geochemical processes are chemical complexing (which determines species present in the groundwater), and precipitation and sorption/desorption (which affect the amounts of radionuclides dissolved in groundwater).

Laboratory tests can be used to estimate maximum solubilities, and field measurements can be made to verify laboratory measurements. Similarly, laboratory measurements can be used to determine sorption/desorption properties. However, the relevance of laboratory measurements to actual field conditions is only beginning to be investigated.

Theoretical geochemical models have recently been developed to investigate element speciation in realistic geochemical environments. (Ref. 5-22 and 5-23). However, the requisite field data and thermodynamic data, particularly for transuranic elements, are difficult to obtain. Most of the available thermodynamic data are at a temperature of 25°C and standard atmospheric pressure (Ref. 5-24) and need to be adjusted to expected repository conditions. Experiments at elevated temperatures are being conducted (Ref. 5-25). In addition, the models involve important assumptions, such as that of chemical equilibrium, which may be unrealistic if the spatial variation in geochemical properties of the geologic setting is severe. Finally, theoretical models do not yet incoporate kinetic effects in the predictions of element speciation, nor do they relate speciation to predictions of retardation in groundwater transport. Theoretical geochemical models alone cannot provide an adequate substitute for empirical data from experiments approximating anticipated repository conditions, especially for elements such as Pu, Np, U, and Tc, whose mobility characteristics depend strongly on geochemistry (Ref. 5-26). All three approaches: experimental solubility and sorption measurements, field migration studies, and theoretical calculations are necessary to provide and understanding of radionuclide migration.

(iii) Implications

A large body of experimental data on solubilities and Kd's has been obtained for many of the important radionuclides in HLW (Ref. 5-27 and 5-28). However, serious questions have been raised about the relevance of Kd's to observed retardation effects, and about the ability to measure and to predict the in situ conditions which must be known to reduce the uncertainties associated with both solubilities and Kd's to tractable levels (Ref. 5-29). Nonetheless, estimates of solubilities and Kd's and the uncertainties associated with them have been made for the geologic media of interest to the national program (Ref. 5-30) and are used in the calculations appearing in Chapters VII and VIII of this document.

(c) Geologic Environment

(i) Properties

The characteristics customarily used to describe the geologic environment relate to its mechanical and thermal properties, its mineralogy, and its geologic structure. The processes which affect these characteristics include climatic changes, surface erosion/deposition, diagenesis, and tectonic processes such as uplift, subsidence, folding, and faulting.

(ii) Characterization of the geologic environment

Geologic characteristics, i.e., both the present thermal, mechanical, chemical, etc., properties of a given location and the geologic processes anticipated to be operating there now and in the future, are essential not only for understanding factors relevant to transport of wastes by groundwater, but also for confidence in the performance of any engineering over the long term. Not only must conditions in the present be favorable for waste isolation, but also there must be some assurance that the processes expected in the future at the location will have no significant adverse effect. That is, the processes and events which occur at this location either 1) leave the relevant characteristics unchanged, or 2) change them in a way that allows confident predictions of no-adverse consequence to the isolation of the wastes. Measurements can be made of the mechanical and thermal properties, mineralogy, and structure of a particular location, although complexity of a location and spatial inhomogeneity add to the difficulty of interpreting the results of such measurements. Inferences are made from the geologic record as to the likelihood of continued or renewed activity of geologic processes.

(iii) Implications

Uncertainties in our understanding of the present state of a geologic environment result from the potentially complex spatial variations in pressure, structure, and mineralogy. In order to reduce uncertainties, field measurements should employ sample sizes and spacings of sampling locations which match the scale of important inhomogeneities at the location. Some uncertainties are quantifiable, e.g., those associated with the extrapolations and interpolations based on field data which are numerical and, thus, are subject to statistical analyses (Ref. 5-31). The magnitude and significance of these uncertainties are site specific.

The predictions as to which geologic processes are likely to be active into the future and which events are likely to occur are based primarily on interpretations and temporal extrapolations of the geologic record. Significant uncertainties may result from the incompleteness or possible misinterpretation of the geologic record. Predictions based on the geologic record are inherently judgmental, particularly for discrete events at specific locations. Nonetheless, the geologic record can be used to estimate bounds for the future effects of anticipated geologic processes and events. At locations which have exhibited little change since the beginning of the Quaternary, the uncertainties in predicting the effect of geologic processes on repository performance are likely to be unimportant for time periods of about 10^4 years or less, but may become significant for longer times (Ref. 5-32). However, there is always a residual uncertainty as to whether a process or event might occur which is not expected or considered likely on the basis of the geologic record and which will cause the engineering to fail.

Thermal and mechanical perturbations of the natural geologic environment caused by development and operation of a repository and emplacement of wastes also need to be taken into account in determining the suitability of a location for waste disposal (Ref. 5-33). For about the first 10^3 years, when the decay heat generated in the waste is most important (see Fig. 4-6), it is likely that the thermal perturbations will have important effects in the rock in close proximity to the underground facility. In principle, uncertainties associated with predicting the post-closure effects of thermal and mechanical perturbations (e.g., in salt) are quantifiable on the basis of field tests. Testing is difficult, however, both because of the long time period over which the decay heat is significant and because the physical size and layout of a test facility should simulate expected repository conditions.

3. Assessment of performance over long periods of time

In the previous sections we discussed the properties by which engineered and geologic systems could contribute to isolation of radioactive wastes. We also discussed the kinds of measurements and experiments needed to conclude that those systems would perform the various functions that might be attributed to them. Finally, we discussed the uncertainties associated with those measurements and experiments and touched upon the implications of those uncertainties with respect to confidence in the isolation of high-level radioactive wastes.

From the preceding discussions of this chapter it is seen that, of the uncertainties which affect confidence in geologic disposal of HLW, the most easily accommodated is measurement uncertainty. There are, of course, practical limitations to the accuracy and precision of measurements of the relevant properties, especially field measurements of the geologic setting in which a repository might be located. Yet, measurement uncertainty is quantifiable and amenable to statistical analyses. Not only the values of properties deemed relevant can be known, but also some quantitative statement can be made as to how well those values are known.

Mathematical models must figure prominently in any assessment of long-term performance of a HLW repository since there will be no opportunity to observe actual repository performance prior to licensing. The reliability of the predictions of these models is limited by the reliability of the input data to these models and by the reliability of the models themselves. The geologic sciences are far from being precisely predictive and, as a result, the models and most of the geological data upon which they rely are subject to sizeable uncertainties. These uncertainties could make repository licensing problematical for the Commission unless adequate compensating measures are employed. Engineered barriers can, as the preceeding paragraphs indicate, substantially reduce and compensate for these uncertainties. Some engineered barriers, e.g., waste forms, can reduce uncertainties by reducing the source term which the geologic environment must control. Other engineered barriers, such as canisters, can reduce uncertainties by preventing contact between the waste form and the groundwater until the temperature and radiation levels are low enough that the mechanisms controlling radionuclide releases to the geologic setting are understood and the data scatter in measuring and predicting these releases is reduced to tractable levels. Additional engineered barriers, such as backfill materials, can compensate for uncertainties in ways which may be largely qualitative, but which will nevertheless lend confidence to a decision on overall repository performance.

In a complementary manner, the geologic setting will compensate for uncertainties in the performance of the engineered barrier system. A minimum groundwater travel time can provide quantifiable compensation for premature failure of or excessive early releases from the waste package and underground facility. Siting criteria addressing resources can reduce the liklihood of inadvertant intrusion into the engineered barriers system. Overall, this element of redundancy of barriers is expected to play a significant role in any Commission decision to license a HLW repository.

The specific contributions which individual barriers can make to overall repository performance and to reductions in uncertainty, are discussed in more detail in subsequent chapters.

VI. IMPACT OF UNCERTAINTIES ON REGULATIONS FOR GEOLOGIC DISPOSAL OF HLW

1. Regulatory policy

If we examine the implications of uncertainties (discussed in Chapter V) associated with determining whether the engineered and natural barrier systems will function as desired as components of a geologic repository, we see that none is free from the uncertainties discussed above. Further, no matter how good the design or how excellent the site, and no matter how precise and accurate the measurements and observations of the components of the repository, the best that can be known is the state of the repository at the time the Commission must decide whether to allow closure. The state of the repository beyond that decision point is an inference. While it is conceivable that the DOE could develop a design that does not require anything of the geology other than to provide a location, or could choose a site so good that no engineered barriers would be needed, there will be no opportunity to see the engineering or the site work under all the anticipated conditions, or to observe whether the actual conditions are those for which the engineering is designed or the site selected. Further, there is always the uncertainty as to whether processes and events not anticipated in the design or not expected to occur at the site will indeed occur, and fail the repository.

Faced with this same type of uncertainty for other licensing decisions in the past, although not to the same degree, the Commission has applied a policy of multiple protective systems. This is commonly known as the defense-in-depth approach. In the case of geologic disposal of HLW, this policy would be realized as a requirement that the site and the engineering share in the task of isolating the wastes. Moreover, no one who has been involved in the formulation of national policy for the disposal of HLW, including the DOE, the USGS, the EPA, and the Interagency Review Group on the management of radioactive wastes has suggested exclusive reliance on either geology or engineering for isolation of HLW. The reasoning behind the implementation of the Commission's policy and its advantages for licensing geologic disposal of HLW are discussed below.

First, requiring both engineering and geology to contribute to isolation can be used to limit the consequences of an unanticipated process or event, which could cause failure of one barrier to properly perform its isolation function. Since the Commission will need to make a judgement as to whether it has reasonable assurance that the public health and safety suffers no unreasonable risk from permitting disposal of HLW within a repository in the absence of any experience and proof-testing, the knowledge that mechanisms are in place which limit the consequences of partial failure will add to confidence in that judgement, despite the knowledge that unanticipated processes and events could occur. Further, since some of the functions of the engineering and the site operate by different mechanisms (e.g., groundwater flow and canister corrosion), requiring DOE to use both in a repository provides multiplicity in the methods by which safety is provided. Although one can never be sure that all eventualities have been addressed, viewing possible failure modes/mechanisms from more than one perspective adds confidence that nothing major has been ovelooked.

Finally, although isolation of wastes through engineering or geology involves many of the same properties, and indeed in some instances involves similar processes (e.g., both containment of wastes by a waste package and retardation of radionuclides by the geochemistry of the geologic setting could rely on sorption of radionuclides suspended in groundwater), the major contributors to uncertainty for each arise from different considerations. For example, poor correspondence between laboratory and field measurements has resulted in considerable uncertainty associated with retardation factors for the geologic setting. In the case of material incorporated in the waste package to retard radionuclides, however, retardation factors can be measured with relatively little uncertainty. Hence, to the extent, and over the times, that we can rely on waste packages to contain radionuclides, the uncertainties associated with retardation by the geology are less important. On the other hand, as time progresses our confidence in the waste package's continued performance diminishes. The long history of geologic conditions provided by the geologic record permits more confident evaluation of the ability of the location to maintain some level of retardation of radionuclides into the future. Hence confidence in the geologic record compensates for the uncertainty in the survivability of engineering, while confidence in containment for an initial period compensates for uncertainty in geochemical retardation.

2. Numerical requirements

Numerical specification of the contribution to isolation to be made by the site and by the engineering should be consistent with both the standard to be met (the generally applicable standard for radiation in the environment from the disposal of HLW), and whatever the Commission regards as an appropriate level of risk from unanticipated processes and events.

Although no HLW standard exists at present, the Commission can proceed to specify numerical performance objectives by assuming a standard based upon a reasonable expectation of what an HLW standard might be. Several comments on the proposed rule referred to Draft 19 of the EPA standard, which has been under development for some time. We have therefore chosen this draft as the basis for an assumed standard*, and in Chapter VII we consider numerical requirements for containment, controlled release, and groundwater flow time which, if met, will contribute to meeting it.

3. Additional considerations

Use of an assumed HLW standard provides a basis for specifying numerically, at this time, performance of individual barriers (e.g., containment) under anticipated processes and events. However, when a HLW standard is promulgated, the Commission should have the discretion to review and change as needed the numerical values specified for those barriers in light of that standard. Among the factors the Commission might take into account in exercising this discretion are the age and

* On December 29, 1982 the EPA published a Proposed HLW Standard which is somewhat different from Draft 19. An analysis of the impact of the differences between the two versions appears in Appendix A to this Rationale.

nature of the wastes, characteristics of the geologic setting, and particular sources of uncertainty in predicting the performance of the engineered barrier system or the geologic setting. Finally, in specifying performance numerically at this time, we have not foreclosed the possibility that considerations related to unanticipated processes and events could form a basis for changing the specification, for requiring additional specifications, or both.

VII IMPACT OF NUMERICAL REQUIREMENTS ON ROUTINE RELEASES

As stated in Chapter VI, Draft 19 of the EPA standard, referenced by a number of comments on the proposed rule, has been employed to show the relationship between overall system performance and the numerical requirements on the engineered barrier system and the geologic setting. We expect EPA to publish soon a proposed standard for public comment similar to this draft. This chapter contains an assessment of the contributions to overall performance under anticipated processes and events. An assessment of the mitigation of unanticipated processes and events appears in Chapter VIII. The working draft of the assumed standard fixes a number of parameters against which the overall performance of a repository will be evaluated, including a location at which performance is to be measured (the boundary of the accessible environment), a measure of performance (cumulative releases of specific radionuclides measured in curies), and an interval during which performance is to be measured (10,000 years). In the draft Supplementary Information accompanying the working draft, the EPA also notes its judgment that regulation of releases for a 10,000 year interval will protect public health and safety beyond 10,000 years. Specific limits for releases for reasonably foreseeable (anticipated) processes and events appear in Table 2, and were applied here in accordance with the footnote to that table.

Table 2

Limits of Cumulative Releases to the Accessible Environment for 10,000 Years After Disposal According to the Assumed Standard

Radionuclide	Release Limit Curies Per 1000 MT
Americium-241	10
Americium-243	4
Carbon-14	200
Cesium-135	2000
Cesium-137	500
Neptunium-237	20
Plutonium-238	400
Plutonium-239	100
Plutonium-240	100
Plutonium-242	100
Radium-226	3
Strontium-90	80
Technetium-99	2000
Tin-126	80
Any other alpha-emitting radionuclide	10
Any other radionuclide which does not emit alpha particles	500

NOTE: In cases where a mixture of radionuclides is projected to be released, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 2. The sum of such ratios for all the radionuclides in the mixture may not exceed one.

For example, if radionuclides A, B, and C are projected to be released in amounts Q_a, Q_b, and Q_c, and if the applicable Release Limits are RL_a, RL_b, RL_c, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} \leq 1$$

For purposes of our assessment, consistent with the assumed standard, the accessible environment is assumed to be all areas on the land surface regardless of distance from the repository and to include all subsurface locations beyond a vertical surface one mile away from the location of the emplaced wastes. These boundaries appear in Figure 13. (A more recent working draft of the standard allows a distance of up to 10 km rather than 1 mile. This change does not significantly affect the results of the present study, however, since only the groundwater travel time explicitly appears). For an actual repository the distance from the wastes to the vertical boundary of the accessible environment is expected to be site specific but not to exceed 10 km.

Routine Release Scenario: The Undisturbed Repository

The NRC staff identified a scenario for the purpose of showing the effect of numerical requirements for the engineered barrier system and the geologic setting on the performance of a geologic repository which is operating normally. A diagram of this scenario appears in Figure 13.

It is anticipated that if radionuclides are released from an undisturbed repository to the accessible environment, this release will take place by failure of the container surrounding the wastes, dissolution of the wastes by groundwater, and migration of the radioactive material dissolved from the wastes with the groundwater to the accessible environment. For this reason, location of the underground facility in the saturated zone is considered a realistic bounding case for routine release. In this scenario, groundwater is presumed to resaturate the repository within a few centuries after closure and to initiate deterioration of the waste packages, causing eventual breaching of the waste packages and start of radionuclide release to the underground facility. In time, the radionuclides are released to the geologic

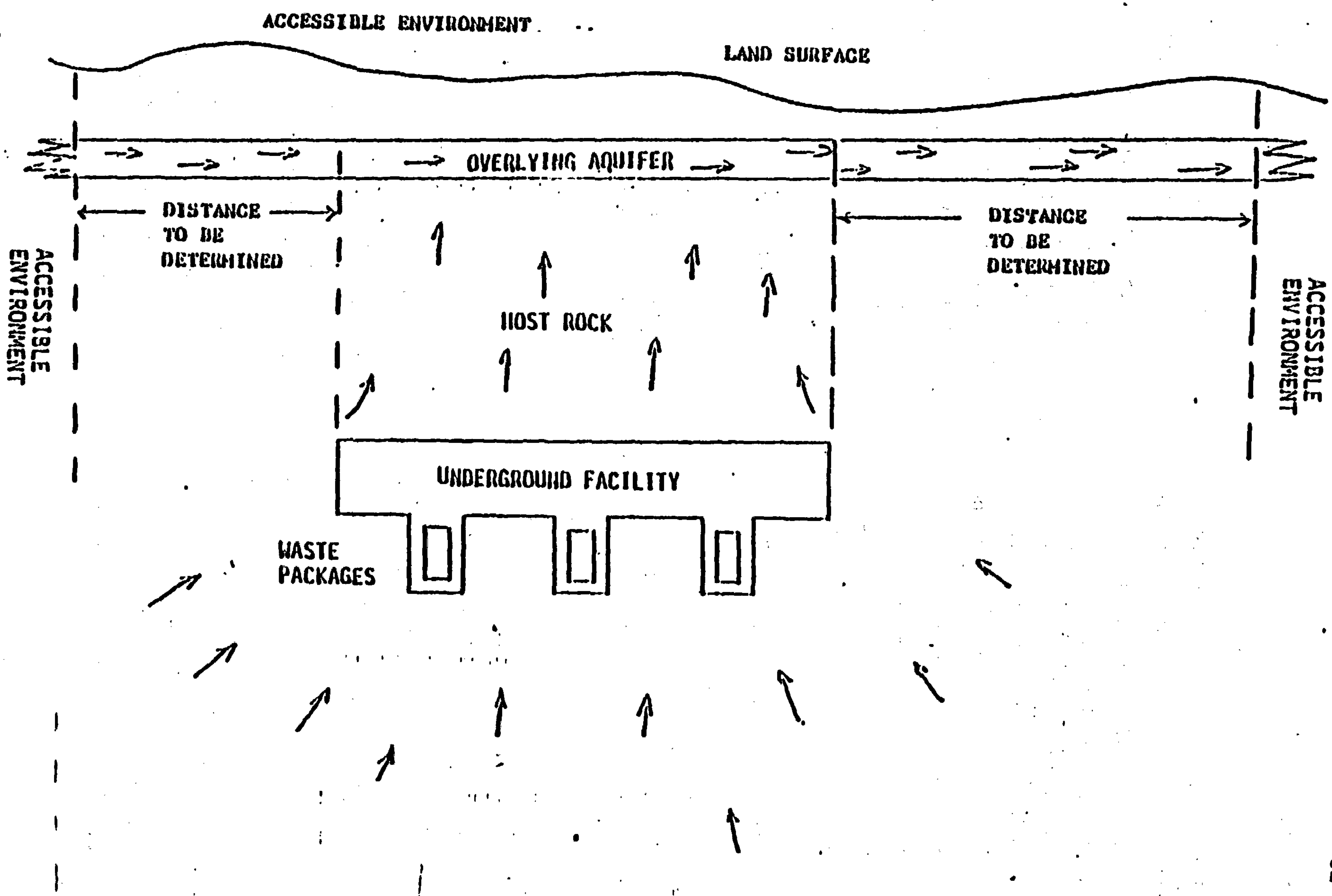


FIGURE 13 - DIAGRAM OF ENGINEERED BARRIER SYSTEM AND GEOLOGIC SETTING FOR THE ROUTINE RELEASE SCENARIO FOR ALL MEDIA.

setting. The assumption of prompt resaturation is conservative but reasonable because void spaces in the backfilled repository will result in a hydraulic gradient that will tend to promote flow inward, and because some natural leakage is anticipated. An upward hydraulic gradient in the geologic setting is assumed, causing groundwater carrying the radionuclides to move vertically through the host rock from the repository to an overlying aquifer. The radionuclides then follow the groundwater flowpath horizontally along the aquifer away from the repository and eventually reach the accessible environment. Transport of some radionuclides through both the host rock and the aquifer is assumed to be impeded by chemical retardation and by limitations on radionuclide solubility. Alternative release paths might be selected, such as a downward gradient which could move radionuclides to an underlying aquifer. However, thermal effects will tend to enhance transport to an overlying aquifer, so this upward case is considered realistic. This scenario will be considered for the three media currently of greatest interest for HLW disposal: basalt, tuff, and salt. Evaluation of this scenario involves prediction of the behavior of an undisturbed repository taking into account uncertainties associated with significant parameters.

Numerical Assessment: The Model Chosen

To quantify the effects of numerical requirements for the engineered barrier system and the geologic setting in the routine release scenario, it is necessary to specify a quantitative model which corresponds to the qualitative description above. That model may then be used to determine how each of the barriers affects the performance of the overall geologic repository. The model selected for describing this scenario is a quasi-two dimensional model in which the radionuclides travel vertically upward, both through the repository and from it to the aquifer, after which they travel horizontally along the aquifer. This model approximates the groundwater flow shown in Figure 13 by a series of legs, shown in Figure 14. Legs A and B correspond to the upper aquifer, leg C corresponds to flow through the underground facility itself, and leg D corresponds to flow from the underground facility through the host rock to the upper aquifer.

A number of simplifying assumptions have been made in order to implement this model. These assumptions are consistent with generally accepted practice in transport modeling and are not intended to introduce either conservatism or non-conservatism into the analysis. First, one-dimensional Darcy flow is assumed, implying low Reynolds number flow in porous media, and implying that all significant flow is unidirectional. Low Reynolds number flow is reasonable in view of the small conductivities and hydraulic gradients involved in geologic disposal systems. Porous flow is reasonable for sandstone aquifers assumed to overlie bedded salt, but for basalt and tuff flow through fractures is likely. Therefore, the hydraulic conductivity has been adjusted for basalt and tuff to roughly approximate fracture flow. Presumption of unidirectional flow in the legs has been shown to lead to good agreement with complex multi-dimensional models such as SWIFT (Ref. 7-1) for applications similar to this one (Ref. 7-2 and 7-3).

The model also presumes that rock properties are invariant for the length of an individual leg, so that properties such as permeability and chemical retardation are constants. A radionuclide passing through an actual unit is likely to encounter a spatially varying environment that may affect its velocity. The constant properties of the leg specified in the model therefore are spatial averages of estimates of the aquifer properties, so that a radionuclide is modeled to traverse the leg in the same length of time it would take to traverse the aquifer unit the leg

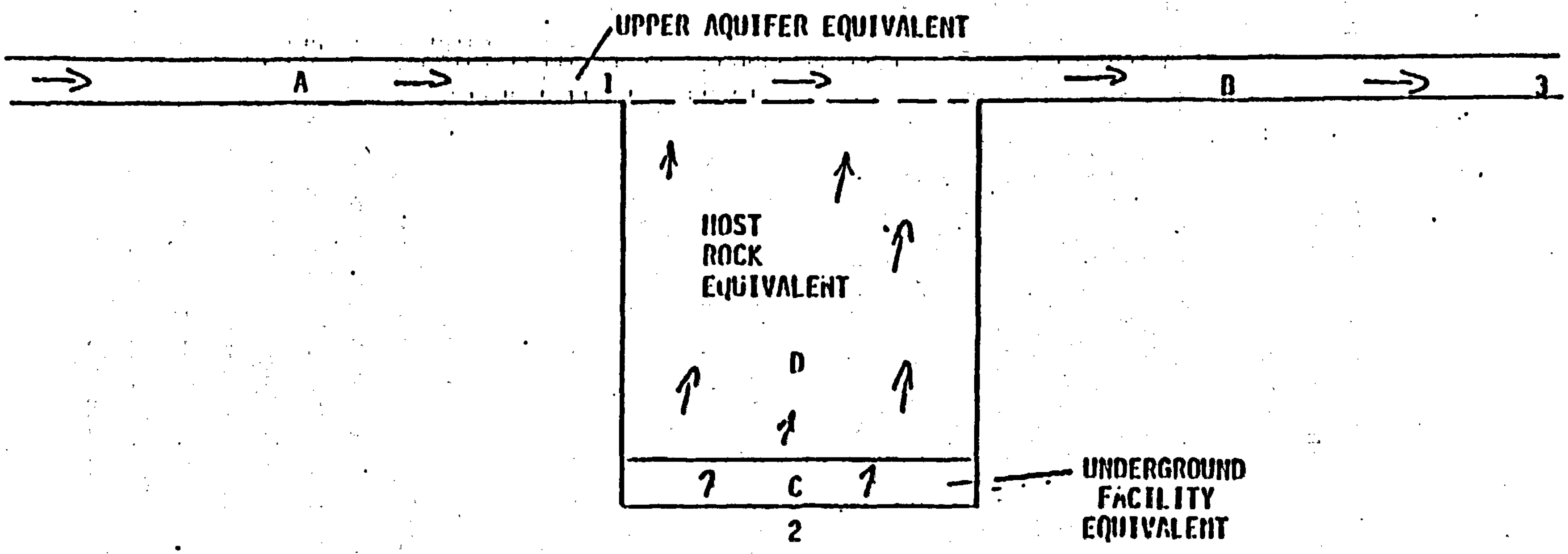


FIGURE 14 - UNIDIRECTIONAL FLOW MODEL CORRESPONDING TO FIGURE 1, ROUTINE RELEASE SCENARIO

represents. Further, the ranges of the properties considered below are considered to encompass the changes in these properties that are anticipated to occur along actual aquifer units.

Another simplification made by this model is that it does not account for all of the effects of the heat released by the waste. The model does account for thermal buoyancy effects on flow in leg D, by adjusting the pressure at point 2, the point where flow enters the underground facility. The model does not account, however, for possible permeability changes in the overlying host rock which might result from thermomechanical effects. Finally, as applied here, the model does not deal with the specific processes which cause canister failure or which affect radionuclide release rates from the engineered barrier system. It therefore does not deal with the uncertainties associated with early failure of containment such as hydrothermal dissolution of waste forms or failure of the backfill to retard radionuclides due to elevated temperatures or radiation fluxes.

Clearly, the model described above is highly idealized, and the behavior and models of an actual site will probably be much more complex. However, it is the staff's view that the model is more than sufficient to accomplish its purpose in this document. That is, the model provides significant, realistic insight into the relationship between numerical criteria and repository performance.

To implement this model, the NWFT/DVM code was used (Ref. 7-4 and 7-5), which requires an extensive set of parameters as input data. These parameters, whose selection reflects the assumptions mentioned above, have been divided into two groups; the first is subject to relatively little uncertainty, the second reflects many of the sources of uncertainty discussed in Chapter V. The first, to be called fixed parameters, are those quantities which define the system and which are specified as point values. In an actual case these parameters would be fixed by the geometry of the site and the properties of the fluid and waste which are relatively well known. These include the distances along the legs shown in Figure 14, the cross-sectional area of the legs, fluid properties such as density and viscosity, and waste properties such as initial inventory and half-lives. The second group, to be called variables, consists of parameters whose values are subject to uncertainties which may span several orders of magnitude. These parameters are not taken as point values in the calculation, but are approximated by distributions. These variables include solubility and retardation factors for individual radionuclides, and factors affecting groundwater travel time, such as permeability and hydraulic gradients. In addition, this group includes parameters for which numerical criteria were established in the Proposed Technical Rule, such as containment time by the waste packages and radionuclide release rates from the underground facility, so that repository performance can be assessed as these parameters vary over the given ranges.

Table 3 identifies the fixed parameters used by the model and the values used in the analyses. Table 4 identifies the variables whose values are approximated by distributions in the calculations, and gives the ranges of those values used in these analyses.

Input Data for Routine Release Scenario

The point values for the fixed parameters shown in Table 3 reflect the media and underground facility designs currently being given the most emphasis by DOE. The dimensions of the underground facility which lead to the areas of leg C and D and the length of leg C are taken from EPA's granite reference repository (Ref. 7-6). The areas of legs A and B are consistent with overlying aquifers for repositories located in basalt, tuff, and salt (Ref. 7-7) and the length of leg B corresponds to the one mile distance to the accessible

TABLE 3. FIXED PARAMETERS FOR ROUTINE RELEASES IN BASALT, TUFF, AND SALT

Description	Value	Units
Area of leg A	1×10^6	ft^2
" " " B	1×10^6	"
" " " C	8×10^6	"
" " " D	8×10^5	"
Length of leg A	Not needed	ft
" " " B	5280	"
" " " C	16	"
" " " D (Basalt)	1530	"
" " " " (Tuff)	1825	"
" " " " (Salt)	1850	"
Conductivity of leg C	infinite	
Porosity of leg C	Not needed	
Pressure at point 1	0	psi
Initial radionuclide inventory	*	Curies
Radionuclide half lives	*	years
Water Density	62.3	$\#/ft^3$
Water Viscosity	1.02	Centipoise

*From Ref. 7-7.

TABLE 4. Variables and their ranges. (For normal and lognormal distributions, ranges are for .001 and .999 quantiles.)

Variable	Distribution	Range in basalt	Range in welded tuff non-zeolitized	Range in bedded salt	units
Kd for Am in host rock	Lognormal	(2.5E1, 2.0E6)	(8.5E1, 9.5E3)	(5.0E1, 1.0E4)	ml/g
Kd for Pu in host rock	Lognormal	(4.5E1, 5.2E3)	(7.0E1, 2.0E3)	(3.0E1, 1.0E4)	ml/g
Kd for U in host rock	Lognormal	(4.0E0, 1.3E3)	(1.0E-2, 1.5E1)	(1.0E-2, 2.7E2)	ml/g
Kd for Np in host rock	Lognormal	(1.5E0, 2.8E4)	(4.5E0, 3.1E1)	(2.0E0, 4.0E2)	ml/g
Kd for fission products in host rock	Lognormal	(1.7E1, 5.8E3)	(5.0E1, 2.1E3)	(1.0E-2, 3.0E3)	ml/g
Kd for Am in aquifer	Lognormal	(1.0E-2, 1.0E5)	(8.5E1, 3.6E2)	(5.0E1, 1.0E4)	ml/g
Kd for Pu in aquifer	Lognormal	(1.0E-2, 1.0E4)	(7.0E1, 4.5E2)	(3.0E1, 1.0E4)	ml/g
Kd for U in aquifer	Lognormal	(1.0E-2, 1.0E4)	(1.0E-2, 1.1E1)	(1.0E-2, 2.7E2)	ml/g
Kd for Np in aquifer	Lognormal	(1.0E-2, 5.0E1)	(5.0E0, 7.0E0)	(2.0E0, 4.0E2)	ml/g
Kd for fission products in aquifer	Lognormal	(1.0E-2, 5.0E2)	(1.2E2, 8.6E3)	(1.0E-2, 3.0E3)	ml/g
Solubility limit for Am		leach-limited	leach-limited	leach-limited	g/g
Solubility limit for Pu	Lognormal	(2.5E-12, 2.5E-8)	leach-limited	(6.0E-17, 4.0E-4)	g/g
Solubility limit for U	Lognormal	(2.0E-6, 2.0E-4)	leach-limited	(1.6E-8, 3.0E-2)	g/g
Solubility limit for Np	Lognormal	(2.5E-19, 2.5E-13)	leach-limited	(1.3E-25, 5.0E-7)	g/g
Solubility limit for Tc	Lognormal	(1.0E-9, 1.0E-7)	leach-limited	(1.5E-9, 9.5E-5)	g/g
Solubility limit for fission products		leach-limited	leach-limited	(6.3E-17, 1.6E-4)	g/g
Dispersivity	Uniform	(5.0E1, 5.0E2)	(5.0E1, 5.0E2)	(5.0E1, 5.0E3)	ft
Radionuclide release time	Loguniform	(1.0E3, 1.0E7)	(1.0E3, 1.0E7)	(1.0E3, 1.0E7)	yr
Conductivity in aquifer (legs A & B)	Lognormal	(1.0E0, 1.0E4)	(1.0E-5, 2.0E0)	(1.5E-1, 6.8E2)	ft/da
Porosity in aquifer (legs A & B)	Normal	(1.0E-1, 3.0E-1)	(2.0E-1, 4.8E-1)	(1.0E-1, 2.0E-1)	--
Conductivity in host rock (legs C & D)		Loguniform (1.0E-7, 1.0E0)	Lognormal (3.1E-5, 9.1E0)	Lognormal (2.3E-10, 3.3E-2)	ft/da
Porosity in host rock (legs C & D)	Lognormal	(1.1E-3, 1.0E-1)	(1.8E-5, 1.2E-2)	(8.8E-4, 7.2E-2)	--
Gradient in host rock	Uniform	(5.0E-3, 3.0E-2)	(1.0E-2, 4.0E-2)	(5.0E-3, 3.0E-2)	ft/ft
Gradient in aquifer		Uniform (1.0E-4, 1.0E-2)	Loguniform (1.0E-3, 1.0E-1)	Uniform (2.0E-3, 1.0E-2)	ft/ft
Canister life	Loguniform	(1.0E2, 1.0E4)	(1.0E2, 1.0E4)	(1.0E2, 1.0E4)	yr

environment. The initial radionuclide inventory is taken from DOE's projections for spent fuel (Ref. 7-8).

The variables which appear in Table 4 reflect many of the uncertainties discussed at length in Chapter V. Uncertainties in geohydrology include predictions of conductivities, porosities, hydraulic gradients and dispersivities. These sources of uncertainty are accounted for in the model by expressing these variables as distributions of values which span the range of available data. Similarly, distributions of solubilities and distribution coefficients (Kd's) are used in recognition of the uncertainties involved in predicting these properties. Three radionuclides, ^{129}I, ^{14}C, and ^{99}Tc, do not appear to be retarded chemically, and are therefore presumed to move at the same speed as the groundwater. This information was developed by Sandia National Laboratory under contract to NRC through a review of the available data for pertinent sites and rock formations (Ref. 7-7). These data are consistent with conditions to be found in the media being investigated by DOE and are considered appropriate for this modelling exercise. However, it is recognized that a thorough analysis of a specific site might well make use of additional or different data which would be more pertinent to that particular site. The ranges and distributions for waste package life and radionuclide release rate were selected to uniformly bound the numerical values in the proposed rule.

Output From Routine Release Scenario

The effects of the variables whose uncertainties are modeled by the distributions in Table 4 on repository performance were investigated by repeatedly running NWFT/DVM using a standard statistical sampling technique (Ref. 7-9, 7-10). In this statistical technique, a "case" composed of 26 values, one for each of the variables in Table 4, was selected from within the ranges shown in the table. By selecting the values at random and by running enough cases to investigate the entire data range, the effects of each of the variables on repository performance can be determined.

The effect of radionuclide release rate from the underground facility to the host rock on the fraction of cases tested which meet the assumed standard can be seen in Figure 15 for routine releases from basalt. In this figure, release rates are varied along the horizontal axis and groundwater travel times are varied along the vertical axis. It should be noted that the release rates shown are limits which apply to all radionuclides for a particular case; if the solubility for a particular nuclide for that case was sufficiently low, that radionuclide might be released more slowly than the release limit associated with that case. The lines plotted on the figure are for constant fractions of cases tested which fail to meet the assumed standard. For example, for a groundwater travel time of 1000 years and a release rate from the underground facility of about 1 part in 40,000 per year, the fraction of cases failing to meet the assumed standard is 0.10 or 10%. Similarly, at a groundwater travel time of 100 years, the release rate from the underground facility at which the fraction of cases failing to meet the standard is 0.10 is about 1 part in 300,000 per year.

Engineered Barrier System Release Rate Requirement

Impact of Release Rate on Performance

Figures 16 and 17 are like Figure 15, but for bedded salt and non-zeolitized tuff, rather than basalt. In interpreting all three figures it is very important to note that the range of groundwater travel times in each figure has been selected to illustrate the impact of the numerical value

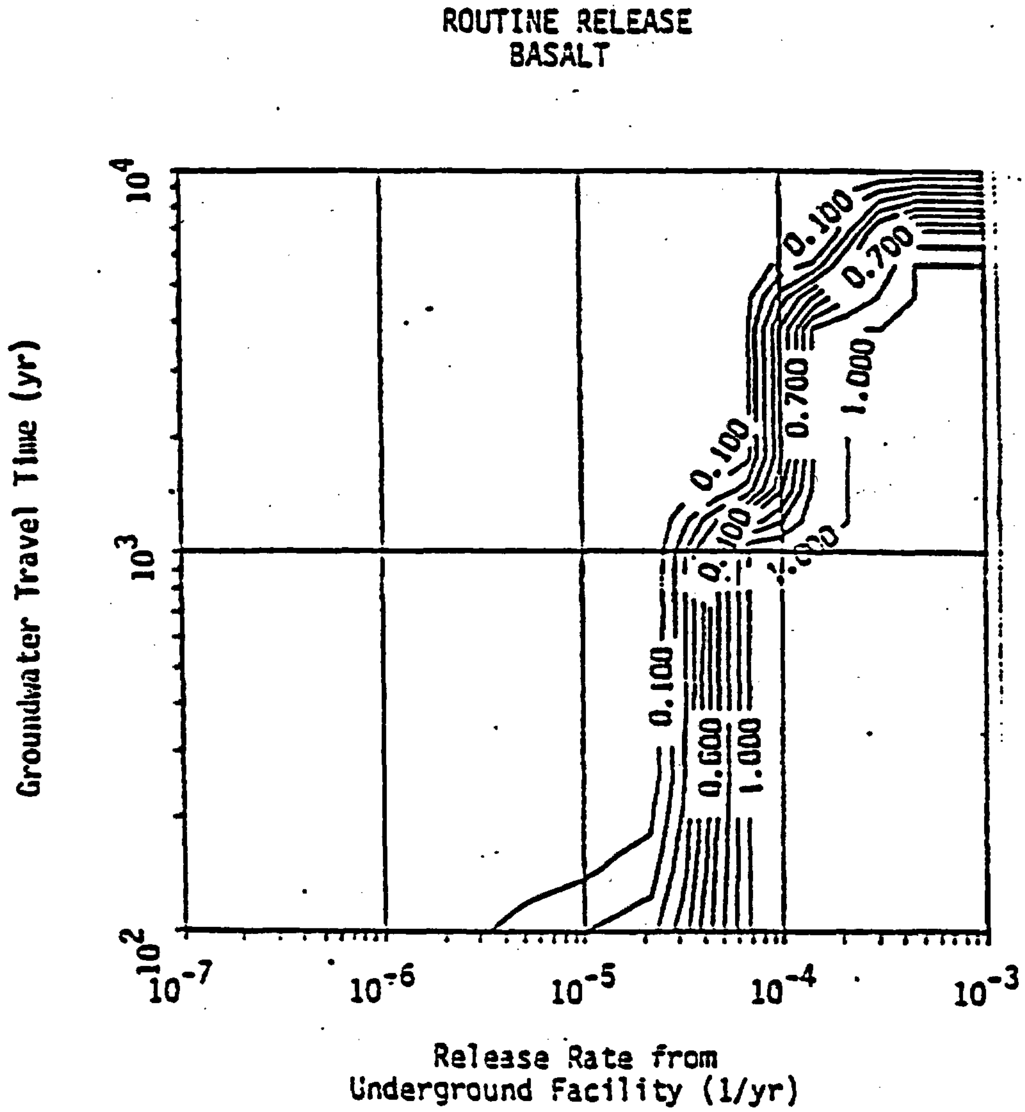


Figure 15. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is basalt.

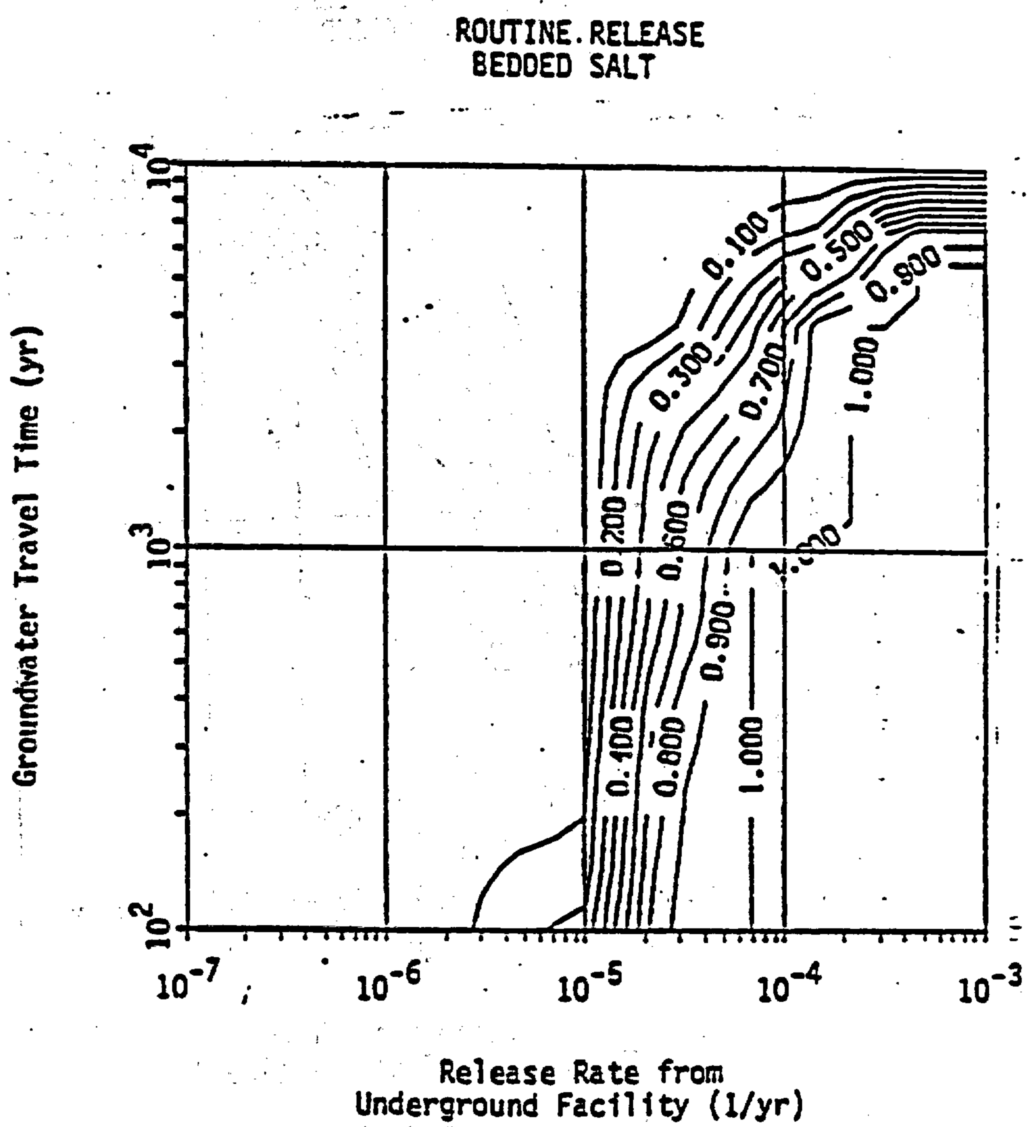


Figure 16. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is bedded salt.

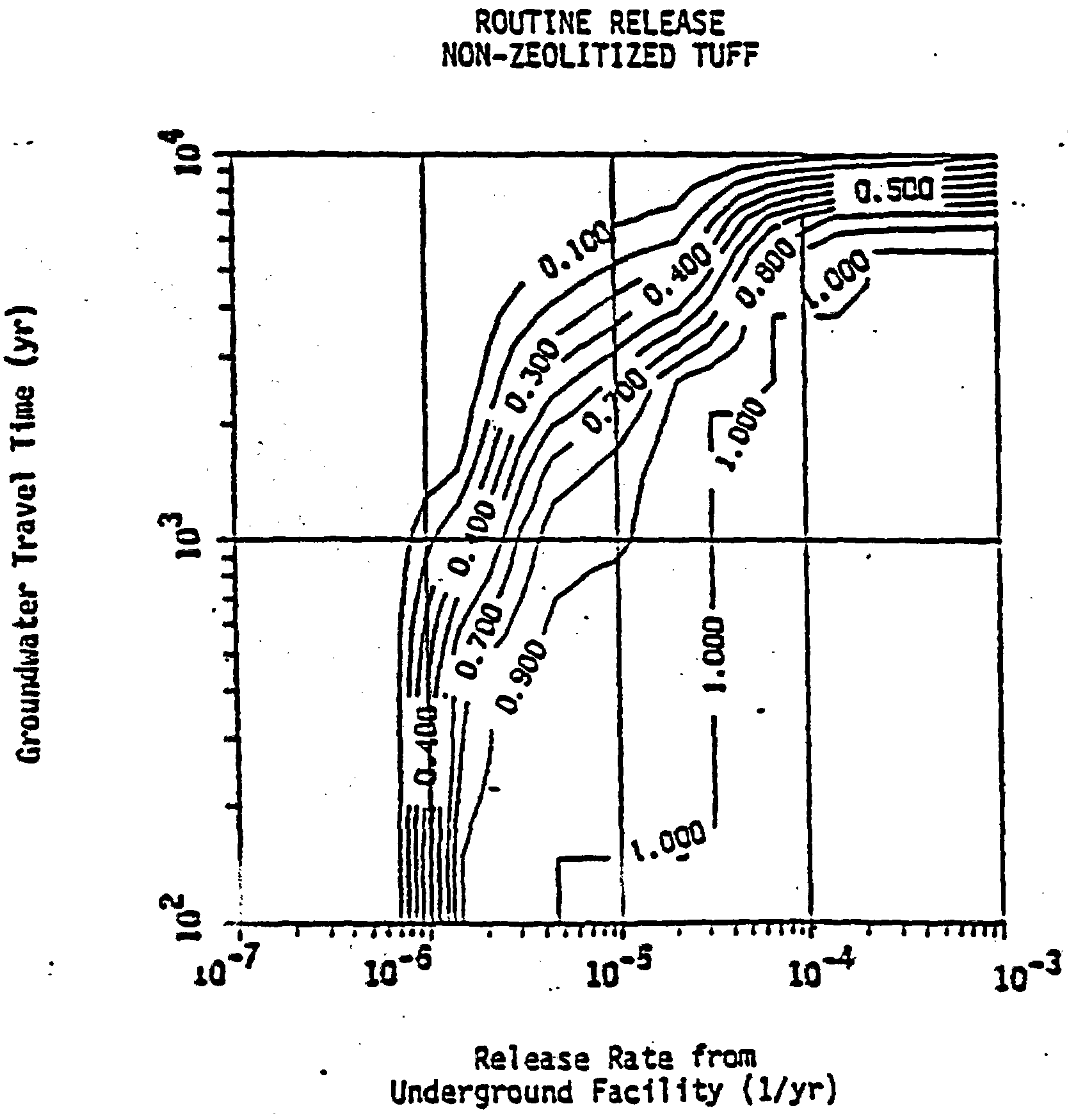


Figure 17. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is non-zeolitized tuff.

of 1,000 years proposed in 10 CFR 60. The staff does not intend to imply that this range is necessarily likely for an actual site. In particular, the staff recognizes that the generally low permeability of salt may result in longer groundwater travel times. Nevertheless, a routine release scenario in salt is considered because of the uncertainties discussed previously.

In Figures 15 and 16, it is seen that as the release rate from the repository decreases, the probability of failing to meet the assumed standard decreases significantly for both basalt and bedded salt. It may also be seen that there is a region in each figure in which the lines of constant fractions of cases lie relatively close to each other. In these regions, relatively small changes in release rate from the underground facility or in groundwater travel time are observed to make relatively large changes in the fraction of cases whose releases fail to comply with the assumed standard. Outside these regions, changes in release rate from the underground facility and in the groundwater travel time have less impact, since they do not cause the lines of constant failure rate to be crossed. (Although no fractions less than 0.10 are shown in the figure, it is apparent that the largest gradients are near the lines shown.)

For basalt (Figure 15), decreasing release rates from the underground facility from about 1 part in 5,000 per year to about 1 part in 50,000 per year reduces the fraction of cases failing to meet the assumed standard from about 1.00 to 0.10, while for bedded salt (Figure 16) reducing release rates from the underground facility to about 1 part in 100,000 per year is needed to achieve a fraction of failures below 0.10. For these media, it is therefore quite advantageous to have a release rate from the underground facility as low as about 1 part in 100,000 per year, but there is little further improvement to be gained from a substantially slower release rate, since this release rate results in compliance with the assumed standard for most travel times.

On the other hand, inspection of Figure 17 reveals that for a repository in the saturated zone in non-zeolitized tuff, the greatest improvement is gained by having releases less than about 1 part in 1,000,000 per year. This result is due to inferior geochemical retardation of uranium in non-zeolitized tuff compared to basalt or bedded salt, consistent with the relatively lower range of Kd's for uranium in non-zeolitized tuff which appears in Table 4. However, it is recognized that many tuffs are zeolitized, with geochemical retardation properties substantially better than non-zeolitized tuffs. Table 4-A consists of a comparison of the retardation properties of zeolitized and non-zeolitized tuff aquifers (Ref. 7-7). Figure 18 results from an analysis identical to that of

Table 4-A. Kd Ranges in Zeolitized and Non-Zeolitized Tuff Aquifers (All distributions are lognormal)

Variable	Range Zeolitized Tuff	Range Non-Zeolitized Tuff
Kd for Am	(6.0E2, 9.5E3)	(8.5E1, 3.6E2)
Kd for Pu	(2.5E2, 2.0E3)	(7.0E1, 4.5E2)
Kd for U	(5.0E0, 1.5E1)	(1.0E-2, 1.1E1)
Kd for Np	(4.5E0, 3.1E1)	(5.0E0, 7.0E0)
Kd for fission products	(2.9E2, 2.2E5)	(1.2E2, 8.6E3)

Figure 17, except that the aquifer is presumed to be zeolitized, and for that case, the behavior of a tuff repository is very much like those in basalt and bedded salt. In Figure 17, reducing release rates from the underground facility to about 1 part in 100,000 per year will achieve a fraction of failures below 0.10. Figure 17 also demonstrates that the impact of the rate of release of radionuclides from the engineered barrier system is media specific. The staff does not intend to imply that at an actual tuff site radionuclide transport must be through either zeolitized or non-zeolitized tuff, but recognizes that both types of tuff are likely to be traversed.

Alternatively, the influence of the engineered barrier release rate can be evaluated by directly comparing releases from the engineered barriers with the release limits of Table 2. Table 5 presents such a comparison for a release rate of 10^{-5} per year following an initial 1000 year containment period. The quantities released do not greatly exceed the limits for any of the nuclides except Am and Pu. This table demonstrates that a low release rate from the engineered barriers is able to contribute substantially to overall repository performance, and may provide a very desirable degree of redundancy for nuclides such as ^{99}Tc which are unlikely to be controlled very effectively by the geologic barriers.

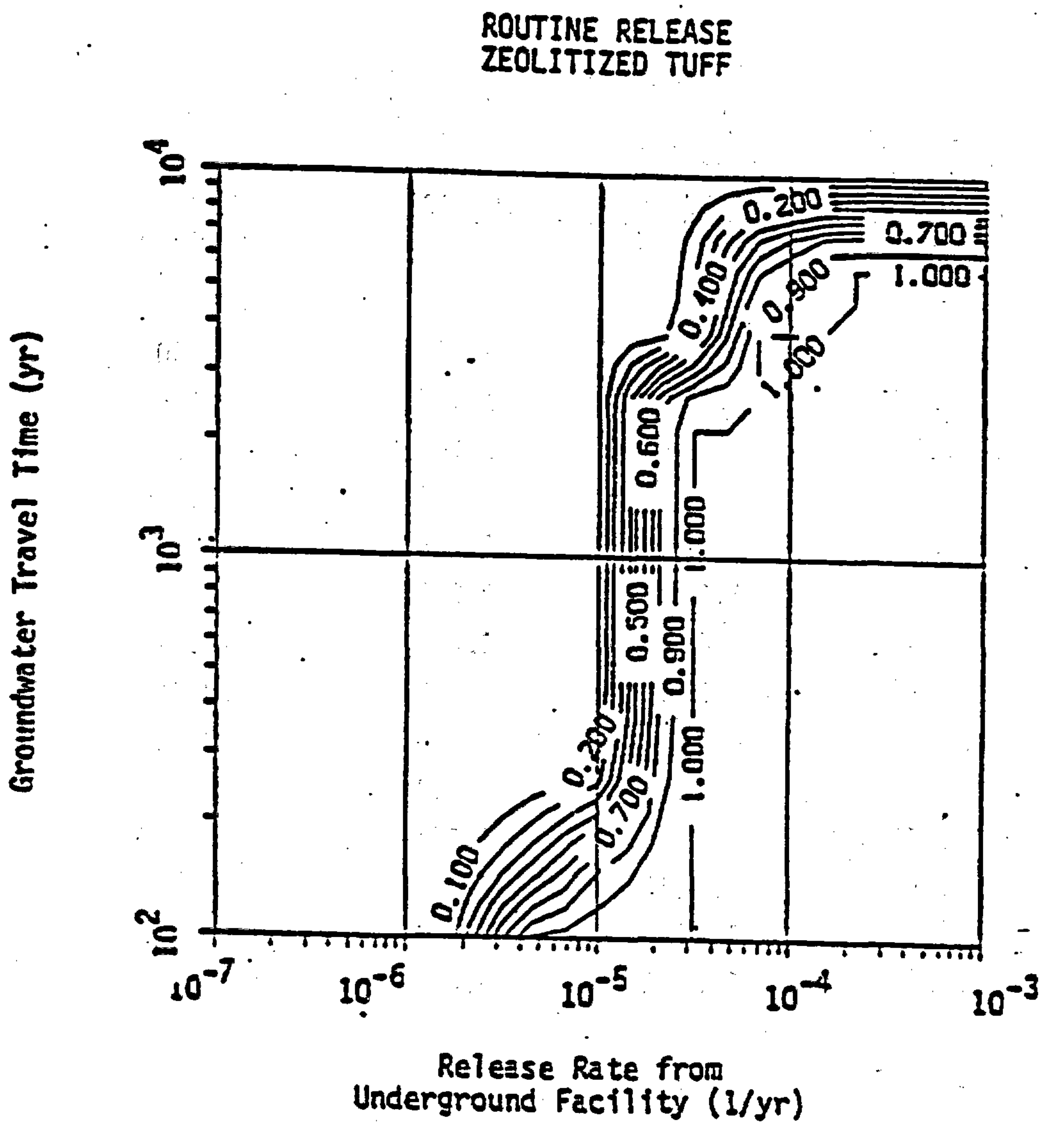


Figure 18. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is zeolitized tuff.

Table 5. Effectiveness of 10^{-5} per year release rate in complying with the EPA standard.

NUCLIDE	REPOSITORY INVENTORY @ 1000 yr (Ci/100,000 MTHM)	RELEASE RATE IF EQUAL TO INVENTORY TIMES 10^{-5}* (Ci/yr)	TOTAL RELEASES (YEARS 1000 to 10,000) (Ci)	EPA LIMIT (Ci/100,000 MTHM)	RATIO OF TOTAL RELEASE TO EPA LIMIT
Am-241	9.24E7	9.2E2	3.0E6	1000	3,000
Am-243	1.57E6	1.6E1	1.4E5	400	350
C-14	1.35E3	1.4E-2	1.2E2	20,000	0.00[illegible]
Cs-135	2.23E4	2.2E-1	2.0E3	200,000	0.01
Cs-137	1.00	1.0E-5	3.4E-3	50,000	0
Np-237	1.0E5	1.0E0	9.0E3	2,000	4.5
Pu-238	9.8E4	9.8E-1	8.2E2	40,000	0.02
Pu-239	3.2E7	3.2E2	2.9E6	10,000	290
Pu-240	4.4E7	4.4E2	4.0E6	10,000	400
Pu-242	1.7E5	1.7E0	1.5E4	10,000	1.5
Ra-226	2.84E2**	2.84E-3	2.6E1	300	0.09
Sr-90	1.5E-1	1.5E-6	4.8E-4	8,000	0
Tc-99	1.4E6	1.4E1	1.3E5	200,000***	0.65
Sn-126	5.6E4	5.6E-1	5.0E3	8,000	0.62
Total	1.7×10^8	1.7E3			

*Equal to 10^{-5} x values in column 1. Note that release rates at or below 1.7 Ci/yr (0.1% of total rate) meet the rule.

**Release calculations based on inventory at 1000 years. In the absence of leaching, the quantity of Ra-226 would increase to 1.22E4 Ci per 100,000 MTHM at 10,000 years.

***The proposed EPA standard published in the Federal Register revised the Tc-99 release limit to 1,000,000 Ci/100,000 MTHM. The corresponding ratio of total release to the EPA limit would be 0.13. This change has no impact on the overall conclusions regarding the effectiveness of a 10^{-5} per year release rate in complying with the EPA standard. See Appendix A for further discussion.

Achievability

As stated in the proposed rule, "Proof of the future performance of engineered systems and geologic media over time periods of a thousand or many thousands of years is not to be had in the ordinary sense of the word." Demonstration of compliance with any of the performance objectives will be accomplished through extrapolations and data using physical models based on accelerated tests and natural analogs which are subject to uncertainties. These uncertainties can only be expressed as a statement of reliability or probability that the criterion will be achieved. To require absolute assurance of exact numerical compliance is neither reasonable nor intended. Rather the quantity and quality of the data and the methods will be carefully reviewed as part of the licensing process.

While DOE has not proposed a particular design to control releases from the engineered barrier system, considerable research and development has been devoted to the subject. The NRC staff has been following DOE's technology development program closely, and has been assessing the uncertainties associated with achieving a release rate of 1 part in 100,000 per year.

Brookhaven National Laboratory (Ref. 7-11) has concluded that the criterion is readily achievable, and in some cases exceeded, using borosilicate glass encased in non-radioactive glass.

Savannah River Laboratories consider that this requirement can be met by either of their waste forms currently receiving most attention, borosilicate glass or SYNROC (Ref. 7-12). The Department of the Interior in its comments on the proposed rule supported the achievability of this criterion by means of a succession of barriers at low temperature conditions (Ref. 7-13).

Nowak considers that a one-foot-thick backfill barrier around the waste can delay breakthrough of most fission products for 1000 to 10,000 years, and the breakthrough of transuranics for substantially longer (Ref. 7-14). Smith, Salter and Jacobs suggest that, for the case of Hanford basalts, low solubility alone may limit releases from the underground facility to very low levels (Ref. 7-15). Therefore, having reconsidered the matter, the staff continues to conclude that the requirement to limit the release rate from the engineered system to 1 part in 100,000 per year at 1000 years is reasonably achievable, particularly in view of the Commission's statement that absolute proof of compliance is not required.

The staff also notes that in proceeding from the proposed rule to the final rule the performance objectives have been stated with significantly more flexibility. The staff recognizes that a limit on the rate at which wastes can be released will depend on such factors as the nature of the waste, the properties of the geologic setting, and the uncertainties associated with all aspects of geologic disposal. Proper consideration of such factors must be a part of any requirement on release rates from the engineered barrier system.

Geologic Setting Groundwater Travel Time Requirement

Impact of Travel Time Requirement on Performance

Figures 15 and 16 also show the effect of groundwater travel time on the fraction of cases whose results fail to comply with the assumed standard for basalt and bedded salt. In each figure, groundwater travel times of several hundred years are required to reduce the fraction of cases which fail to 0.10 or less, without simultaneously requiring excessively low release rates from the underground facility. It is also seen that groundwater travel times approaching 10,000 years are needed to reach the region where rapid release rates from the engineered barrier system such as 1 part in 5,000 per year and faster can be tolerated. (This is intuitively reasonable since the model assesses repository performance over a 10,000 year interval and a 10,000 year groundwater travel time would prevent radionuclides from reaching the accessible environment during that time.)

It has already been demonstrated that a release rate from the underground facility of 1 part in 100,000 per year is appropriate, and a nominal groundwater travel time requirement should be consistent with it. Such a value could lie between several hundred and several thousand years for basalt and bedded salt, and a value of 1,000 years, in conjunction with reasonably achievable leach rates, can significantly increase confidence that the assumed EPA standard will be met.

Figure 17 shows that a groundwater travel time of more than 6,000 years is needed to achieve reasonably low repository failure rates in tuff if the release rate from the underground facility is 1 part in 100,000 per year and if the aquifer is non-zeolitized. As shown in Figure 18 and as noted in the discussion of the release rate criterion, this result is improved if the aquifer is assumed to be zeolitized, in which case a groundwater travel time of 1,000 years can significantly increase confidence that the assumed EPA standard will be met.

Achievability

The NRC staff has estimated the time necessary for groundwater to travel one mile from the underground facility. Using data from Table 4, the staff evaluated the fraction of these travel times which exceeded 1,000 years. Those fractions are 0.67 for basalt, 0.93 for bedded salt, and 0.98 for welded tuff. While the permeability and hydraulic gradient data (from Table 4) used in these analyses are not intended to represent a particular site, it is considered that these data are representative of conditions likely to be found in these media.

Further, Battelle has modeled the Hanford site, and reports (Ref. 7-16) that the average distance which groundwater travels from the underground facility in 10,000 years is 5,800 feet, (less than 1.1 miles). Rockwell has also modelled the Hanford site, and shows how far groundwater travels in 100,000 year increments (Ref. 7-17). According to this report, after 800,000 years, the groundwater has moved less than 5 kilometers (about 3 miles) from the underground facility.

The staff considers that these results provide significant support for the achievability of a minimum groundwater travel time requirement of 1,000 years between the disturbed zone and an accessible environment which is located up to 10 kilometers away.

Conclusion

A 1000 year groundwater travel time can be of significant value in providing reasonable assurance that the assumed standard can be met without placing an undue reliance on the ability of the underground facility to minimize release rates, and is readily achievable.

Further, the 1000 year groundwater travel time requirement is an essential component of the defense-in-depth concept as applied to waste disposal. This requirement constitutes a quantifiable criterion for the geologic setting to meet, in contrast to the remainder of the siting criteria for which compliance will be determined by expert judgement. The 1000 year groundwater travel time requirement thus constitutes an invaluable measure of the quality of the geologic setting.
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The staff again notes that performance objectives have been stated with significantly more flexibility in the final rule than in the proposed rule. The staff recognizes that a minimal groundwater travel time will depend on such factors as the age and nature of the waste, the design of the engineered system, the properties of the geologic setting, and the uncertainties associated with all aspects of geologic disposal. Proper consideration of such factors must be a part of any minimal groundwater travel time requirement.

Engineered Barrier System Containment Time Requirement

Impact of Containment Time on Performance

The impact of a containment interval on repository performance is discussed from a different perspective than criteria on release rates from the engineered barrier system or groundwater travel time. Use of a long lived package to achieve containment is a means to compensate for, and to an extent avoid, uncertainties in the prediction of rates of release and migration of the individual radionuclides, particularly during the critical period when the hazard of the wastes is greatest and the heat generation rates are the highest. These uncertainties have been discussed in Chapter V, but for convenience, they are briefly reviewed below.

Temperature is one of the principal factors in calculating what the source term to the geologic setting is. During the initial period the uncertainties in predicting release rates for long times are very great. Even if we did understand the mechanisms completely, the data scatter increases with temperature so that test programs to gather the data to narrow the uncertainties to reasonable bounds are very cumbersome (Ref.7-18).

Additional uncertainties due to thermal effects influence radionuclide transport following release. Thermally induced convection near the underground facility may occur and may transport radionuclides in unanticipated ways. Thermomechanical effects may create pathways for groundwater to travel through the host rock in the disturbed zone. By containing the wastes until the repository temperatures have peaked and are spatially relatively uniform, much of the uncertainty associated with these effects can be avoided.

A further source of uncertainty arises from the large number of different fission product radionuclides, each of which has a variety of solubilities and retardation factors. The latter uncertainties recall Chapter II and the Untreated Dilution Indices appearing in Figures 10, 11, and 12. By containing the wastes until the fission products are nearly depleted, these uncertainties can be greatly reduced.

In order to determine a nominal containment time requirement which can be expected to reduce these sources of uncertainty, it is necessary to consider how fission product inventories and near-field temperatures change as a function of time. Fission product inventories and their changes appear in Figures 1 through 12, and have the same general characteristic in each figure. It is seen in Figures 4, 5, and 6, that the rate at which total heat is generated by the waste decreases so that at least a 99% reduction in heat generation rate occurs within the first few hundred years for each of the waste types. Repository temperatures may have peaked and become spatially relatively uniform by this time, or may require additional time, depending on parameters such as the thermal properties of the host rock and the design of the engineered barrier system. As seen in Figures 7 through 12, the toxicity of the fission products decreases by more than five orders of magnitude during the first 1,000 years and then remains essentially constant for the next 100,000 years. Thus, to a large extent, the uncertainties introduced by the heat generation rate and the fission product contributions to hazard can be compensated for by containment times in the range of several hundred to 1,000 years. However, the staff recognizes that the interval during which wastes should be contained will depend on such factors as the age and nature of the waste, the design of the engineered system, the properties of the geologic setting, and the uncertainties associated with all aspects of geologic disposal. Proper consideration for such factors must be a part of any containment requirement. Therefore, by compensating for several of the principal sources of uncertainty in assessing repository performance, a containment time of several hundred to 1,000 years is appropriate to contribute to reasonable assurance that the EPA standard, as it pertains to anticipated processes and events, can be satisfied.

Achievability of Containment Requirement

As expressed more generally in the discussion of the achievability of release rates, the staff does not intend that the containment time requirement be achieved absolutely for all of the waste (i.e., absolute proof of zero release for 1000 years is not required). It is expected that containment of the waste will be substantially complete, with releases during the containment time limited to a small fraction of the inventory present. What is intended is that the waste package design have a high reliability, taking into account anticipated processes and events that could affect package performance. It is realized that a small fraction of the approximately 100,000 packages will be breached before 1000 years due to variations in materials, manufacturing processes, etc. that can only be estimated using statistical procedures. Similarly, a significant fraction of the packages may remain intact for much longer than 1000 years.

There has been considerable emphasis in the DOE program over the last several years on the research and development needed to design a long lived waste package. NRC has, in its own program, been reviewing DOE's R&D and has been performing assessments of the uncertainties involved in designing a waste package that could reasonably be expected to contain waste for 1000 years.

Brookhaven National Laboratory (Ref. 7-11) states that a multilayered metal container can provide containment for 1,000 years, as can carbon coated particles and high silica glass coated waste forms. Westinghouse has developed for DOE conceptual designs for titanium clad and self-shielded cast steel and cast iron containers which they consider will contain wastes for 1,000 years in basalt (Ref. 7-19). A report for the Electric Power Research Instituta describes a container capable of retaining its integrity for 13,000 years (Ref. 7-20). While DOE has not yet proposed a waste package design, the NRC staff considers that the concepts being considered have promise and that a design objective for containment by the waste package of 1000 years is reasonable.

Combined Performance Objectives For The Routine Release Scenario

Impact of the Proposed NRC Requirements

The combined impact of all three performance objectives for the case of the routine release scenario in basalt is shown in Figure 19. Like Figures 15 through 18, Figure 19 results from repeatedly running NWFT/DVM using a standard statistical sampling technique (Ref. 7-10). However, in the analyses leading to Figure 19, groundwater travel times were not limited to those shown in the preceeding figures, but took the values naturally resulting from the distributions of gradients and permeabilities appearing in Table 4. In this figure, the horizontal axis displays ratios of releases of radionuclides determined by NWFT/DVM to the releases permitted by the assumed EPA standard for routine releases described on page 49 and Table 2. The vertical axis displays the fraction of cases in the sample which exceed the value appearing on the horizontal axis. The figure displays results for the unrestricted cases, whose variables span the entire data ranges in Table 4 regardless of whether or not they satisfy the 10 CFR 60 criteria, and the results for all cases which are in compliance with 10 CFR 60. It may be seen that for a given frequency of releases, the consequences associated with that frequency decrease by two to three orders of magnitude. For example, in the unrestricted case there is about a 0.05 or 5% probability of exceeding the assumed standard by a factor of 10. However, for the case of a repository which complies with 10 CFR 60, the probability of about 0.05 or 5% is associated with releases of about 1/30 of the assumed standard, an improvement by a factor of 300. Likewise, about the worst 1% or 2% of the unrestricted cases result in releases exceeding the assumed standard by a factor of about 200, but the worst 1% or 2% of the restricted cases result in releases of about 15% of the assumed standard, an improvement by a factor of more than 1,000.

Figures 20 and 21 contain similar results for bedded salt and non-zeolitized tuff, respectively. In each case, the releases resulting from about the worst

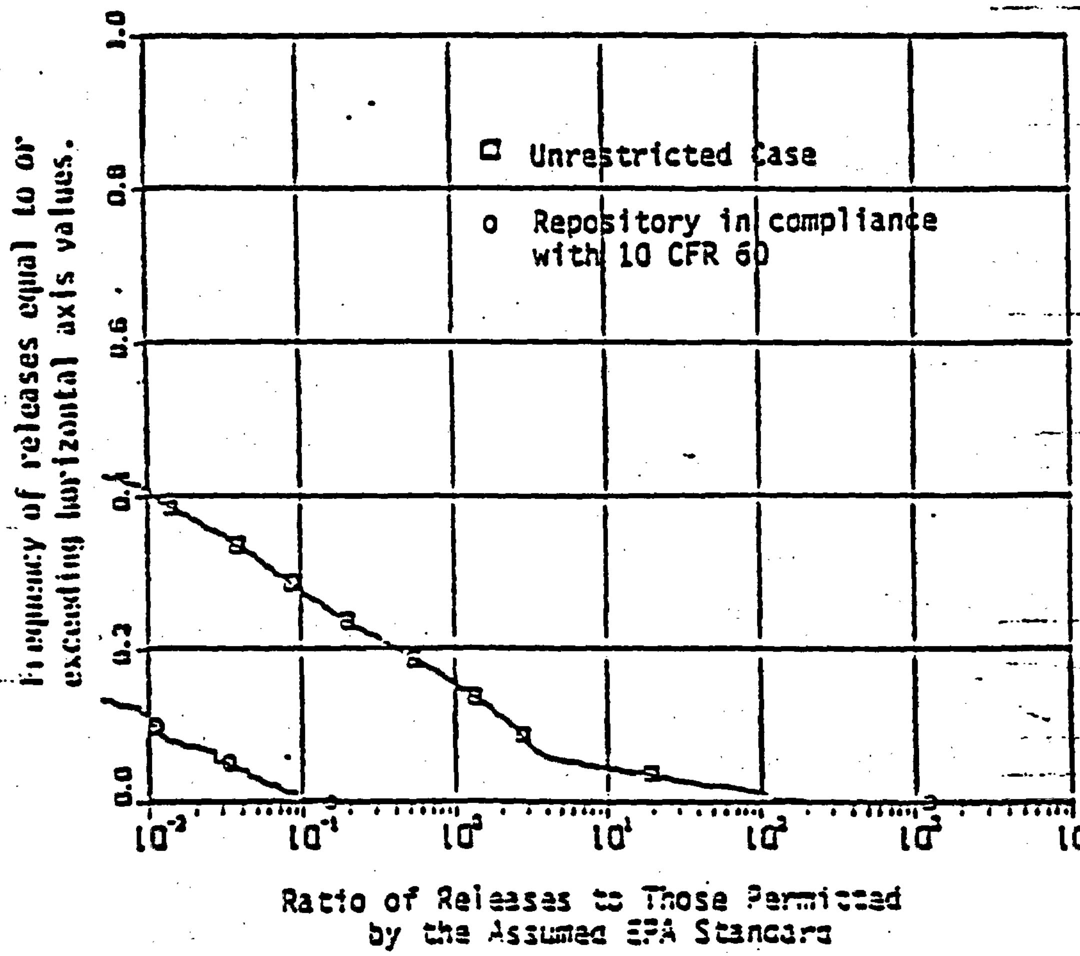

Figure 13. Relationship Between Releases From a Geologic Repository and the Probability of Those Releases for the Routine Release Scenario for Basalt.

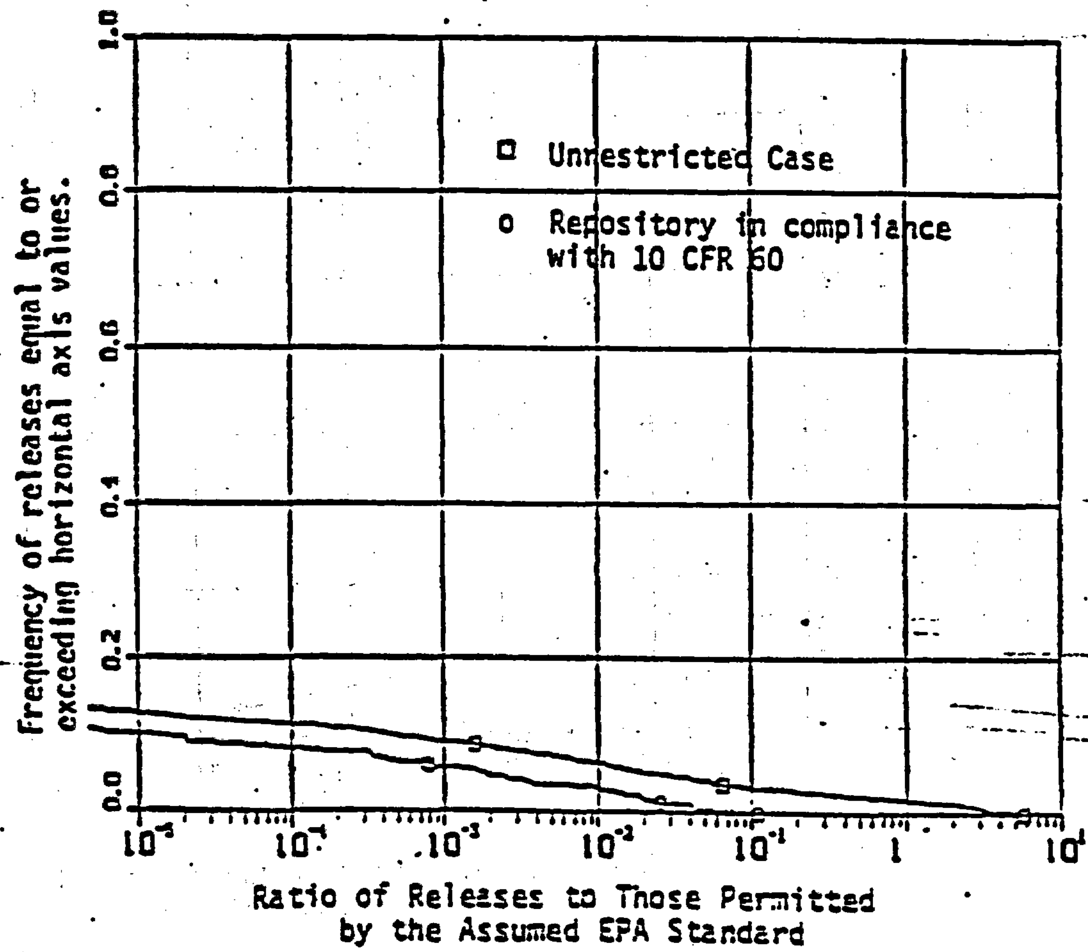

Figure 20. Relationship Between Releases From a Geologic Repository and the Probability of Those Releases for the Routine Release Scenario for Bedded Salt.

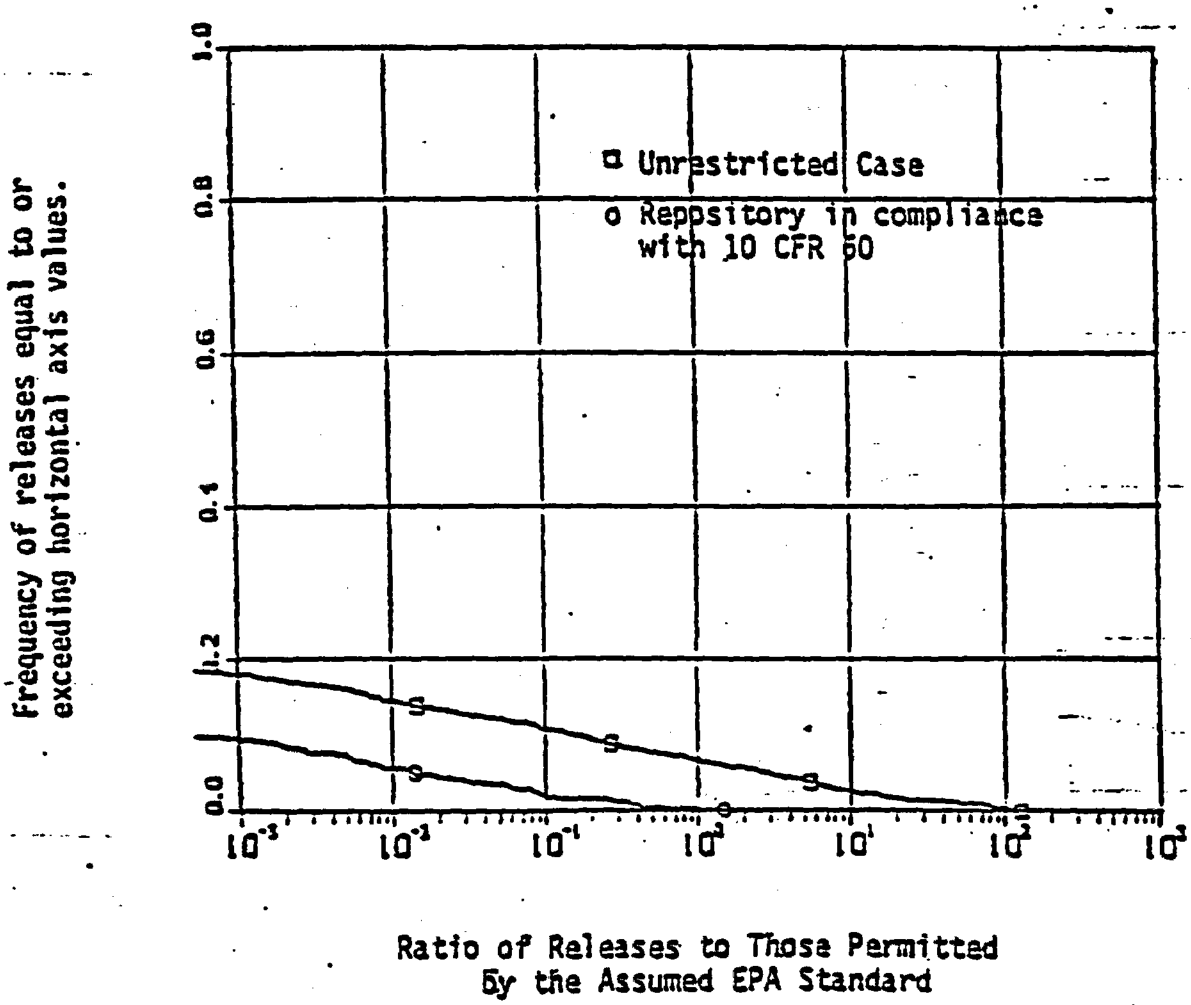

Figure 21. Relationship Between Releases From a Geologic Repository and the Probability of Those Releases for the Routine Release Scenario for Non-Zeolitized Tuff.

1% or 2% of the cases tested are reduced by about a factor of 50 and are brought within the release limits permitted by the assumed standard.

A comparison of Figures 17 and 21, for non-zeolitized tuff, raises the point that in Figure 17, compliance with the release rate and groundwater travel time values still permits about a 90% probability of repository failure to meet the assumed standard, but Figure 21 indicates that similar compliance will result in a near-zero probability of failure. These figures are consistent, because the permeability and hydraulic gradient data for tuff which appear in Table 4 generally result in long groundwater travel times, and the entire range of these data was used to arrive at Figure 21. Thus, for non-zeolitized tuff, the relatively low geochemical retardation of uranium compared to other media, which was discussed in connection with Figure 17, is compensated for by relatively long groundwater travel times. Therefore, in Figure 21, both the unrestricted case and the case in compliance with 10 CFR 60 have sample points with groundwater travel times which generally exceed thousands of years, and therefore result in releases to the accessible environment below the assumed standard.

In summary, for a routine release scenario in basalt, bedded salt, and non-zeolitized tuff, for the variable ranges tested, the consequences associated with various probabilities of releases are reduced by between a factor of 50 and a factor of 1,000 by complying with the performance objectives in 10 CFR 60. The staff considers that these improvements demonstrate that compliance with 10 CFR 60 can substantially increase confidence that the assumed EPA standard will be met.

VIII IMPACT OF NUMERICAL REQUIREMENTS ON UNANTICIPATED EVENTS

In the previous chapter we showed how meeting the controlled release rate of 1 part in 100,000 per year and minimum groundwater travel time of 1000 years to the accessible environment contributed to meeting the assumed

HLW standard. We also discussed how requiring containment of the wastes within the waste package substantially contributed to confidence that the assumed standard would be met. In this chapter we show how the numerical requirements, if met, would limit the consequences of a failure of a portion of the repository system (the natural barriers). We present this chapter by way of illustration only. We have made no estimate of the probability of such events actually occuring. Estimates of the likelihood of a low probability geologic event that could disrupt the repository can only be made on the basis of the geologic record for a particular site, and even then will involve considerable uncertainty. However, we illustrate how the numerical requirements for the individual barriers mitigate the consequences of failure of the natural barriers with respect to the assumed EPA standard as it applies to unanticipated processes and events.

1. FAULTING SCENARIO

There are plausible scenarios in which the geologic barrier is breached. One such scenario assumes a fault through the underground facility, extending through an overlying aquifer. We assume that the fault offers no hydrologic resistance to vertical flow to the overlying aquifer, which carries the contaminant to the accessible environment. However, we assume that the fault does not breach any waste packages and does not influence the release rate from the engineered barrier system.

The code used to evaluate this scenario is the same NWFT/DVM code that was used in the routine release scenario. In this case leg D has been modified to simulate the result of the fault described above by assuming infinite permeability and a zero retardation factor. The variable ranges for the fluid parameters are those for basalt shown in Table 4 of Chapter

VII. Figure 22 shows the flow model for this scenario, and Table 3 shows the fixed parameters selected. The time of the occurrence of the fault was a random variable distributed uniformly over the 10,000 years.

Conclusions

Figure 23 shows the fraction of outcomes of the faulting scenario exceeding various multiples of the assumed EPA standard. Results are displayed both for repositories which meet the numerical criteria associated with the engineered barrier system and for repositories whose containment interval and release rates span the ranges for these variables shown in Table 4. The staff has not attempted to establish a standard for releases for this scenario. However, for comparison purposes, it may be seen that for an unrestricted repository, the 20 per cent of the cases whose releases are highest result in releases from about 1,000 to 15,000 times those permitted by the assumed standard. For a repository which complies with 10 CFR 60, the 20 per cent of the cases whose releases are highest result in releases from about 30 to 450 times those permitted by the assumed standard. Clearly, for this scenario, controlling the rate of release of radionuclides to the geologic setting does have the effect of limiting consequences.

2. Borehole Scenario

We have re-examined the human intrusion question in light of the public comment on the proposed technical criteria. We make no assumption with respect to the question of whether small-scale unintentional intrusion may warrant examination at the time of licensing, and, therefore, may be appropriate for inclusion in the safety analysis report to be prepared by DOE as part of a license application. Nevertheless, in this section we

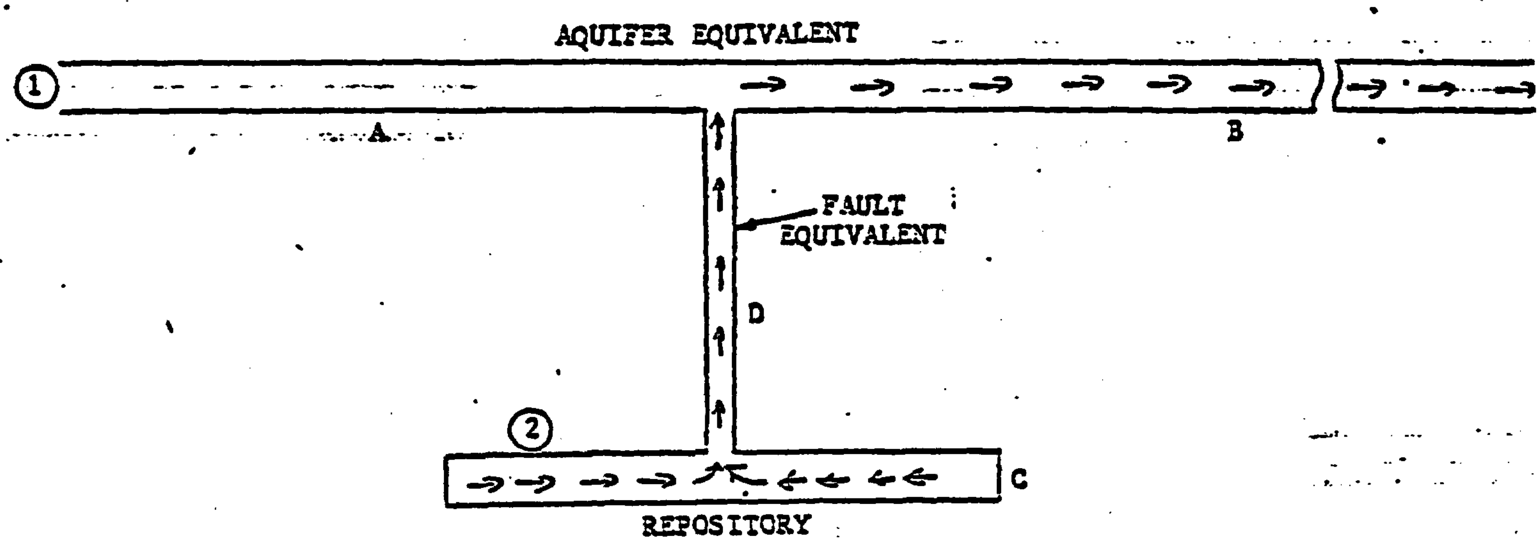

FIGURE 22. FLOW MODEL FOR FAULT SCENARIO

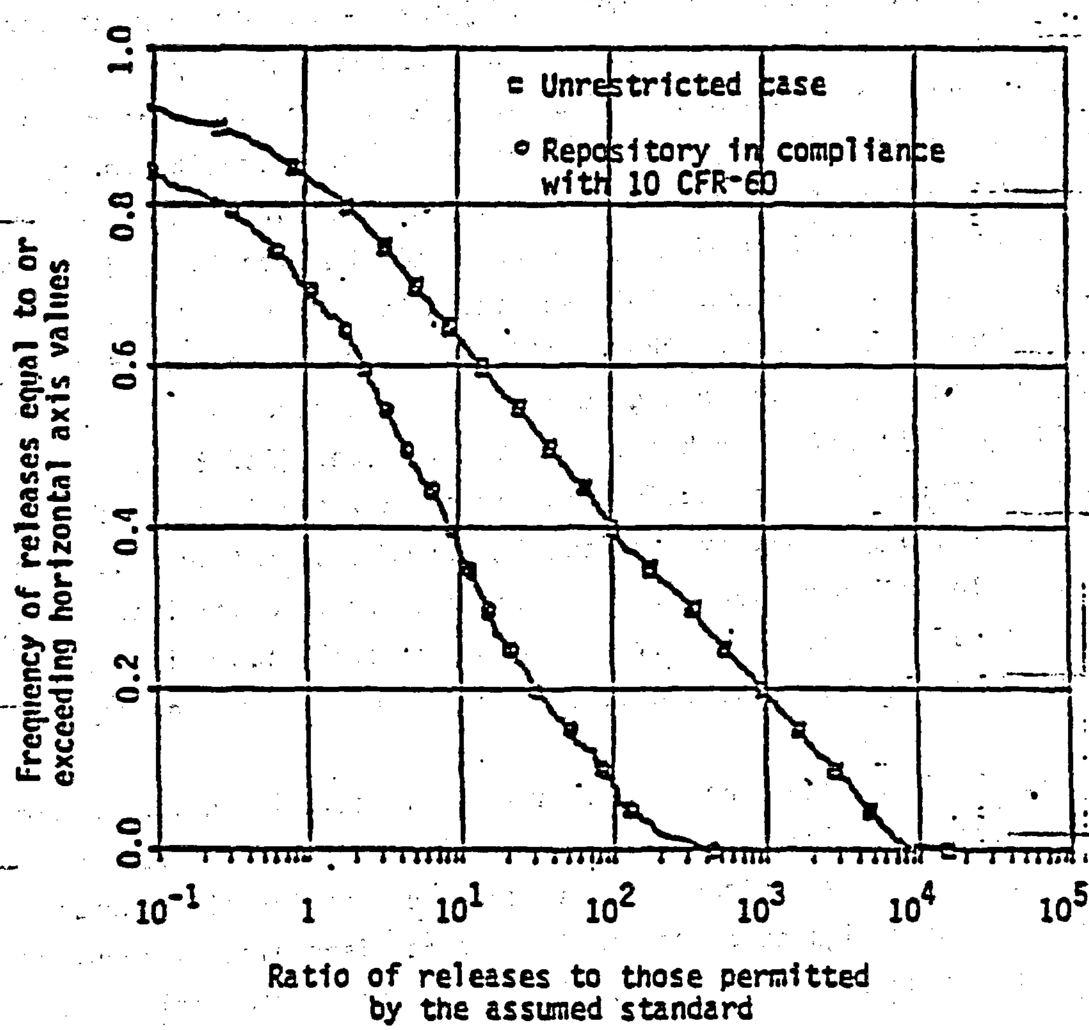

Figure 23. Relationship between releases in the fault scenario and probability of those releases.

examine the consequences of a small scale intrusion scenario which assumes a borehole penetration into the underground facility as an example of such small-scale intrusion, and examine the consequences. The model for this scenario appears in Figure 24. As in the preceeding scenarios, groundwater is presumed to resaturate the repository shortly after closure and to initiate deterioration of the waste packages. The eventual breach of the packages releases radionuclides to the underground facility, and in time, to the geologic setting. The time when the borehole is drilled is distributed uniformly between 100 and 10,000 years after repository closure. Release occurs by the bulk removal of contaminated water during the drilling process. A volume of 200 m^3 (7058 ft^3) of water from the underground facility is assumed to mix with the drilling fluid and to be brought to the surface. (Ref 8-1). The concentrations of radionuclides in the groundwater in the repository determine the quantity of each nuclide brought to the surface (the accessible environment). If a larger quantity of contaminated water were brought to the surface, or if more frequent small-scale intrusions were considered credible, the consequences would be proportionately greater.

Figure 25 illustrates the effect this small-scale intrusion in terms of consequence relative to the assumed standard of Chapter VII. We note that under the assumptions of this scenario, small-scale intrusion of this type is mitigated by the engineered barriers already required to meet the assumed EPA standard as it applies to routine releases.

IX RETRIEVABILITY

In its licensing procedures for disposal of high-level radioactive waste in geologic repositories, the NRC has adopted a step-by-step approach that consists of four principal stages:

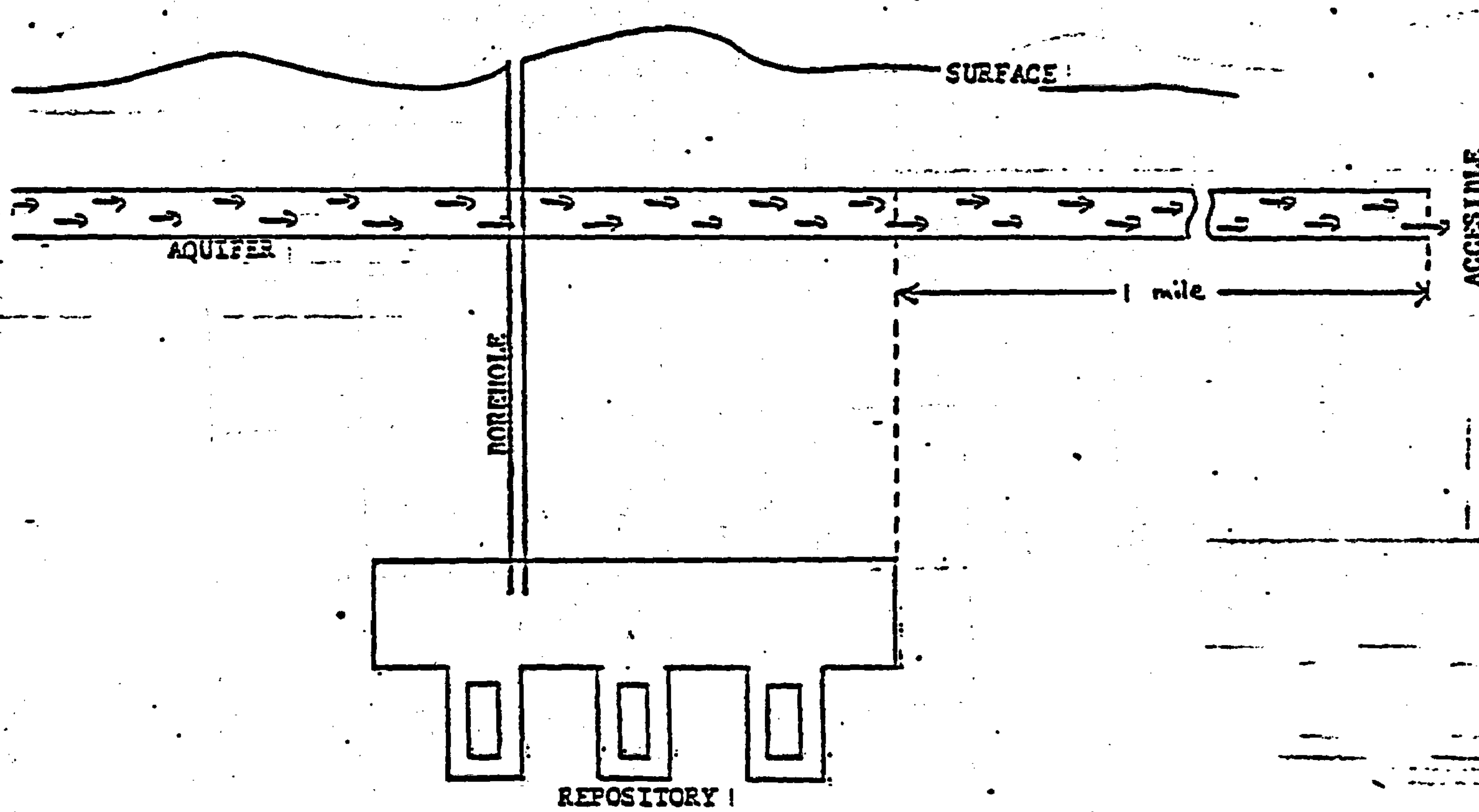

FIGURE 24. MODEL FOR BOREHOLE SCENARIO

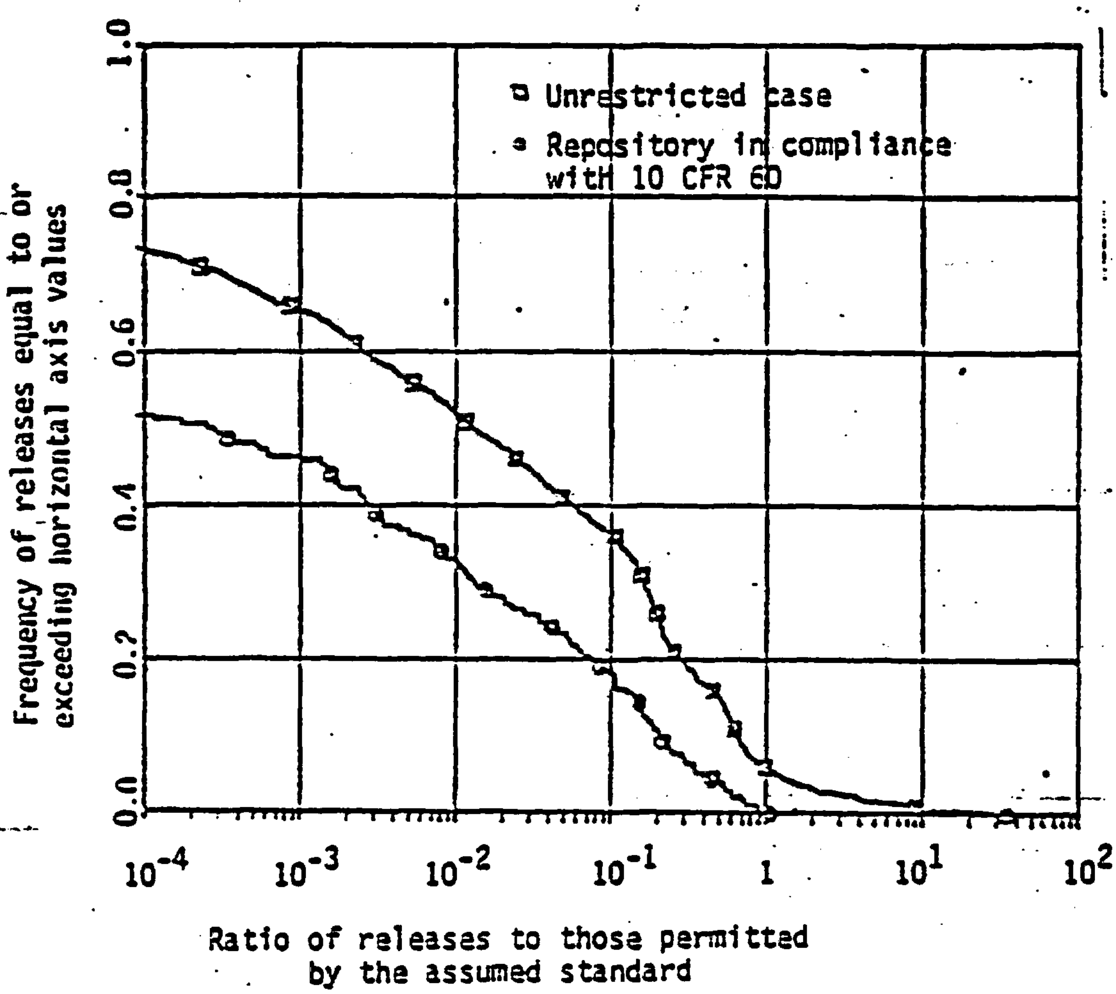

Figure 25. Relationship between releases in the borehole scenario and probability of those releases.

(1) Site characterization, during which detailed studies of alternative candidate sites are conducted before selection of one of the sites for development as a repository.

(2) Construction authorization, during which NRC reviews a license application that contains a detailed design and an analysis of the performance of the repository based on the site specific information obtained during a site characterization.

(3) License to receive wastes, when the application is reviewed again prior to operation. At this time, the repository design and performance assessment are updated in light of new information obtained about the site during construction of the repository.

(4) Permanent closure, at which time an application to terminate operations and seal the repository is submitted. The application will again contain updated analyses of the performance of the repository in light of: (1) information obtained about the site during the operation of the repository; and (2) data collected about the performance of the engineered barrier system to verify that performance can be expected to be within design limits.

At the permanent closure stage, the Commission will determine whether the DOE's performance confirmation program demonstrates that the repository can be expected to work as planned. Here performance confirmation means the program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine reasonable assurance that the performance objectives for the period after permanent closure can be met. Commission's intent in separating the license application and permanent closure decisions was to be able, following emplacement of the waste, to obtain further information concerning the workability of the repository and to use this information in making its final decision on the acceptability of permanent closure. The retrievability option provides the capability to implement this regulatory approach.

The NRC staff therefore considers that the option to retrieve the wastes must be preserved long enough to complete a program of monitoring and verification of repository performance. The design must also ensure that the option is preserved long enough to permit a decision to permanently close the repository or take any corrective actions shown to be necessary by the verification and monitoring program. Since some of the assumptions and issues that will need to be verified and resolved by the monitoring program may not be identified until the underground facility is excavated, it is not possible to specify prior to construction the complete content of the verification program or how long it will take. We expect the verification program to evolve throughout the operating lifetime of the repository.

On the other hand, important design decisions will need to be made before submitting an application. Some of these design decisions will affect the length of time available to take corrective action or conduct retrieval, if found to be necessary. For example, the thermal loading of the waste in the emplacement areas will affect the temperature of the host rock and the stability of the underground structure. These factors will have a large effect on the ability to retrieve the wastes, since the structure could become too unstable or the rocks too hot to safaly recover the wastes. Therefore the staff concluded that a retrievability period must be chosen early in the design process to permit the design to go forward, and a retrievability requirement was included in the proposed technical criteria.

For the licensing procedures to be workable, the staff considers that the option to retrieve should be preserved for the time necessary to emplace all of the wastes, complete a performance confirmation program, arrive at a decision as to whether retrieval must be undertaken, and execute retrieval, if found to be necessary. The design for retrievability should encompass all of these considerations.

Present estimates of the time to be devoted to the operation of the repository are 25 to 30 years (Ref. 9-1, 9-2). Performance confirmation programs have been suggested which require a variety of periods to complete. For example, some proposed hydro-thermomechanical studies (Ref. 9-3) will require 8 years to complete. Alternatively, performance confirmation may require approaching maximum temperatures in the host rock near the waste package. Reaching these temperatures will require up to 10 years for reprocessed high level waste and 20 to 25 years for spent fuel depending on the geologic medium, according to the DOE Final GEIS (Ref. 9-4). For some media and conceptual repository designs more than 25 years may be required according to TM-36 (Ref. 9-5). While the appropriate length of such a program will be site and design specific, the above estimates suggest that a program extending through the period waste is being emplaced is not unreasonable.

Clearly, such a program should be initiated as early in the operational phase as practicable, both to provide guidance during operations and to ensure that completion of the program does not delay closure. However, common sense dictates that the option to modify or to initiate a new phase of a performance confirmation program late in the operational phase should be maintained to be able to respond to variability in the host rock or to technological developments which lead to engineering changes. The capacity to keep the repository open for 10 to 15 years after the operational phase if needed is therefore advisable.

Adding the time needed for the operational phase to the time needed to provide the options discussed above results in a total interval of around 35 to 45 years.

Therefore, we have concluded that the repository should be designed so that the waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement is initiated. We consider a reasonable schedule to be one in which the waste could be retrieved in the same overall time that the repository was constructed and wastes were emplaced. We do not intend to preclude a decision to permanently close the repository before 50 years has elapsed, if sufficient data are available to support an earlier decision, and if the people charged with the decision to seal the repository are satisfied. However, we do not want the underground facility design to be such that retrieval would be so expensive or difficult or entail such high occupational exposures that the option is foreclosed and needed corrective actions could not be taken.

As discussed earlier, the staff recognizes that site and design specific factors will strongly influence selection of the design for retrievability. The performance objective has therefore been expressed to permit flexibility to take these factors into account during licensing.

Maintaining the option to retrieve the wastes does not entail keeping the mined areas open, although DOE may choose to do so in some geologic media. A design in which the emplacement rooms are backfilled and sealed, but corridors and shafts are kept open and surface handling facilities are maintained could be acceptable, provided that the rooms could be remined and the wastes removed, if necessary. Remining of the backfill should not be precluded because of high temperatures or because it was needed for structural stability. Trade-offs between keeping rooms open and ventilated, backfilling, and areal heat densities are design options that DOE must consider in meeting this requirement. Both the proposed and final rules do not require that retrieval be essentially the reverse of emplacement. We can foresee no situation where protection of the public health and safety would require the waste to be removed very rapidly.

Rather, we envision that if, as the result of years of data collection and analysis, a decision is made that the site or design is not adequate to isolate the wastes for the long term, corrective actions could be taken. These actions could be performed over a period of years or decades without an imminent health and safety hazard. Therefore, the final rule requires that if a decision to retrieve is made, the design should be such that the inventory of wastes could be removed in about the same number of years in which it was emplaced. We intend for DOE to have considerable flexibility in the design of the repository in meeting these requirements.

A repository designed to permit retrieval of the waste has advantages in addition to the limiting case of preserving a Commission option to order abandonment of the site at as late a stage as permanent closure. From the time waste emplacement starts until permanent closure any of a variety of eventualities may require corrective action. Examples might include repair or replacement of canisters that prove to have manufacturing defects, changes to more effective backfill, or perhaps installation of additional barriers in the exits. Design of the repository for retrievability of the waste assures that it will remain practical to take corrective actions should they become necessary.

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RATIONALE FOR THE PERFORMANCE OBJECTIVES IN 10 CFR PART 60

APPENDIX A - IMPACT OF PROPOSED EPA STANDARD (40 CFR PART 191)

On December 29, 1982, the Environmental Protection Agency published its proposed Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (Ref. A-1). The proposed standards contain environmental standards for management and storage (Subpart A) and environmental standards for disposal (Subpart B), which are further partitioned into containment, assurance, and procedural requirements. The containment requirements, along with related definitions, are comparable to Draft No. 19 of the Standard, and are the subject of this appendix.

The containment requirements (§191.13) and definitions (§191.12) of the proposed standards differ from Draft No. 19 as follows.

1) The definition of 'Underground Sources of Drinking Water' has been deleted.

2) Defintions of 'Groundwater', 'Lithosphere', 'Active Institutional Controls' and 'Passive Institutional Controls' have been added.

3) In the definition of 'Performance Assessment' the following sentences have been deleted:

"The [Performance Assessment] analysis should address the uncertainties in the estimates. To provide reasonable confidence in the results, the analysis shall be subjected to peer review by technically competent individuals independent of the organization preparing the assessment."

4) The first paragraph of §191.13 has been deleted. This paragraph read:

"(a) Disposal systems shall be designed to comply with the projected performance requirements of this section [191.13]. These requirements are upper limits. In accordance with Appendix A [Table 2 of the proposed version], the implementing agency should establish design objectives which will reduce releases as far below these limits as reasonably achievable."

5) In the second paragraph in §191.13, reproduced below, the lined-out phrase has been deleted.

"(b) Disposal systems for high-level or transuranic wastes shall be designed to provide a reasonable expectation, based ~~upon quantitative performance assessments~~, that for 10,000 years after disposal:"

6) The definition of accessible environment has been changed so that the distance from the original location of the radioactive wastes to the accessible environment, which was 1 mile in Draft No. 19, is 10 kilometers in the proposed standard.

7) The release limit for technetium-99 which appears in Table A of Draft 19 was increased from 2,000 to 10,000 curies in the corresponding table (Table 2) of the proposed version of the standard.

Only the latter two of the above changes, Items 6 and 7, could have any effect upon the calculations and, hence, the conclusions of the analysis upon which the Rationale document is based. In particular, potentially affected calculations (and conclusions) involve Figures 15-21, 23, and 25 and Table 5 in Chapters VII and VIII. Therefore, these calculations were redone, reflecting these two differences, and results compared with the earlier calculations, as discussed below. For ease in comparison, Figures 15A-21A, 23A, and 25A, based on the proposed standard, are presented side-by-side with the corresponding figures based on Draft No. 19.

Figures 15 and 15-A contrast the results, assuming anticipated processes and events, for a geologic repository in basalt, using Draft No. 19 and the proposed standard as the performance measure, respectively. Comparison of the two figures leads to the conclusion that the differences between the results of Draft No. 19 and proposed standard calculations are negligible and do not change the validity of the conclusion based on the Draft No. 19 calculations. The same result and conclusion obtain for the geologic repository in non-zeolitized tuff, Figures 17 and 17-A.

Figures 16 and 16-A contrast the results, assuming anticipated processes and events, for a bedded salt repository, while Figures 18 and 18-A treat a geologic repository in zeolitized tuff. A change in the repository system is found as a result of the changes in the EPA standard. For example, in both media, for a groundwater travel time of 1,000 years, to achieve a fraction of failures below 0.10, it is necessary to reduce release rates from the underground facility to about 1 part in 100,000 per year if Draft No. 19 is assumed to be the standard, while the same fraction of failures can be achieved with a release rate from the underground facility as high as about 1 part in 40,000 if the proposed version of the standard is assumed, a difference of about 2 - 2½ or less.

Given the two to four order of magnitude range of the variables and results, the staff does not consider that a factor of 2 - 2½ difference constitutes a basis for altering the conclusions in the rationale document.

Figures 19 and 19-A contrast the results, assuming anticipated processes and events, of the relationship between releases and the probability of those releases for a geologic repository in basalt, using Draft No. 19 and proposed standard assumptions, respectively. Comparison of the two figures leads to a conclusion that the differences between Draft No. 19 and proposed standard calculations are negligible for the range of conditions considered in this case and do not change the validity of the conclusion based on the Draft No. 19 calculations. Similar results and conclusions obtain for a geologic repository in bedded salt, Figures 20 and 20-A.

Comparison of the respective figures for non-zeolitized tuff, Figures 21 and 21-A, however, shows a significant difference in performance with respect to the two standards being considered. These differences arise out of the different distances to the accessible environment which are reflected in different lengths of the horizontal leg in the model. In the tuff model, the horizontal leg makes a major contribution to isolation; by increasing its length, the performance of the repository can be significantly improved. The proposed standard establishes a distance to the accessible environment of 10 kilometers, whereas Draft No. 19 set a distance of 1 mile, a difference of about a factor of 6. It is important to note, however, that in both figures, compliance with 10 CFR Part 60 reduces the releases resulting from about the worst 1% or 2% of the cases by a factor of about 50 to 100. Thus the results for non-zeolitized tuff for both Draft No. 19 and the proposed standard demonstrate the contribution of the multi-barrier approach of 10 CFR Part

60 to confidence in meeting an EPA standard.

However, if this kind of result were to occur at a real site, it could support a decision to take advantage of the flexibility provisions in the performance objectives. Since the proposed final version of 10 CFR Part 60 allows DOE to consider 'up to 10 kilometers' to be within the controlled area, the Commission could use such a result as part of a basis for approving some other performance requirements for particular barriers.

Figures 23 and 23-A contrast the results for the fault scenario in basalt for the Draft 19 and proposed versions of the standard. For both the unrestricted case and for a repository in compliance with 10 CFR Part 60, the differences between Draft No. 19 and the proposed standard cause the releases associated with a particular probability of those releases to be reduced by about 10% to 20 %. The relative impact of 10 CFR Part 60 on limiting the consequences of this scenario is not significantly affected.

Figures 25 and 25-A display the consequences of the borehole scenario. Comparison of the two figures again leads to the conclusion that the differences in performance, based on the ranges of parameters considered by the staff, between Draft No. 19 and proposed standard calculations are negligible and do not change the validity of the conclusion based on the Draft No. 19 calculations.

The change to Table 5 is minor and is discussed in a footnote to that table where it appears in the Rationale.

In summary, the staff concludes that the differences which result from the changes to the EPA Standard do not form a basis for altering the conclusions in the Rationale.

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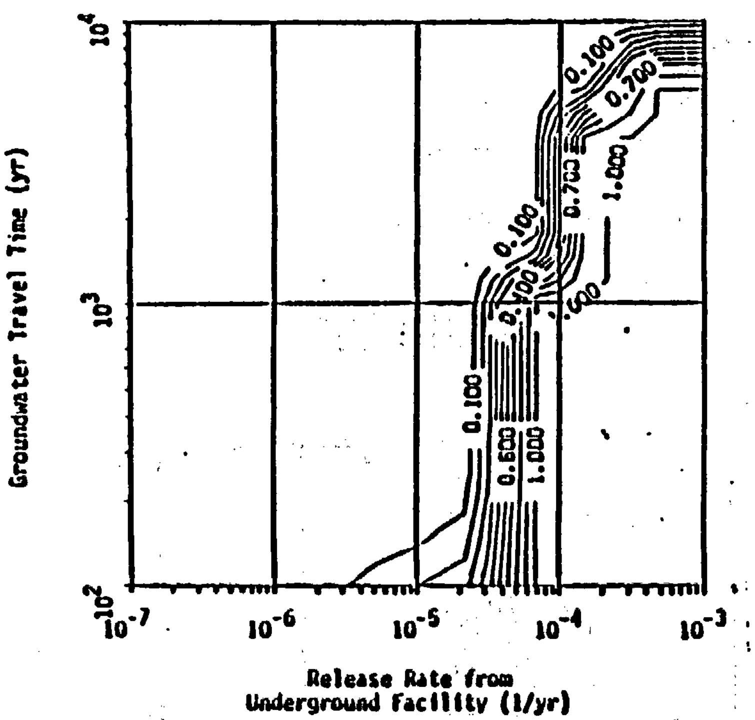
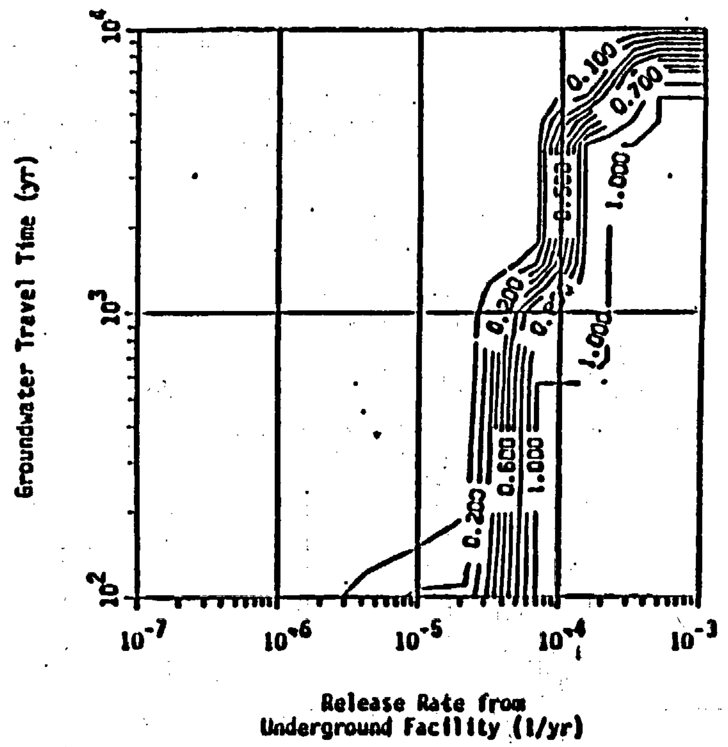
ROUTINE RELEASE

BASALT



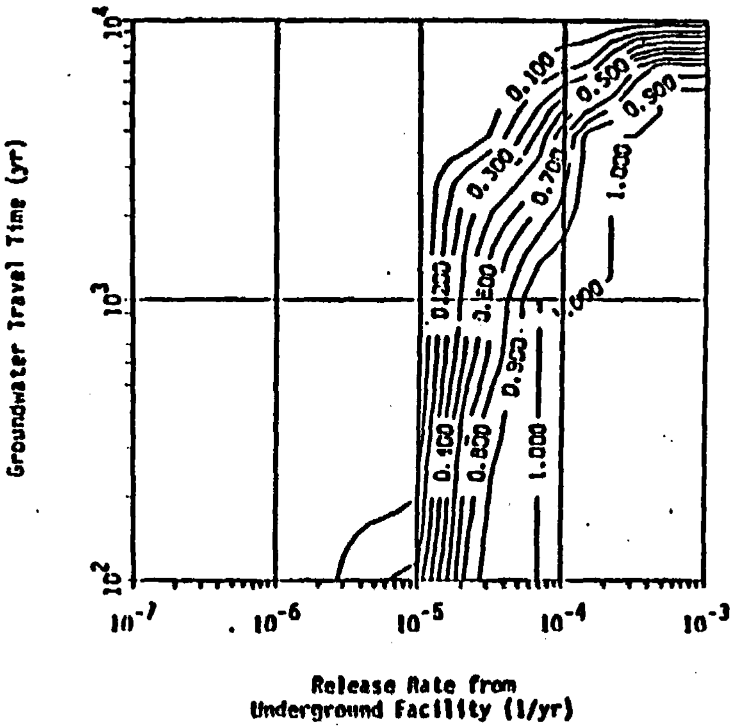
15. Draft 19 Assumed



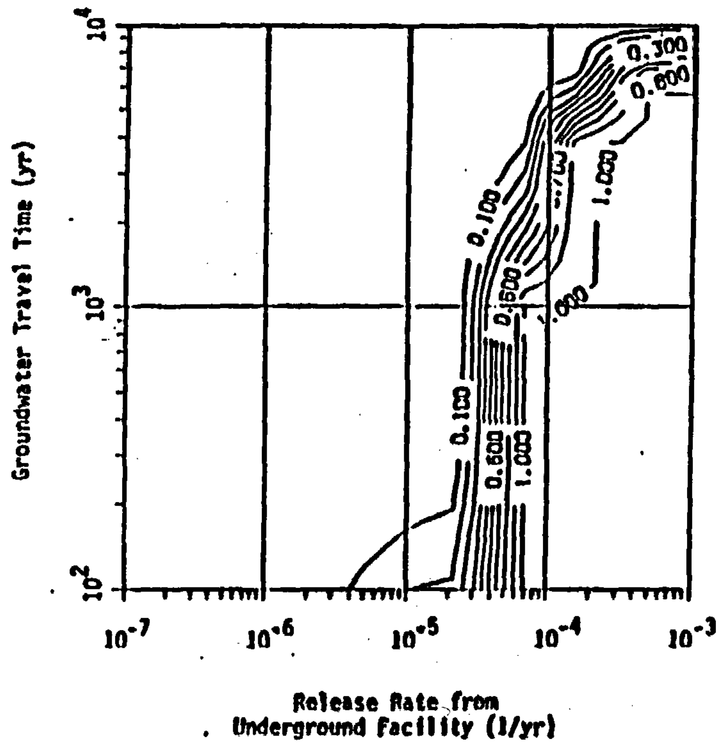
15A. Proposed Version Assumed

Figures 15 and 15A. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is basalt. Figure 15 assumes Draft 19 of the EPA standard; Figure 15A assumes the proposed version.

ROUTINE RELEASE
BEDDED SALT



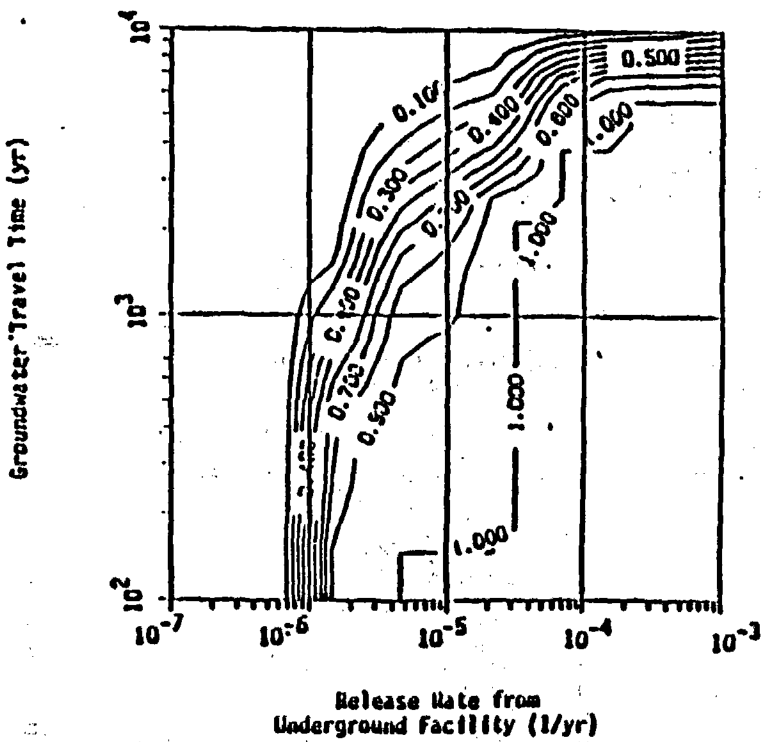
16. Draft 19 Assumed



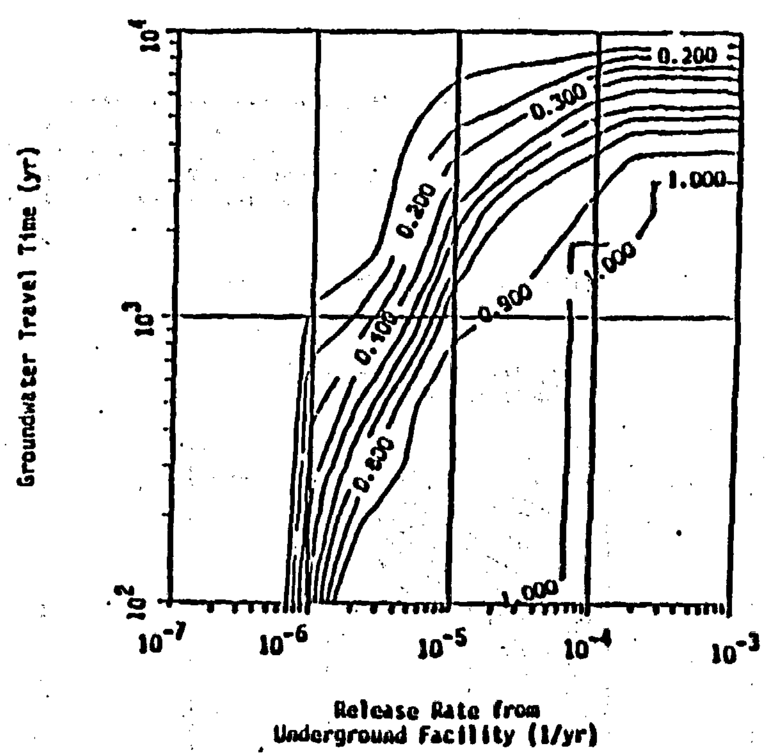
16A. Proposed Version Assumed

Figures 16 and 16A. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is bedded salt. Figure 16 assumes Draft 19 of the EPA standard; Figure 16A assumes the proposed version.

ROUTINE RELEASE
NON-ZEOLITIZED TUFF



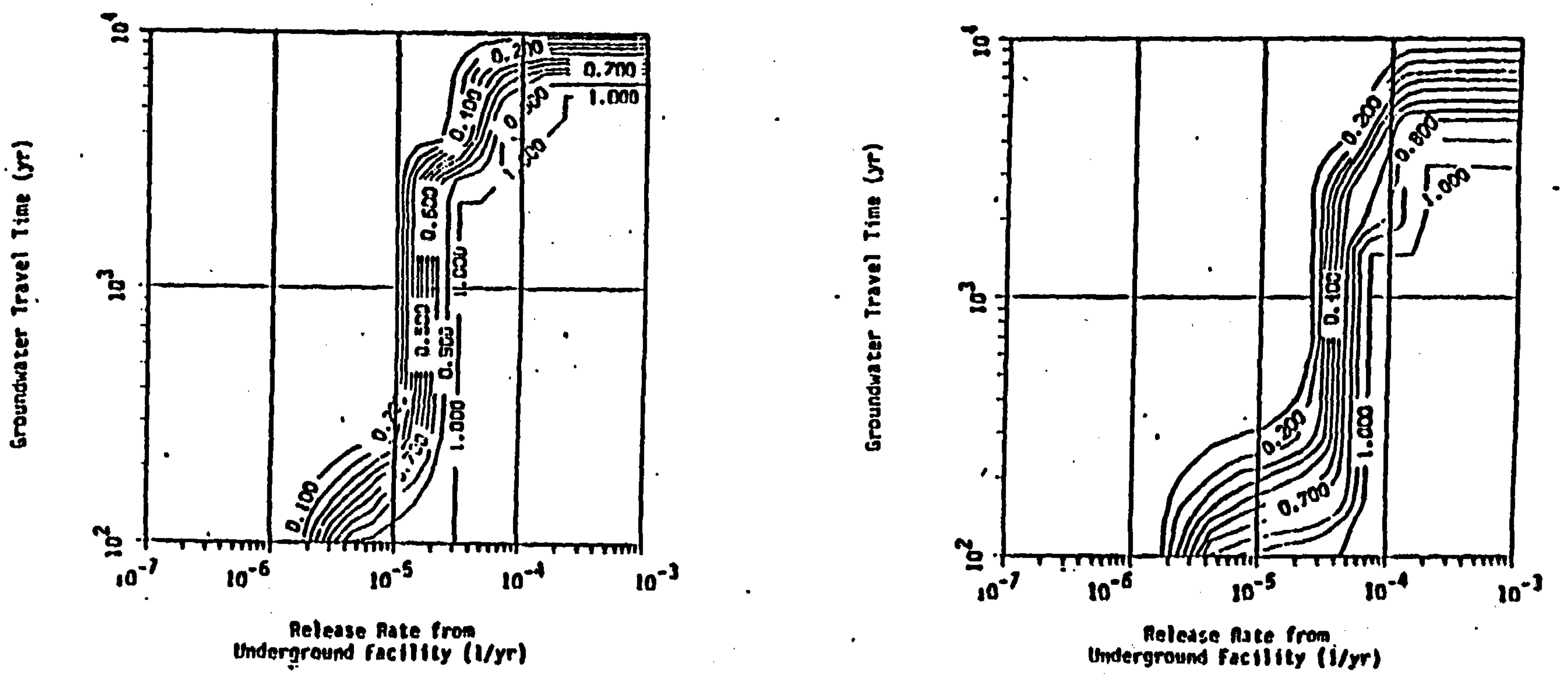
17. Draft 19 Assumed



17A. Proposed Version Assumed

Figures 17 and 17A. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is non-zeolitized tuff. Figure 17 assumes Draft 19 of the EPA standard; Figure 17A assumes the proposed version.

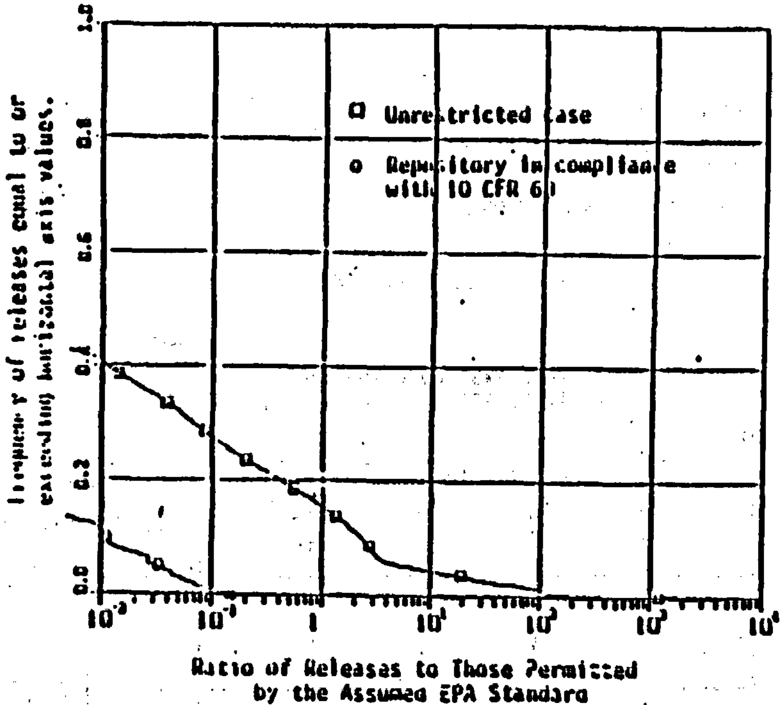
ROUTINE RELEASE
ZEOLITIZED TUFF



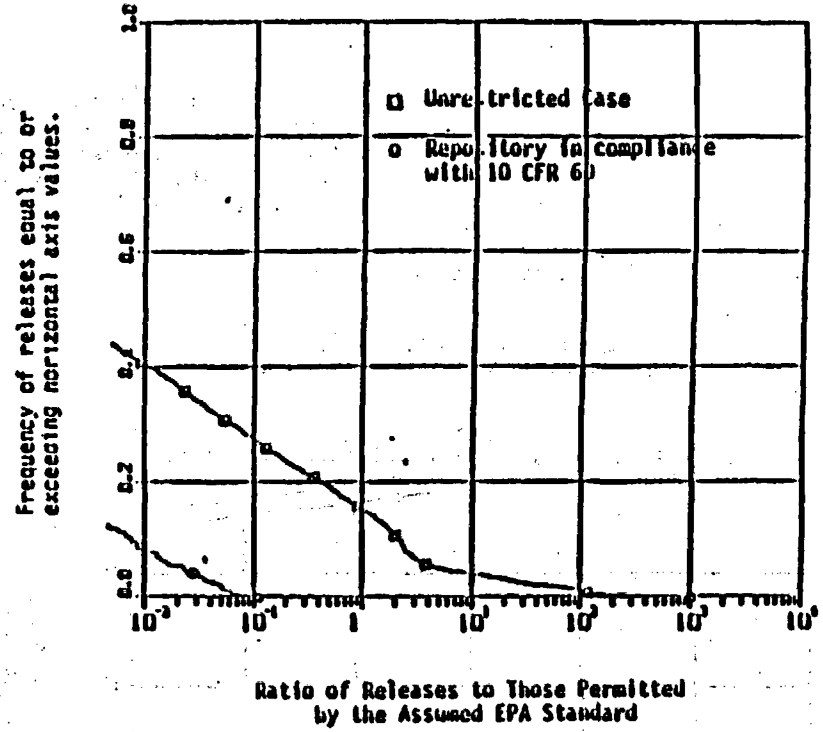
10. Draft 19 Assumed

10A. Proposed Version Assumed

Figures 10 and 10A. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is zeolitized tuff. Figure 10 assumes Draft 19 of the EPA standard; Figure 10A assumes the proposed version.

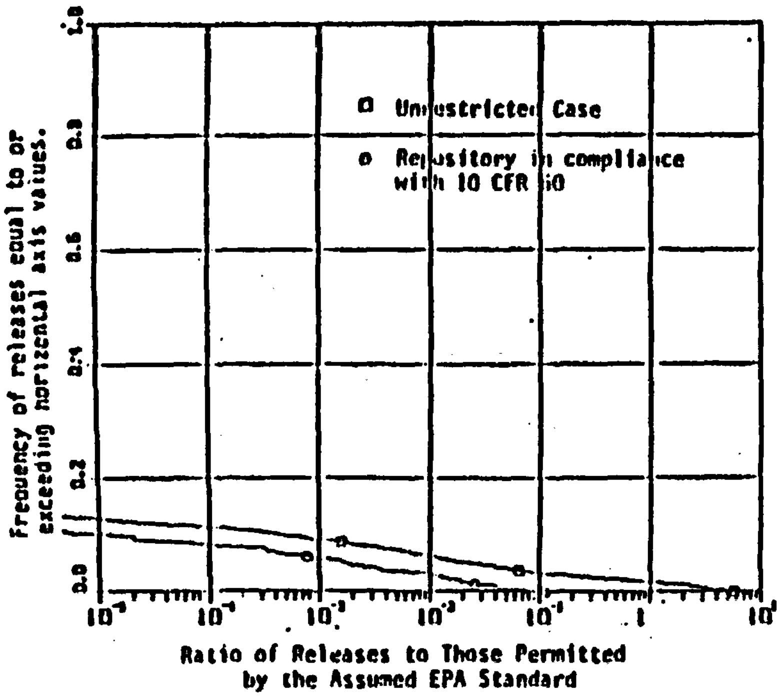


19. Draft 19 Assumed

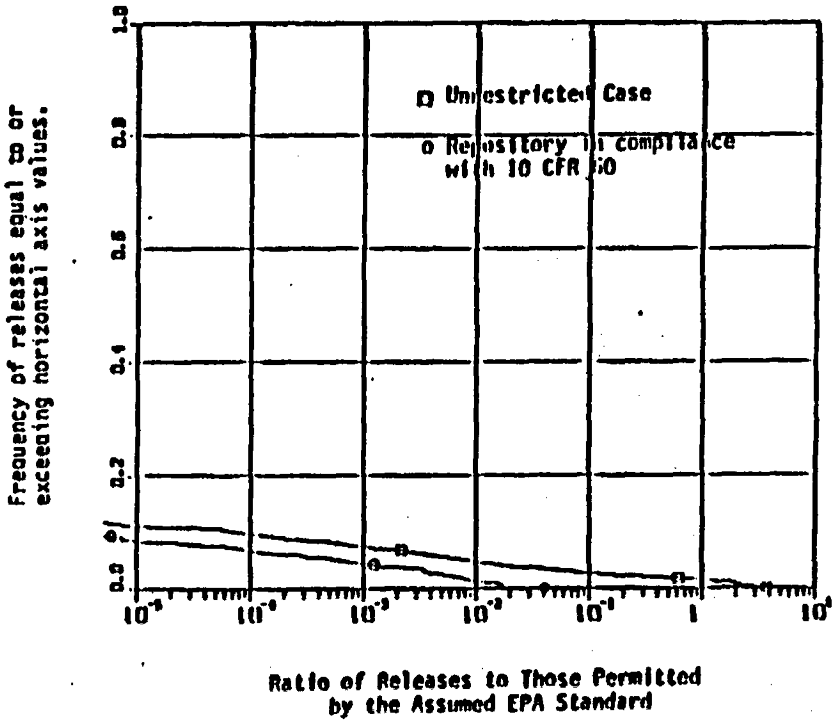


19A. Proposed Version Assumed

Figures 19 and 19A. Relationship between releases from a geologic repository and the probability of those releases for the routine scenario for basalt. Figure 19 assumes Draft 19 of the EPA standard; Figure 19A assumes the proposed version.

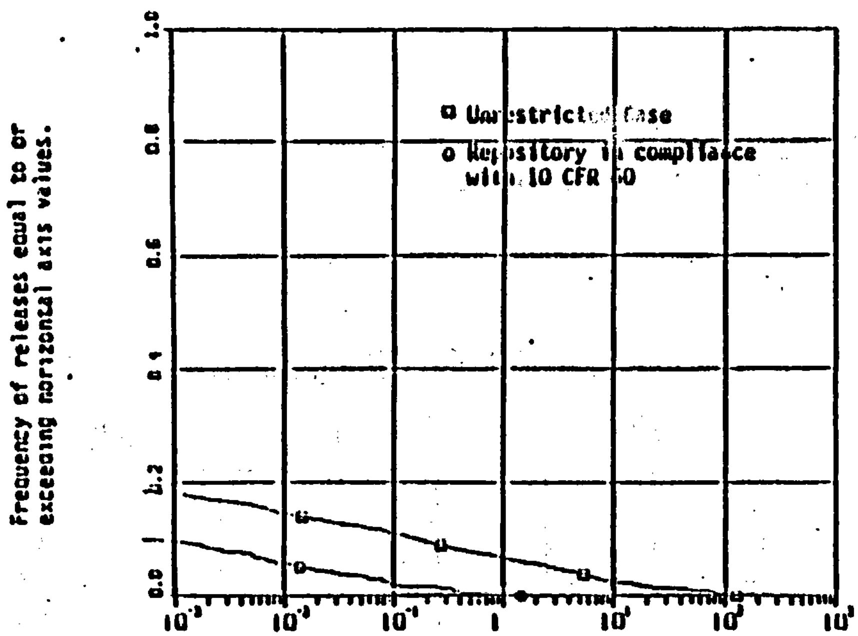


20. Draft 19 Assumed

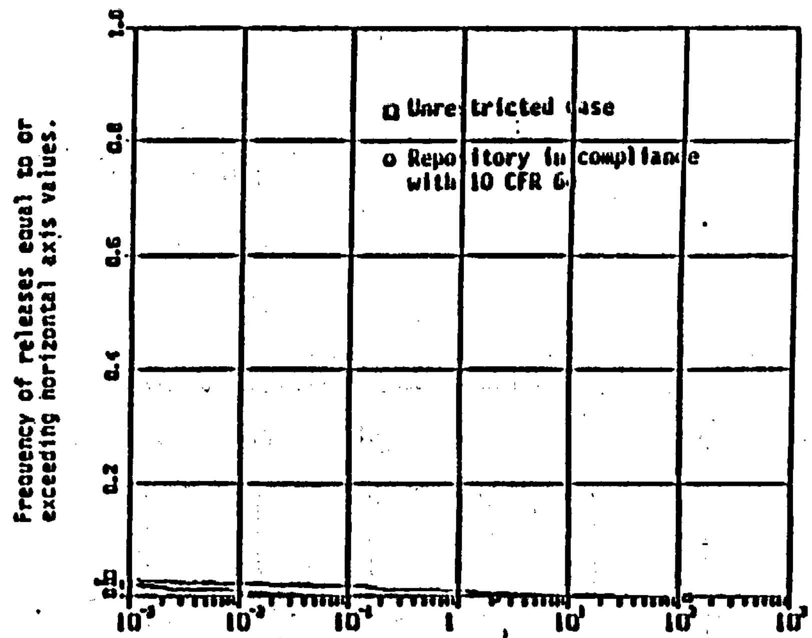


20A. Proposed Version Assumed

Figures 20 and 20A. Relationship between releases from a geologic repository and the probability of those releases for the routine release scenario for bedded salt. Figure 20 assumes Draft 19 of the EPA standard; Figure 20A assumes the proposed version.

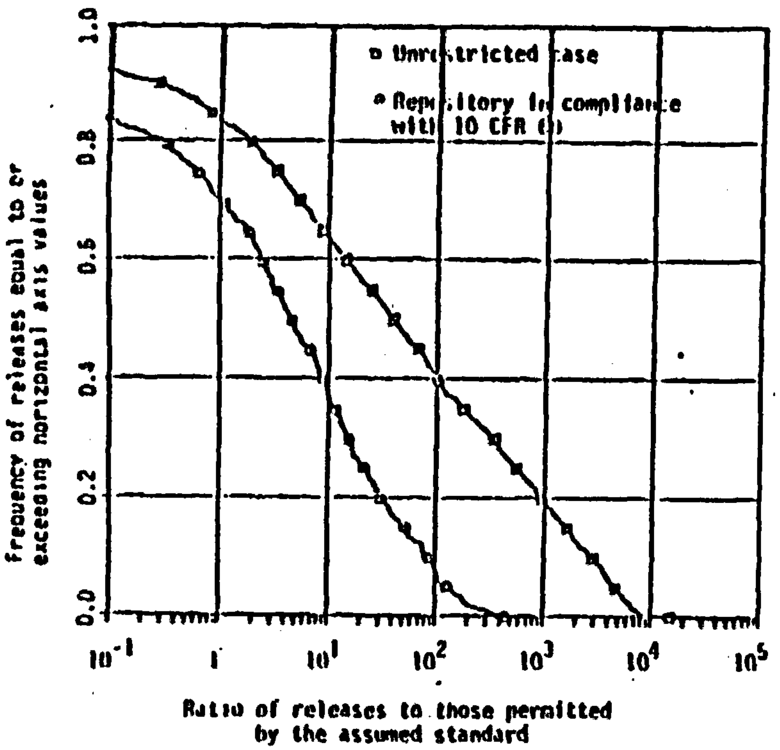


21. Draft 19 Assumed

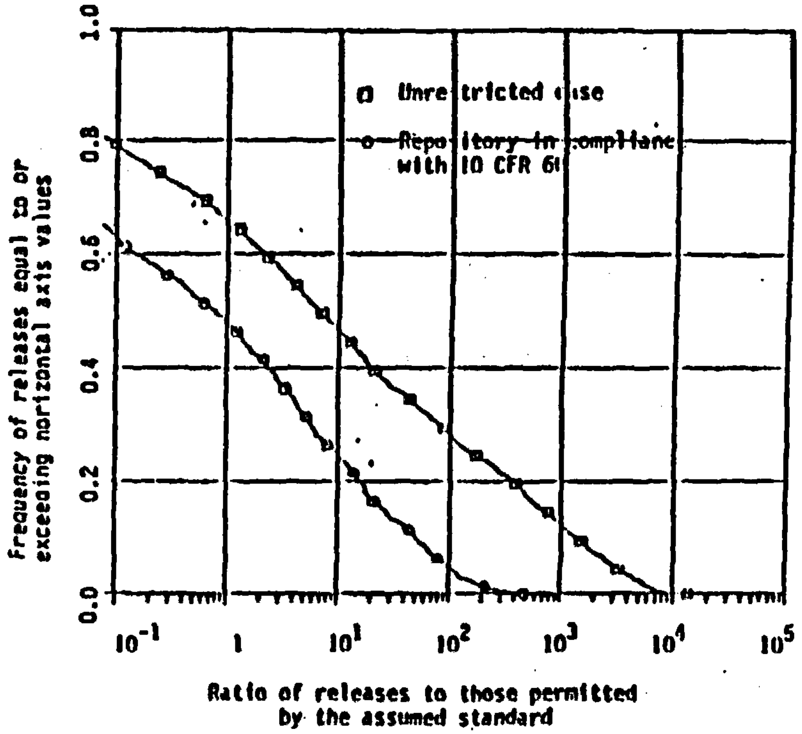


21A. Proposed Version Assumed

Figures 21 and 21A. Relationship between releases from a geologic repository and the probability of those releases for the routine release scenario for non-zeolitized tuff. Figure 21 assumes Draft 19 of the EPA standard; Figure 21A assumes the proposed version.

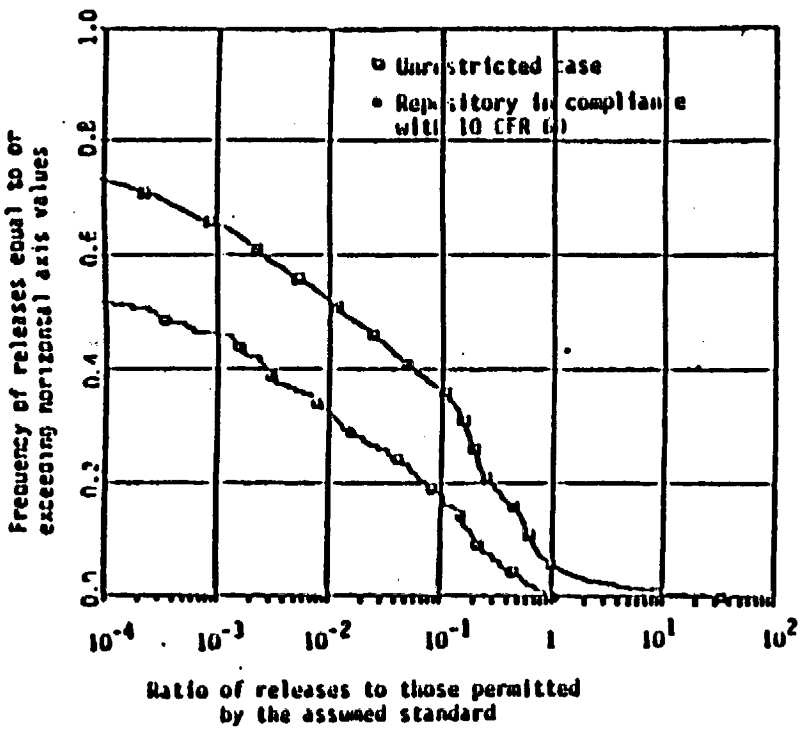


23. Draft 19 Assumed

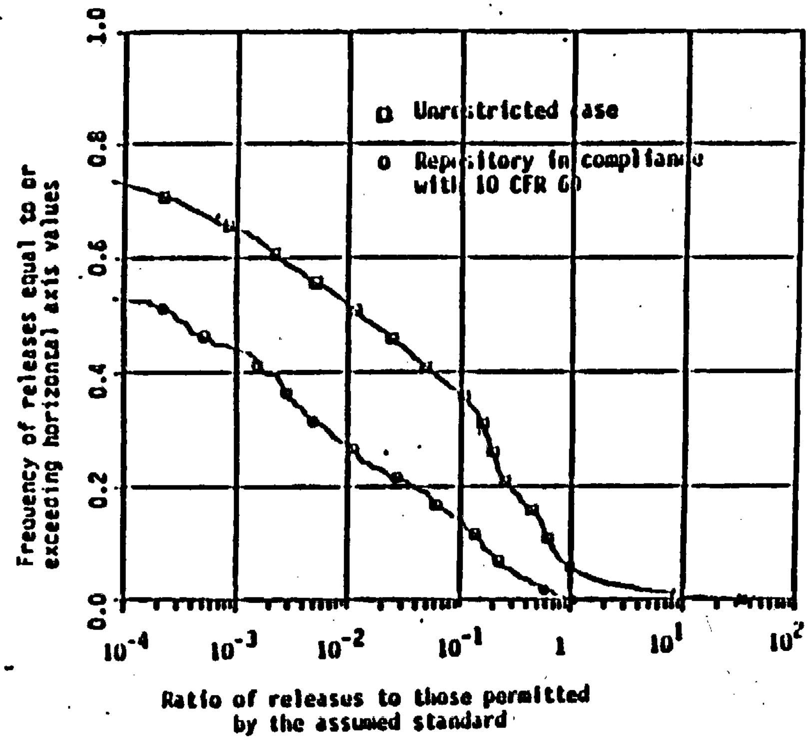


23A. Proposed Version Assumed

Figures 23 and 23A. Relationship between releases in the fault scenario and probability of those releases. Figure 23 assumes Draft 19 of the EPA standard; Figure 23A assumes the proposed version.



25. Draft 19 Assumed



25A. Proposed Version Assumed

Figures 25 and 25A. Relationship between releases in the borehole scenario and probability of those releases. Figure 25 assumes Draft 19 of the EPA standard; figure 25A assumes the proposed version.

ENVIRONMENTAL PROTECTION AGENCY

40 CFR 191

ENVIRONMENTAL STANDARDS AND FEDERAL RADIATION PROTECTION GUIDANCE FOR MANAGEMENT AND DISPOSAL OF SPENT NUCLEAR FUEL, HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

AGENCY: U.S. Environmental Protection Agency

ACTION: Proposed Rule

SUMMARY: The Environmental Protection Agency requests comments on proposed radiation protection standards and Federal radiation protection guidance for the management and disposal of spent nuclear reactor fuel and high-level and transuranic wastes. The proposed guides would establish seven general criteria to be followed when these wastes are disposed of. They address problems inherent in the design and construction of systems that must isolate hazardous materials for very long periods of time without human intervention. The proposed standards would limit the amount of radioactivity that may enter the biosphere. The standards require a reasonable expectation that these limits will be satisfied for ten thousand years after disposal. These requirements would apply to disposal by any method, except disposal directly into the oceans or ocean sediments. The proposed standards also would limit the radiation exposure of members of the public from management of spent fuel and of waste prior to disposal.

Appendix C

After we consider the comments received on this proposal, we will develop final versions of the standards and guides. We will then recommend that the President approve the guides as Federal Radiation Protection Guidance for all agencies. The final standards will be promulgated as a new Part 191 to Title 40 of the Code of Federal Regulations (40 CFR 191). The standards and guides will be implemented by the Nuclear Regulatory Commission and the Department of Energy under their respective statutory responsibilities.

DATE: Comments should be received on or before (180 days after publication).

Public hearings to receive comments on the proposed standards and guides will be held in several cities.

ADDRESS: Comments should be sent to the Director, Criteria and Standards Division (ANR-460), Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C. 20460. Copies of all documents will be available in Docket No. _-__-_ , which is located in the West Tower Lobby, Gallery 1, Central Docket Section, Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. Single copies of the Draft Environmental Impact Statement for this action may be obtained by writing to the Director.

FOR FURTHER INFORMATION CONTACT: Daniel Egan, telephone number (703) 557-8610, or Dr. Abraham Goldin, telephone number (703) 557-7380.

SUPPLEMENTARY INFORMATION: Proper management and disposal of the wastes produced by the irradiation of fuel elements in nuclear reactors are important because of the inherent hazards of the large amounts of

Appendix C

radioactivity they contain. Large quantities of these wastes already exist and more are being produced in national defense programs, commercial nuclear power plants, and research reactors. They are being held in storage facilities until disposal methods are developed.

These wastes contain many different radionuclides. Some of these nuclides emit alpha particles; others emit beta particles. Some radionuclides emit gamma rays in addition to alpha or beta particles. The radionuclides decay with half-lives ranging from less than one year to millions of years. We have concentrated our attention on radionuclides with half-lives greater than 20 years because they must be isolated from people for very long times. Thus, we exclude radionuclides such as tritium, krypton-85, and plutonium-241, which are present in large quantities in freshly discharged fuel, but they decay so rapidly that they do not require long-term isolation. Radionuclides with half-lives of 20 years or less will decay to less than 0.1% of their original activity in 200 years.

Reprocessing reactor fuel used for national defense activities has produced about 500 million curies of radionuclides with half-lives greater than 20 years. Most of the activity is due to strontium-90 and cesium-137. These wastes are stored in various liquid and solid forms on three Federal reservations in Idaho, Washington, and South Carolina. Relatively small additions are being made from ongoing defense programs.

Spent fuel from commercial nuclear power reactors contains about 800 million curies of radionuclides with half-lives greater than 20 years. About 10 million curies of this radioactivity are due to radionuclides,

Appendix c

such as plutonium, which emit alpha particles. Most of this spent fuel is stored at reactor sites. Over the next few years, this inventory is expected to grow at a rate of about 200 million curies per year from reactors currently licensed to operate. At some reactor sites, spent fuel storage capacity is almost used up. Plans to store additional spent fuel at locations away from reactor sites are under consideration by the Federal Government.

Nuclear reactors use some isotopes of uranium, plutonium, or thorium to produce energy from nuclear fission. These elements are commonly referred to as "heavy metals." The amount of wastes produced is roughly proportional to the amount of these elements placed into a reactor. We use the unit "wastes generated per metric ton of heavy metal (MTHM)" to measure the amount of waste placed in disposal systems. The amount of ore needed to produce one MTHM depends on the reactor type, degree of reprocessing, and quality of ore. For the light water reactors currently used in the United States, about 6,000 metric tons of uranium ore are used to produce one MTHM of reactor fuel. We have used this relationship to associate amounts of waste from reactor fuel with uranium ore.

The Agency's purpose in proposing these standards and guides is simply to protect the public health and the environment from the hazards these wastes present. We neither favor nor oppose nuclear power. Similarly, we do not advocate any particular method for disposing of these materials. We do require that any disposal method offer at least as much protection as the one we have assessed as part of the basis for these standards and guides.

DESCRIPTION OF THE PROPOSED ACTION

Under authorities established by the Atomic Energy Act and Reorganization Plan No. 3 of 1970, we are proposing generally applicable environmental standards and Federal radiation protection guides for disposing of these wastes. The Draft Environmental Impact Statement (EIS) published with this proposal includes detailed discussions of the reasons for our selections of proposed standards and guides, and provides extensive summaries of the technical analyses used. This preamble describes the proposed action and highlights features that we believe are of major interest.

The proposed standards and guides apply to spent reactor fuel, highly radioactive wastes derived from reprocessing spent fuel ("high-level wastes"), and to certain wastes containing long-lived radionuclides of elements heavier than uranium ("transuranic wastes"). Transuranic wastes are covered if they contain 100 nanocuries or more of alpha-emitting transuranic isotopes, with half-lives greater than one year, per gram of waste. People could receive, under some possible (but not likely) circumstances, more than 500 millirems per year from wastes containing more than 100 nanocuries of transuranic elements per gram if these wastes were not well isolated. 500 millirems per year is the Federal limit for individuals in the general population. Because these circumstances could last for very long times, we are proposing the same controls for these wastes as required for high-level wastes. Protection requirements for transuranic wastes containing less than 100 nanocuries per gram will be considered in future standards.

In developing the proposed standards, we estimated the risks from disposal systems that use methods of controlling releases which either are available now or are likely to be available in the near future. We also estimated the doses to individuals and populations from waste management. From these evaluations, we conclude that:

1. Any harm to people, including future generations, from the management and disposal of spent fuel, high-level, and transuranic wastes can be kept very small. The assessments which support this conclusion are outlined below and are discussed extensively in the Draft EIS.

2. These standards and guides adequately protect the public from harm. Under them, the risks to future generations from the wastes will be no greater than the risks from equivalent amounts of unmined uranium ore. These risks will also be less than the other risks currently associated with generating electricity from nuclear energy, and they will be very much less than the risks from natural background radiation.

In determining the release limits given in the standards, we had to project the performance of disposal systems which have not yet been demonstrated. There are significant uncertainties inherent in such projections. To avoid underestimating the risks associated with such systems, we assumed levels of performance that we are confident will be met by well-designed systems. Our estimates are, therefore, upper bounds of the risks. When actual control methods are selected and demonstrated at specific sites, estimated releases are likely to be well below the amounts allowed by the proposed standards. Accordingly, the proposed

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guides instruct the implementing agencies to reduce releases below these upper bounds to the extent reasonably achievable, taking into account technical, social, and economic considerations.

The standards apply to both management and disposal. Subpart A applies to management and includes storage, preparation of the wastes for disposal, and placing them in a disposal site. Off-site transportation is not covered. Subpart B applies to releases after the wastes are isolated enough so that it would be much harder to get them out of the disposal system than it was to put them in. With a geologic repository, for example, Subpart B would take effect when the mine was backfilled and sealed. The proposed Federal guides, included as Appendix A to the standards, apply only to disposal.

DECISION NOT TO PUBLISH GENERAL WASTE DISPOSAL CRITERIA

On November 15, 1978, we proposed general Federal Radiation Protection Guidance for the disposal of all types of radioactive wastes (43 FR 53262). After further thought, we believe that the characteristics of different kinds of radioactive wastes are too dissimilar for general criteria to be appropriate. Therefore, we do not plan to issue them. We believe the best course is to write a series of standards and guides for disposing of specific types of radioactive waste. The insights we gained from working on the general criteria have been useful in developing these standards and guides.

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REGULATORY ANALYSIS

Executive Order 12044, "Improving Government Regulations," requires Federal agencies to prepare a regulatory analysis for significant regulations. This analysis should contain: (1) a succinct statement of the problem, (2) a description of the major alternative ways of dealing with the problem, (3) an analysis of the economic consequences of each of these alternatives, and (4) a detailed explanation of the reasons for choosing one alternative over the others. EPA's plan (40 FR 30988) to implement Executive Order 12044 contains more detailed guidelines for the economic portions of a regulatory analysis.

Most of the topics required for a regulatory analysis are considered in this Federal Register notice and in the Draft EIS supporting this action. Both documents discuss the problems associated with these wastes and indicate why we are developing environmental standards and radiation protection guidance. The Draft EIS describes the possible alternative regulatory approaches that we considered, and it also explains why we chose this proposed action. We did not have sufficient information to determine the economic impacts of choosing either a more restrictive or a less restrictive numerical standard, because the data required to make such evaluations are not available now and may not be available for a long time. Our analyses are based only on information about the costs and effectiveness for a model of a mined deep geologic disposal repository. Both the cost and effectiveness of geologic disposal depend on the characteristics of the particular site. Information on cost and effectiveness for other methods is even more uncertain than for the mined geologic

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repository. As a result of these limitations, we have not been able to estimate the costs of different levels of protection. Therefore, economic considerations have played a very minor role in our comparison of alternatives.

We believe our proposed standards and guides provide adequate protection of public health and the environment. We think that they can be met by careful use of existing technologies, and would not cause unreasonable economic consequences.

Most of the information required for a regulatory analysis is also required for an environmental impact statement. Therefore, because of the lack of the required information described above, we did not prepare a separate regulatory analysis document.

The remainder of this notice describes our proposed action in more detail, summarizes its potential health and economic effects, and discusses the implementation of these requirements. In several places, we identify topics on which we would especially like comments.

(40 CFR 191 Subpart A)

WASTE MANAGEMENT

Certain operations required before disposing of high-level or transuranic radioactive wastes are not regulated under our Uranium Fuel Cycle Standards (40 CFR 190). These operations principally involve storage of the materials, solidification or other preparation for disposal, and placing the wastes in disposal sites. Subpart A applies to spent fuel management, regardless of whether the fuel is considered to be waste, except for management already regulated by 40 CFR 190.

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We estimated the largest expected radiation exposures to members of the public from waste management and storage operations associated with geologic disposal and found them to be somewhat smaller than the requirements set in 40 CFR 190. We propose to extend the limitations contained in Part 190 to the operations addressed by this new Part 191 for two reasons:

1. Other strategies for disposal could involve operations, such as chemical separation of transuranic elements, which are similar to those of spent fuel reprocessing. Reprocessing operations were a significant consideration in selecting the limits of 40 CFR 190. Setting the standards in Part 191 at the levels indicated by assessments based only on geologic disposal activities could preclude other disposal strategies which might be better.

2. Some of the operations addressed by Part 191 may take place near operations regulated by Part 190. Establishing different limitations for different operations at the same site would create difficult implementation problems with little, if any, additional public health protection. The provisions of Part 191 require the combined impacts from multiple operations to meet a single set of dose limitations which will be the same in both Parts 190 and 191.

Section 191.03 therefore requires that the combined annual dose equivalent to any member of the public due to operations covered by Part 190, and to direct radiation and planned discharges of radioactive materials covered by this Subpart, shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other

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organ. It also requires that waste management operations be conducted so as to reduce exposures for members of the public below this level to the extent reasonably achievable, taking into account technical, social, and economic considerations.

(40 CFR 191 Subpart B)

DISPOSAL

Standards and guides for the disposal of high-level and transuranic radioactive wastes require far different considerations than those for management. These include:

1. The intent of disposal is to isolate the wastes from the environment for a longer time than that over which active institutional controls, such as monitoring the disposal site to detect releases of radioactivity, can be relied upon for protection.

2. Disposal systems must be designed so that very little radioactivity will return to the environment if the system performs as intended. Thus, the principal concern is the possibility of unintentional releases, either due to unintended events or inadequacies in the disposal system.

These considerations have several ramifications for standards development. First, the standards can only be implemented in the design phase--by setting design principles or by analytically projecting disposal system performance. The more familiar concepts of implementation involving monitoring of emissions or ambient levels of pollutants are not applicable.

Second, the standards must address unintentional releases such as those resulting from human intrusion or geologic faulting. Their provisions must be applicable to a variety of disposal strategies because the

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Agency does not have the authority to specify details of disposal method designs. Regulations to be developed by the Nuclear Regulatory Commission (NRC) or DOE, as appropriate, will control specific designs.

Third, the standards must allow for unusually large uncertainties. These include both uncertainties in our current knowledge about disposal techniques and inherent uncertainties about the distant future.

We addressed these issues by developing both general criteria and projected performance requirements for disposal systems. The general criteria will be Federal guides and the projected performance requirements will be generally applicable environmental standards. These two parts of our proposed action are complementary: the general criteria provide qualitative requirements to reduce the chance of future environmental damage; the projected performance requirements set numerical limits on potential releases.

(APPENDIX A)

GENERAL CRITERIA

The proposed radiation protection guides given in Appendix A to the proposed 40 CFR 191 include these criteria:

1. The wastes should be disposed of promptly once adequate methods are available in order to reduce the chance of accidents during long-term storage. We have not established a time limit for this disposal, because the appropriate length of storage may depend on details on the disposal system design. For example, it may be desirable to store high-level wastes for ten years or more to allow for decay of most of the short-lived radionuclides. The primary intent of this criterion is to prevent wastes from being stored indefinitely in order to avoid ultimate disposal.

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2. Because they must be effective for so long, disposal systems should offer as much protection as is reasonably achievable.

3. Disposal systems should reduce the consequences of possible mistakes in selection, design, or construction by using several different types of barriers, both engineered and natural, and by taking full advantage of the protection each has to offer. With this redundancy, the unexpected failure of one or more barriers will be compensated for by other barriers. We could also have required that disposal systems meet the numerical performance requirements even if some of their barriers fail. Although additional protection would be provided by such a requirement, we do not believe that this is the best way to increase protection of the public. It would create difficult implementation problems, such as defining "barrier," and it could result in large additional costs and long delays. We believe that making the overall disposal system meet numerical performance requirements by taking advantage of substantial protection from each of its components will provide adequate protection most economically. However, we particularly seek comment on this issue.

4. Protection from the wastes should not depend on the ability of people to control them for more than 100 years after disposal, although measures which require human attention are useful supplements to passive controls.

5. The dangers and locations of disposal systems should be recorded in the most permanent ways practicable in order to reduce the chances of unintended disruption of disposal systems by future generations.

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6. Disposal systems should not be located where there has been mining for resources, or where there is a reasonable potential for future exploration for scarce or easily accessible resources. Furthermore, disposal systems should not be located where there is a significant concentration of any material which is not widely available from other sources. This criterion would discourage the use of geologic formations which are often associated with resources. For example, the frequent mining of salt domes either for their relatively pure salt or for use as storage caverns would argue against locating a repository in this type of structure. However, this same concern would generally not apply to bedded salt deposits because they are much more common. We particularly seek comment on this criterion because it could rule out sites which might otherwise be advantageous in meeting all of our other requirements.

7. Recovery of most of the wastes should be possible long after disposal if unforeseen events require this in the future, unless the wastes are removed from the Earth. The various isolation requirements of these standards would make recovery after disposal very difficult and expensive and probably dangerous. Nevertheless, because some of our scientific understanding may prove to be wrong in a way that would produce much greater risks than we expect, future generations must be able to recover the wastes if they deem it essential. An important implication of this requirement is that the physical location of the bulk of the wastes must be reasonably predictable after disposal. Current plans for mined geologic disposal would meet this requirement. However, some possible disposal methods, such as deep well injection of liquid wastes or rock melting concepts, may not. Since this requirement could eliminate some otherwise

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feasible and perhaps advantageous disposal methods, we particularly seek public comment about it.

Executive Order 12088 makes the head of each Executive agency responsible for compliance with these guides, once the President has approved them as Federal Radiation Guidance. In addition, the Order directs the Administrator of the Environmental Protection Agency to monitor compliance by Executive agencies and to review and approve required compliance plans. Conflicts on implementation may be resolved by the Director of the Office of Management and Budget. Exemptions may be granted by the President.

(SECTION 191.13)

PROJECTED PERFORMANCE REQUIREMENTS

The projected performance requirements assume that we can predict some aspects of the future well enough to use the predictions for selecting and implementing disposal methods. Assessment of any disposal plan will require the combination of assumptions about the future with engineering and design information about the disposal method and geologic data for the site. Such assessments can be used to decide whether a particular disposal method provides adequate protection and to compare various methods to determine the degree of protection that is reasonably achievable.

To develop these standards, we assessed the environmental impacts of high-level waste disposal in mined geologic repositories. Geologic repositories were chosen because much more information is available on this method than on others. The projected performance requirements,

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however, are meant to apply to any method of disposal except disposal directly into the oceans or ocean sediments. Thus, any other disposal method would have to provide at least as much protection as that projected for geologic disposal.

The standards do not apply to disposal in oceans or ocean sediments because such disposal of high-level waste is now prohibited by the Marine Protection, Research, and Sanctuaries Act of 1972 and the London Dumping Convention of 1972. However, disposal in deep ocean sediments is currently being studied and may prove to be a technically feasible option. Thus, we specifically request public comment on extending these standards to include possible ocean disposal methods so that, if the law and treaty were changed, these standards could apply to disposal of high-level waste in the oceans or ocean sediments.

In our assessments of geologic disposal, we identified expected and accidental releases of radioactivity from a generic model of a repository. The model repository contains 100,000 metric tons of heavy metal (MTHM) as spent reactor fuel, about as much as would be generated during the operating lifetimes of 100 reactors of current design. The initial amounts of some of the principal radionuclides in this model repository would be: eight billion curies of cesium-137; six billion curies of strontium-90; 200 million curies of americium-241; 30 million curies of plutonium-239; and one million curies of technetium-99.

We examined the capabilities of waste canisters, waste chemical forms, repository design, and geologic media to prevent or delay the release of radionuclides. We selected reasonably achievable characteristics for each

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portion of the disposal system. For accidental releases, we estimated the probabilities of events leading to releases. Intentional disruption of the disposal system was not considered.

Radionuclides were considered to be released from the disposal system if they reach the "accessible environment," which includes: surface waters, land surfaces, the atmosphere, and underground formations which might provide ground water for human consumption. Including these formations in the definition of "accessible environment" protects aquifers which might become significant sources of water in the future, regardless of whether they are now being used as water supplies.

We propose to use the designations to be established under Agency regulations for underground injection control (UIC) programs (40 CFR 146) to identify ground water supplies which should be part of the "accessible environment." Under these rules, most geologic formations which can provide useable quantities of water with a total dissolved solids (TDS) content less than 10 grams per liter are protected. Specific exceptions can be made for formations which are impractical sources of water, for example, because of depth or low productivity.

We plan to make one exception to the UIC procedure. The proposed disposal standards do not limit releases to geologic formations which are within one mile of a disposal system, because the formation itself can be an important barrier in a disposal system. A one-mile distance is long enough to allow significant retention of radionuclides by geologic barriers, but short enough so that only a very small part of available ground water could be significantly contaminated.

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Our regulations and the assessments on which we base them cover releases of radionuclides to the accessible environment for a period of 10,000 years after disposal. We believe that a disposal system capable of meeting these requirements for 10,000 years will continue to protect people and the environment beyond 10,000 years. We selected 10,000 years as the assessment period for three reasons:

1. It is long enough for releases through groundwater to reach the accessible environment. If we had selected a shorter time, such as 1,000 years, our estimates of radionuclides reaching the accessible environment would be deceptively low, because groundwater could take 1,000 years to travel a mile at a well-selected site, and most radionuclides would take much longer. Choosing 10,000 years for assessment encourages selection of sites where the geochemical properties of the rock formations can significantly reduce releases of radioactivity through groundwater.

2. Major geologic changes, such as development of a faulting system or a volcanic region, take much longer than 10,000 years. Thus the likelihood and characteristics of geologic events which might disrupt the disposal system are reasonably predictable over this period.

3. Radioactive decay will reduce the radionuclide inventory of the wastes to about 0.1% of its original value in 10,000 years. Any hazards from the radioactivity in the wastes will have decreased to about those from the equivalent amount of unmined ore.

We estimated the amounts of radioactivity that might reach the accessible environment over this time period under various circumstances. Then, the premature deaths from cancer caused by these releases were

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estimated using very general models of environmental transport and a linear, nonthreshold dose-effect relationship between exposure and cancers caused. This relationship assumes that the number of premature cancer deaths induced in a population is proportional to the total dose received by the population, even at very low individual doses, and does not depend on the population size.

Releases from geologic repositories fall into three general categories. Relatively small releases would be caused by expected processes and by fairly likely but unintended events, such as human intrusions. These processes and events lead to what we call "reasonably foreseeable" releases. Moderate releases would result from much less likely events, such as fault movements or other disruptive geologic events and these we call "very unlikely releases." Very large releases would result only from the intrusion of volcanos or impacts by huge meteorites. If sites are selected away from regions of volcanic activity, these large releases will be extremely unlikely.

We used our estimates of releases and their likelihood to select limits on total releases of radioactivity over 10,000 years. Limits were set for two categories of releases in terms of their probabilities: "reasonably foreseeable," and "very unlikely." Reasonably foreseeable releases are those which have more than one chance in 100 of occurring within 10,000 years. Very unlikely releases are those whose chance of occurring within 10,000 years is less than one in 100 and more than one in 10,000. No limits were set for releases which have less than one chance in 10,000 of occurring within 10,000 years.

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Our assessments of repository performance gave estimates of the possible premature cancer deaths expected from releases after disposal. These estimates can vary considerably depending upon the assumptions used and the geologic media considered. For well-designed 100,000 MTHM model repositories in salt and granite, we estimate several hundred premature deaths over 10,000 years. Because our analyses are too uncertain to determine reliably more than the order of magnitude of the risks, we adjusted our estimates to 1,000 premature deaths over 10,000 years for a 100,000 MTHM repository. We then used these adjusted estimates as the basis for calculating the release limits specified in Appendix B of the standards.

According to our model, more of the projected harm from releases results from possible human instrusions than from geologic processes. However, predicting human actions is much more uncertain than predicting natural events. In particular, we could only guess at the frequency at which some actions (such as drilling for resources) would be taken. We considered setting separate performance requirements that would limit the radioactivity that could be released by any one likely human intrusion, in order to avoid having to estimate such frequencies. However, we did not do this because: (1) setting separate requirements for natural and human events would not place an upper limit on risk; and (2) setting separate requirements for individual intrusions in addition to the total combined requirements would not appreciably increase confidence that the overall limits would be met unless we made the individual limits unreasonably low. We specifically request comments on this issue.

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The release limits are given in Table 1 in terms of curies per 1,000 MTHM. The release limit for each radionuclide is the number of curies of that radionuclide that we estimate could cause 1,000 premature deaths over 10,000 years if it were the only radionuclide released from a 100,000 MTHM repository. For releases involving more than one radionuclide, the allowed release for each radionuclide is reduced to the fraction of its limit that insures that the overall limit on harm is not exceeded. For transuranic wastes, the release limits are in units of an amount of wastes containing three million curies of alpha-emitting transuranic radionuclides. These units were chosen so that the standards would require alpha-emitting radioactivity from either high-level or transuranic wastes to be isolated with about the same degree of effectiveness. This procedure for using the release limits is described in Appendix B to the proposed standards. Compliance with these performance requirements will be achieved if the projected releases from a disposal system do not exceed these release limits.

EFFECTS ON HEALTH

A disposal system that could hold wastes from 100,000 MTHM could contain all existing wastes and the future wastes from all currently operating reactors. We estimate that this quantity of wastes, when disposed of in accordance with the proposed standards, would cause no more than 1,000 premature deaths from cancer in the first 10,000 years after disposal: an average of one every 10 years.

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Our estimate of 1,000 deaths over 10,000 years is not intended to be a precise projection of the actual risk from waste disposal. Food chains, ways of life, and the size and geographical distributions of populations will undoubtedly change over any 10,000 year period. Unlike geological processes, factors such as these cannot be accurately predicted over long periods of time. Thus, in making our health effects projections we found it necessary to depend upon the use of very general models of environmental pathways, and to assume current population distributions and death rates. As a consequence, these projections are intended to be used primarily as a tool for comparing the performance of one waste disposal system to another and for comparison of the risks of waste disposal with those of undisturbed ore bodies. The results of our analysis should not be considered a reliable projection of the "real" or absolute number of health effects resulting from compliance with our standards.

Most of the excess cancer deaths caused by the waste would occur more than 1,000 years after disposal. This discontinuity between when the wastes are generated and when the projected health effects manifest themselves has resulted in a particularly difficult problem in determining what level of residual risk should be reasonably permitted by these standards. The difficulty arises from the fact that most of the benefits derived in the process of waste production fall upon the current generation while most of the risks fall upon future generations. Thus, a problem of intergenerational equity with respect to the distribution of risks and benefits becomes apparent. This problem is sometimes referred

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to as the intergenerational risk issue, and it is not unique to the disposal of high-level radioactive wastes. If we were to insure that our standards fully satisfy a criterion of intergenerational equity with respect to the distribution of risks and benefits, it appears we should require that no risk be passed on to future generations. This is a condition which we conclude cannot be met by disposal technologies foreseeable within this century.

In the face of this dilemma, we are left with two major options: (1) delay setting standards in the hope that future technologies would provide better control, or (2) proceed to set standards on the basis of the best technology that can reasonably be achieved given current scientific, technical, and fiscal capabilities. We have chosen the latter approach. In so doing we have made the judgment that current knowledge is sufficient to allow for the development of repositories which will reduce risks to a reasonable level. We believe these risks are reasonable because they are very small and the only alternative available is to delay disposal to some indefinite time in the future.

There is one additional factor which has contributed to our decision on the reasonableness of the risks permitted under our proposed standards. This is an analysis we have prepared of the risks associated with undisturbed uranium ore bodies.

<u>Uranium Ore:</u> Most uranium ore in the United States occurs in permeable geologic strata containing flowing ground water. Radionuclides in the ore, particularly uranium and radium, continuously enter this

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ground water. We estimated the harm from these undisturbed ore bodies using the same environmental models that we used for releases from the waste repository. The effects associated with the amount of ore needed to produce the high-level wastes that would fill the model geologic repository can vary considerably. Part of this variation corresponds to actual differences from one ore body to another; part can be attributed to uncertainties in the assessment. The estimates ranged from 300 to 1,000,000 excess cancer deaths over 10,000 years. Thus, leaving the ore unmined presents at least as great a risk to future generations as disposal of the wastes covered by these standards.

It remains unclear to us whether this analysis provides an adequate means of resolving the question of intergenerational risk. It has, however, helped to influence our decision of what is an acceptable level of residual risk given our current scientific, technological, and fiscal capabilities. We particularly invite comment upon the questions of intergenerational risk and the acceptability of risk. Additionally, for purposes of comparisons of risks permitted under the standards to radiation risks we are currently exposed to, we have included a brief discussion of the risks from natural background and from the uranium fuel cycle.

Variations in Natural Background: Radionuclides occur naturally in the earth in very large amounts, and are produced in the atmosphere by cosmic radiation. Everyone is exposed to natural background radiation from these natural radionuclides and from direct exposure to cosmic

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radiation. These natural background radiation levels have remained relatively constant for a very long time. According to the same linear, nonthreshold dose effect relationship used in the other analyses, an increase of one millirem per year (about one percent) in natural background in the United States would result in about 40 additional deaths per year, or 400,000 over a 10,000 year period. Natural background rates vary within the United States by tens of millirems per year, and future generations will experience this same variation.

Nuclear Power Generation: The model geologic repository considered in developing these standards contains the wastes produced in generating about 3,000 gigawatt-years of electricity. This is the output of about 100 large nuclear power plants operating for 40 years each. We estimate that the normal operations of these reactors and their supporting facilities, such as uranium mills and fuel fabrication plants (but excluding uranium mines), will cause about 3,000 excess deaths in the first 100 years after the power is produced. (These estimates do not include deaths from any accidental radioactive releases at these facilities.) Therefore, risks to future generations from disposal of high-level wastes are significantly less than the risks to the generations receiving the immediate benefits from the electric power generated.

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ECONOMIC ANALYSIS

The proposed standards for disposal of high-level radioactive wastes will be applied to a developing technology, where the available information base is still incomplete. Therefore, it is difficult to determine the added costs of compliance with the standards. Instead, we have designated a reference program, which is based on disposal cost estimates previously published by DOE. We then increased these DOE estimates to allow for additional expenditures which might be needed to implement a high-level waste disposal program in full compliance with our proposed standards and guides. The difference between the cost of the reference program and the cost of a program in compliance with these proposed standards does not necessarily represent the cost of implementing these standards. In fact, it seems likely that prudent considerations and current public opinion will require that any waste disposal method will cost more than the earlier DOE estimates. Thus, the incremental difference represents our estimate of the maximum potential economic impact of the proposed standards. Commercial and military high-level wastes are considered separately in this section.

Commercial Waste

We assumed a reference waste management and disposal program based upon studies performed by DOE to support the President's spent fuel policy. This reference program involves the geologic disposal of spent fuel in salt formations using carbon steel canisters. We based our estimates of the economic impacts of this reference program on potential charges to

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utilities for waste management services to be provided by the Government. From the DOE analyses, we estimate that the cost to utilities in 1990 would range from 0.6 to 1.4 (1978) mills per kwh. The total annual cost for 1990 would be 500 million to 1.2 billion (1978) dollars. This charge covers all waste management costs, except for reactor site storage of spent fuel. The year 1990 was selected because the DOE estimates were based on the waste management program being established by then.

We assessed the costs, above those for the reference program, that might be caused by our proposal. First, we estimated the cost for each component involved in the management and disposal of spent fuel. The costs of the management and disposal of spent fuel include: storage of spent fuel for ten years after discharge from the reactor, which covers both reactor-site and away-from-reactor storage; transportation of the spent fuel from the storage site to a facility designed for encapsulation of the waste; the encapsulation of the waste, which includes the necessary handling and processing before disposal; disposal in a geologic repository; Government research and development; Government overhead; and decommissioning of waste management facilities and post-operational activities.

Three of these components may be affected by this action. Encapsulation costs may be larger if compliance requires more durable canisters (e.g., stainless steel or titanium canisters). Disposal costs, which include constructing, operating, and backfilling a geologic repository, will be affected if compliance requires the use of geologic media which are more expensive to mine than salt formations (e.g., granite). Research and development costs may increase because of additional site evaluation

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and additional research for improved control technologies (e.g., more stable waste forms). Based on these three possible effects, we estimate that the proposed action could result in commercial waste management costs up to 50 percent larger than those for the reference program. The total waste management costs would increase the cost of nuclear generation of electricity by about 10 percent. We estimate the total annual cost of the waste management program in compliance with the standards in 1990 as no more than 1.8 billion (1978) dollars. These waste management and disposal costs would be less than 3 percent of total electric utility revenues in 1979, and should be a smaller portion of future revenues. Thus, they should cause no more than a 3 percent average increase in future electricity rates.

Military Waste

We considered a DOE reference program based on disposal in on-site geologic repositories. We estimated that the total cost of this reference program would be about 3.7 billion (1978) dollars to dispose of all existing military wastes and additional military wastes generated through 1990. The present value of this reference program cost, at a discount rate of 10 percent, is 1.8 billion (1978) dollars.

Our proposed requirements could increase this cost in five areas: waste processing, encapsulation, transportation, disposal, and research and development. In the reference program, long-lived technetium-99 would be left in processed salt cake and stored in existing on-site tanks. Under our standards, additional processing would be required to separate

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technetium-99 for disposal. Encapsulation costs would be increased if a canister providing greater protection is needed. Transportation would cost much more if the high-level wastes must be disposed of off-site. If the selected off-site geologic media are more difficult to mine than the on-site media, disposal costs may be increased. Research and development costs would be increased because more extensive site evaluation and research on better control technologies may be needed.

We calculated the extra costs for each of these areas, considering both projected costs and potential delays. We estimated that the extra costs could be as large as 1.7 billion (1978) dollars, for a total defense waste program cost of 5.4 billion (1978) dollars. This would be an increase of almost 50 percent over the cost of the reference program. Our estimate of the present value of the additional cost is 320 million (1978) dollars, for a total discounted cost for the defense waste program of 2.1 billion (1978) dollars. This would be an increase of less than 20 percent over the discounted cost of the reference program.

IMPLEMENTATION

Standards for operations (Subpart A) will be implemented by the NRC for commercial nuclear power activities and by the DOE for national defense facilities. Implementation procedures for Subpart A will be very similar to those for the Uranium Fuel Cycle Standards (40 CFR 190).

DOE will select, design, and construct all disposal facilities for high-level and transuranic wastes. Our requirements for disposal (Subpart B and Appendix A) will be implemented by NRC for all high-level

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wastes, whether the wastes come from commercial or military activities. NRC will do this by developing the necessary regulations (primarily 10 CFR 60) and by issuing appropriate licenses to DOE. Under current law, disposal of transuranic wastes from military activities is not regulated by NRC; therefore, DOE will apply our requirements to the disposal of these transuranic wastes.

The standards for disposal must be implemented through design specifications. The implementing agency will have to evaluate long-term performance projections of the designed system. As a result, a vital part of implementation will be the use of adequate models, including the probabilities of unplanned events, to relate appropriate site and engineering data to projected performance.

The NRC has made substantial progress in developing such analytical models to predict long-term performance of actual geologic repositories. These models include estimates of the effects of uncertainties in the data. Thus, they give information about needs for obtaining better data to determine if repositories meet the projected performance requirements of these standards.

At our request, the National Academy of Sciences (NAS) studied the difficulties in verifying compliance with the long-term environmental protection requirements for geologic disposal. They have developed an approach that specifies the types of information needed and outlines appropriate methods for obtaining this data at prospective sites.

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Based on the NAS study, NRC's models, and our own analytical efforts, we have concluded that these disposal standards can be implemented. We believe that it would be best if implementing agencies use generic rule-making proceedings. Such proceedings would consider comprehensive risk assessments which calculate potential releases of radionuclides from various events or processes. The assessments would identify the important engineering design and site selection parameters and would indicate how potential releases depend on these parameters. The generic proceedings would then be able to establish limits for the important design and site parameters which, if met, would provide a reasonable expectation of compliance with these standards. Only these limits would need to be satisfied in subsequent licensing actions. We believe generic proceedings are the best way to proceed because the methods needed to address uncertainties could be developed more easily through generic rulemaking than in specific licensing actions.

DATED:

Administrator

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A new Part 191 is proposed to be added to Title 40, Code of Federal Regulations, as follows:

SUBCHAPTER F - RADIATION PROTECTION PROGRAMS

PART 191 - ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR MANAGEMENT AND DISPOSAL OF SPENT NUCLEAR FUEL, HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

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Appendices

Appendix A General Criteria for Disposal of High-Level and Transuranic Radioactive Wastes

Appendix B Release Limits for Projected Performance Requirements

AUTHORITY: The Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3 of 1970.

SUBPART A - ENVIRONMENTAL STANDARDS FOR MANAGEMENT AND STORAGE

191.01 Applicability

This Subpart applies to radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel, high-level, or transuranic radioactive wastes, to the extent that these operations are not subject to the provisions of Part 190 of Title 40.

191.02 Definitions

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of Part 190.

(a) "Spent nuclear fuel" means any nuclear fuel removed from a nuclear reactor after it has been irradiated.

(b) "High-level radioactive wastes" means: (i) wastes resulting from the operation of the first cycle solvent extraction system, or

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equivalent, in a facility for reprocessing spent nuclear fuels; (ii) the concentrated wastes from subsequent extraction cycles, or equivalent; (iii) solids derived from such wastes; or (iv) spent nuclear fuel if disposed of without reprocessing.

(c) "Transuranic wastes," as used in this Part, means wastes containing more than 100 nanocuries of alpha emitting transuranic isotopes, with half-lives greater than one year, per gram of waste.

(d) "Storage" means placement of radioactive wastes with planned capability to readily retrieve such materials.

(e) "Management and storage" means any activity, operation, or process, except for transportation, conducted to prepare spent nuclear fuel, high-level or transuranic radioactive wastes for storage or disposal, the storage of any of these materials, or activities associated with the disposal of these materials.

(f) "General environment" means the total terrestial, atmospheric, and aquatic environments outside sites within which any operation associated with the management and storage of spent nuclear fuel, high-level or transuranic radioactive wastes is conducted.

(g) "Member of the public" means any individual who is not engaged in operations involving the management, storage, and disposal of materials covered by these standards and guides. A worker so engaged is a member of the public except when on duty at a site.

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191.03 Standards for Normal Operations

Operations covered by this Subpart should be conducted so as to reduce exposures to members of the public to the extent reasonably achievable, taking into account technical, social, and economic considerations. As an upper limit, except for variances in accordance with 191.04, these operations shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public due to: (i) operations covered by Part 190, (ii) planned discharges of radioactive material to the general environment from operations covered by this Subpart, and (iii) direct radiation from these operations; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, or 25 millirems to any other organ.

191.04 Variances for Unusual Operations

The standards specified in 191.03 may be exceeded if:

(a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is in the public interest, and

(b) Information is promptly made a matter of public record delineating the nature of the unusual operating conditions, the degree to which this operation is expected to result in levels in excess of the standards, the basis of the variance, and the schedule for achieving conformance with the standards.

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191.05 Effective Date

The standards in this Subpart shall be effective 12 months from the promulgation date of this rule.

SUBPART B - ENVIRONMENTAL STANDARDS FOR DISPOSAL

191.11 Applicability

This Subpart applies to radioactive materials released into the accessible environment as a result of the disposal of high-level or transuranic radioactive wastes, including the disposal of spent nuclear fuel. This Subpart does not apply to disposal directly into the oceans or ocean sediments.

191.12 Definitions

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of this Part.

(a) "Disposal" means isolation of radioactive wastes with no intent to recover them.

(b) "Underground sources of drinking water" means aquifers which have been designated as such under Part 146 of Title 40.

(c) "Accessible environment" means the Earth's atmosphere, land surface, surface waters, and those underground sources of drinking water that are more than one mile in any direction from the original location of the radioactive wastes in a disposal system.

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(d) "Barriers" means any materials or structures that prevent or substantially delay movement of the radioactive wastes toward the accessible environment.

(e) "Disposal system" means any combination of engineered and natural barriers that contains radioactive wastes after disposal.

(f) "Reasonably foreseeable releases" means releases of radioactive wastes to the accessible environment that are estimated to have more than one chance in 100 of occurring within 10,000 years.

(g) "Very unlikely releases" means releases of radioactive wastes to the accessible environment that are estimated to have between one chance in 100 and one chance in 10,000 of occurring within 10,000 years.

(h) "Performance assessment" means an analysis which identifies those events and processes which might affect the disposal system, examines their effects upon its barriers, and estimates the probabilities and consequences of the events. The analysis need not evaluate risks from all identified events. However, it should provide a reasonable expectation that the risks from events not evaluated are small in comparison to the risks which are estimated in the analysis. The analysis should address the uncertainties in the estimates. To provide reasonable confidence in its results, the analysis shall be subjected to peer review by technically competent individuals independent of the organization preparing the assessment.

(i) "Heavy metal" means all uranium, plutonium, or thorium placed into a nuclear reactor.

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191.13 Projected Performance Requirements

(a) Disposal systems shall be designed to comply with the projected performance requirements of this section. These requirements are upper limits. In accordance with Appendix A, the implementing agency should establish design objectives which will reduce releases as far below these limits as reasonably achievable.

(b) Disposal systems for high-level or transuranic wastes shall be designed to provide a reasonable expectation, based upon quantitative performance assessments, that for 10,000 years after disposal:

(1) Reasonably foreseeable releases of waste to the accessible environment are projected to be less than the quantities calculated according to Appendix B.

(2) Very unlikely releases of waste to the accessible environment are projected to be less than ten times the quantities calculated according to Appendix B.

191.14 Effective Date

The standards in this Subpart shall be effective immediately upon promulgation of this rule.

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APPENDIX A - GENERAL GUIDANCE FOR

DISPOSAL OF HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

The general guidance recommended in this appendix, when approved by the President, would provide radiation protection guidance to all Federal agencies in accordance with Executive Order 10831 and 42 U.S.C. 2021(h). Disposal systems for high-level or transuranic wastes should comply with each of the following recommendations:

Recommendation 1: Wastes should be disposed of promptly once disposal systems which comply with these standards are developed.

Recommendation 2: Disposal systems should be designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations.

Recommendation 3: Disposal systems should use several different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers should be included. Each such barrier should separately be designed to provide substantial isolation, regardless of how well the other barriers perform.

Recommendation 4: Active institutional controls should not be relied upon to isolate the wastes for more than 100 years after disposal.

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Recommendation 5: Disposal systems should be identified by the most permanent markers and records practicable to indicate the dangers of the wastes and their location.

Recommendation 6: Disposal systems should not be located where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or easily accessible resources in the future. Furthermore, disposal systems should not be located where there is a significant concentration of any material which is not widely available from other sources.

Recommendation 7: Disposal systems should be designed so that most of the wastes may be recovered if this is found necessary in the future, unless the wastes are removed from the Earth.

DEFINITIONS:

(1) "Active institutional controls" means maintaining an institutional capability to: (i) restrict or deny access, (ii) monitor, terminate, or clean up releases to the accessible environment, or (iii) preserve knowledge about the location, design, or inventory of a disposal site.

(2) All other terms shall have the same meaning as in 40 CFR 191.

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APPENDIX B - RELEASE LIMITS FOR PROJECTED PERFORMANCE REQUIREMENTS

NOTE 1: The Release Limits in Table 1 apply either to the amount of high-level wastes generated from 1,000 metric tons of heavy metal (MTHM), or to an amount of transuranic (TRU) wastes containing three million curies of alpha-emitting transuranic radionuclides. To develop Release Limits for a particular disposal system, the quantities in Table 1 shall be adjusted for the amount of wastes included in the disposal system. For example:

(a) If a particular disposal system contained the high-level wastes from 50,000 MTHM, the Release Limits for that system would be the quantities in Table 1 multiplied by 50 (50,000 MTHM divided by 1,000 MTHM).

(b) If a particular disposal system contained 15 million curies of transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by five (15 million curies divided by three million curies).

(c) If a particular disposal system contained both the high-level wastes from 50,000 MTHM and 15 million curies of transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by 55:

$$\frac{50{,}000 \text{ MTHM}}{1{,}000 \text{ MTHM}} + \frac{15{,}000{,}000 \text{ curies TRU}}{3{,}000{,}000 \text{ curies TRU}} = 55$$

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NOTE 2: In cases where a mixture of radionuclides is projected to be released, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 1 and Note 1. The sum of such ratios for all the radionuclides in the mixture may not exceed one.

For example, if radionuclides A, B, and C are projected to be released in amounts Q_a, Q_b, and Q_c, and if the applicable Release Limits are RL_a, RL_b, and RL_c, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} \leq 1$$

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April 11, 1983

SECY-83-59B

RULEMAKING ISSUE
(Affirmation)

For: The Commissioners

From: William J. Dircks
Executive Director for Operations

Subject: 10 CFR PART 60--DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS (SECY-83-59)

Purpose: To provide the staff's proposed responses to the comments of Commissioners Gilinsky and Ahearne on SECY-83-59.

Discussion: On February 9, 1983, final 10 CFR Part 60 technical criteria and conforming amendments were forwarded to the Commissioners as SECY-83-59. Comments on SECY-83-59 were received from Commissioners Gilinsky and Ahearne on March 16, 1983, and March 9, 1983, respectively (Enclosures B and C). This paper forwards the staff's proposed responses to the comments of Commissioners Gilinsky and Ahearne in the form of appropriate changes, shown in comparative text, to Enclosures A and G of SECY-83-59.

Commissioner Gilinsky's comment concerned the definition of "geologic repository," Enclosure A, pages 36 and 86. Commissioner Ahearne's comments were seven in number, identified below by enclosure, section heading and page number(s):

Contacts:
P. A. Comella (427-4616)
M. J. Bell (427-4612)
J. R. Wolf (492-8694)

Comment No. 1	Encl. A, ALARA, pp. 14-15
Comment No. 2	Encl. A, Single vs. Multiple Performance Standards, p. 8
Comment No. 3	Encl. A, Important to Safety, p. 27
Comment No. 4	Encl. A, Important to Safety, p. 27
Comment No. 5	Encl. A, § 60.2, "Definitions," p. 85
Comment No. 6	Encl. A, Section-by-Section Analysis, pp. 42-43, and § 60.21, "Content of Application," p. 97
Comment No. 7	Encl. G, Engineered Barrier System Containment Time Requirement, pp. 73-74

A revised p 119 of Enclosure A corrects a spelling error.

It should also be noted that minor stylistic and format changes will be made to the final rule contained in SECY-83-59 to conform to Federal Register requirements.

William J. Dircks
Executive Director for Operations

Enclosures:
A - Changes to Enclosures A and G of SECY 83-59 (in comparative text)
B - Commissioner Gilinsky's comments on SECY 83-59
C - Commissioner Ahearne's comments on SECY 83-59

Commissioners' comments should be provided directly to the Office of the Secretary, ASAP, or along with your vote on SECY-83-59, if you have not yet acted on it.

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ENCLOSURE A

of repository performance. For cases analyzed by the Commission on the basis of specified assumptions, a range of 300 years to 1,000 years would be appropriate. (These values appear in § 60.113(a)(ii)(A)). Yet even a shorter designed containment period might be specified, pursuant to § 60.113(b), in the light of conditions that are materially different from those that had been assumed. For example, if the wastes had been processed to remove the principal heat-generating radionuclides (cesium-137 and strontium-90), the 300-years provision would not be controlling. Similarly, the Commission may approve or specify a radionuclide release rate or a pre-waste-emplacement groundwater travel time that differs from the normal values, provided that the EPA standard, as it relates to anticipated processes and events, is satisfied. Appropriate values will be determined in the course of the licensing process, in a manner sensitive to the particular case, using the principles set out in the performance objectives, without having to have recourse to the exemption provisions of the regulations.

The numerical criteria for the individual barriers included in the rule are appropriate, insofar as anticipated processes and events are concerned, in assisting the Commission to determine with reasonable assurance that the proposed EPA standard has been satisfied. It should be noted, however, that in order to meet the EPA standard as it applies to unanticipated processes and events, higher levels of individual barrier performance may be required. <u>DOE would need to provide in its design for such performance as may be necessary to meet the EPA standard with respect to such unanticipated processes and events even though in all other respects the values specified by § 60.113(a) and § 60.113(b) would be sufficient</u>.

<u>Retrievability</u>

The purpose of this requirement was to implement in a practical manner the licensing procedures which provided for temporal separation of the emplacement decision from the permanent closure decision. Since the period of emplacement would be lengthy and since the knowledge of expected repository performance could be substantially increased through a carefully planned program of testing, the Commission wished to base its decision to permanently close on such information. The only way it could envision this was to insist that ability to retrieve - retrievability - be incorporated into the design of the geologic repository.

The proposed rule would have required in effect that the repository design be such as to permit retrieval of waste packages for a period of

ALARA

The notice of proposed rulemaking requested comment on "whether an ALARA (as low as reasonably achievable) principle should be applied to the performance requirements dealing with containment and control of releases." Some commenters believed that ALARA should be applied to all licensed activities, and that no exception should be made for geologic repositories. Other commenters argued against incorporating ALARA, since the allowable releases under the EPA standard would already be so low as to eliminate any significant risk to public health and safety.

Based in part upon the standard recently proposed by EPA, the Commission considers it reasonable to anticipate that the permissible amounts of radioactivity in the general environment will be established at [such] a very low level. [that-efforts-to-reduce-releases-further-would have-little,-if-any,-demonstrable-value-commensurate-with-their-costs. Accordingly,-the-ability-of-a-geologic-repository-to-perform-at-levels superior-to-the-EPA-standard-should-not-be-the-issue-in-licensing-proceedings.--The-central-issue-with-respect-to-the-EPA-standard-is-whether DOE's-proposal,-and-the-data-presented-in-its-support,-will-enable-the Commission-to-determine-with-reasonable-assurance-that-the-established EPA-standard-will-be-met.--The-Commission-may-insist-upon-the-adoption-of a-variety-of-design-features,-tests,-or-other-measures-in-order-to-be able-to-conclude-with-confidence-that-the-EPA-standard-is-met.--The-result may-be-the-same-as-if-the-Commission-were-to-impose-similar-requirements in-the-name-of-keeping-releases-as-low-as-reasonably-achievable.--But when-the-Commission-finds-that-certain-measures-are-needed-to-improve confidence-in-dealing-with-uncertainties,-it-is-making-a-substantial safety-judgment.

The-same-kinds-of-balancing-that-are-undertaken-in-ALARA-determinations-may-be-appropriate.--That-is,-if-confidence-in-the-performance-of the-geologic-repository-is-sensitive-to-a-particular-source-of-uncertainty,-it-will-be-in-order-for-the-Commission-to-take-into-account-both the-significance-of-the-factor-involved-and-the-costs-of-reducing-or eliminating-it.] In fact, the statement of considerations accompanying EPA's proposed rule explains that the releases from a mined geologic repository, if kept within the numerical "containment requirements," would result in "low levels of exposures" and that the health effects "certainly would not be distinguishable from natural occurrences of cancer." EPA's statement goes on to indicate that appropriate measures must be taken, in light of the uncertainties involved in predicting repository performance, to assure that the "containment requirements" will be met. One of the measures identified by EPA would be the selection and design of disposal systems to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations. The Commission is concerned about this "ALARA" aspect of the proposed EPA standard for three reasons. First, it introduces a significant ambiguity into the standard of performance. Under the proposed standard, not only would a license application have to be reviewed to determine whether releases would meet the numerical standard of the containment requirements, there would also have to be a demonstration that the releases would meet an unspecified ALARA standard. Second, given the uncertainties that will need to be considered with respect to any proposed repository, a requirement to evaluate performance, in formal adjudicatory proceedings, under an ALARA standard could well prove to be administratively unmanageable. Third, the means to be applied to assure confidence in meeting prescribed limits on quantities of radioactive material in the general environment is a matter of implementation strategy to be determined by the Commission (and, in fact, the formulation of appropriate means to assure such confidence has been the principal concern of the Commission in preparing both its licensing procedures and its technical criteria).[5]

In the Commission's view, the central issue with respect to the EPA standard is whether DOE's proposal, and the data presented in its support, will enable the Commission to determine with reasonable assurance that the established EPA standard will be met. The Commission may insist upon

[5]The Commission is recommending to EPA that proposed §191.14(b) be omitted from the final rule. If it is retained, however, the Commission intends to consider once again whether or not, and how, such provision should be reflected in 10 CFR Part 60. The Commission emphasizes that its rules accommodate the underlying concerns of EPA, as articulated in its statement of considerations, that measures must be taken to assure confidence that the numerical release limits will be met.

the adoption of a variety of design features, tests, or other measures in order to be able to arrive at this conclusion. If confidence in the performance of the geologic repository is sensitive to a particular source of uncertainty, it will be in order for the Commission to take into account both the significance of the factor involved and the costs of reducing or eliminating it. While this would involve the same kinds of balancing that EPA indicates would be desirable, it should clearly be understood that the ultimate standard of performance is that which EPA has defined numerically.

In short, the Commission has concluded that the long-term performance requirements should not be tied to an ALARA principle, and the rule remains as it was when proposed. The Commission believes the concerns of the commenters in support of the ALARA approach will be largely accommodated in connection with its treatment of uncertainties in the course of the licensing process.[5]

Human Intrusion

The Commission observed, in the preamble of the proposed rule, that everything that is reasonable should be done to discourage people from intruding into the geologic repository. Those measures which it believed to be reasonable included directing site selection toward sites having little resource value and marking and documentation of the site. Beyond that, the Commission felt there would be no value in speculating on the "virtual infinity of human intrusion scenarios and whether they will or will not result in violation of the EPA standard." The Commission explained that inadvertent intrusion was highly improbable, at least for the first several hundred years during which time the wastes are most hazardous; and even if it should occur, it is logical to assume that the intruding society would have capability to assess the situation and mitigate consequences. The Commission recognized that deliberate intrusion to recover the resource potential of the wastes could result in elevated releases of radioactivity, but concluded that the acceptability of such releases was properly left to those making the decision to undertake resource recovery operations. It noted that comment on its proposal and alternative approaches would be welcome.

[~~5 The proposed EPA standard calls for disposal systems to be selected and designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations. Proposed 40 CFR § 191.14(b). The Commission's rules will accommodate the underlying concerns of EPA, as they are articulated in the preamble to the Agency's proposed standards. There EPA explains that it is concerned, as is the Commission, with assuring confidence in complying with the numerical release limits. The Commission also notes that the definition of "generally applicable environmental standards" in Reorganization Plan No. 3 of 1970 refers to limits such as those contained in proposed § 191.13 and related definitions. Accordingly, the Commission would not contemplate making any revision to its rule even if EPA were to adopt a provision such as proposed § 191.14(b). Because of the measures that will be required to address the uncertainties, the Commission fully expects that actual releases are likely to be well below the upper bounds expressed in the EPA standard.~~]

commenters, the materials received and possessed at a HLW facility will be in a form, and the operations that are carried out will be of a nature, that little potential exists for large releases of radioactive materials to unrestricted areas. The choice of 0.5 rem in this instance should not be construed as implying that it would be appropriate if applied to any other types of activities subject to regulation by the Commission. (The permissible annual dose in unrestricted areas--now 0.5 rem--is currently under review. The Commission contemplates that if this dose limit were to be revised, a corresponding change would be considered here.)

[The-term-"important-to-safety"-has-traditionally-been-linked-to structures;-systems;-and-components-which-must-operate-under-accident conditions-in-a-manner-that-will-prevent-serious-offsite-consequences. The-proposed-rule-inappropriately-referred-to-structures;-systems;-and components-which-must-operate-to-meet-the-performance-objectives--including those-pertaining-to-long-term-isolation-under-anticipated-conditions--as being-"important-to-safety."--The-effect-of-this-was-to-extend-accident-related-design-criteria-to-elements-not-subject-to-relevant-kinds-of-accidents. Design criteria related to isolation are important, and are included, but not because the structures, systems, and components in question are "important to safety." [in-the-traditional-sense.]

"Important to safety" is also important in defining the actions that are necessary elements of a quality assurance program. For a geologic repository, however, quality assurance must be extended to structures, systems, and components important to waste isolation. Since, [for-the reasons-discussed-above;] these concerns [are] would no longer be encompassed by the term "important to safety," the quality assurance provisions have been amended to apply to structures, systems, and components "important to waste isolation" as well.

Also, the proposed rule inappropriately referred to structures, systems, and components which must operate to meet the performance objectives--including those pertaining to long-term isolation--as being "important to safety." The effect of this was to extend accident-related design criteria to elements not subject to relevant kinds of accidents.

Commission considers this definition to be synonymous with the term "engineered barriers" which appears at Section 2(11) of the Nuclear Waste Policy Act of 1982.

"Far field." The term "far field" has been deleted from the rule. Therefore, the definition is no longer necessary.

"Floodplain." Deleted. This definition was taken from Executive Order 11988, which relates to environmental consequences of occupancy and modification of floodplains. Those effects need to be considered as part of the Commission's environmental review, but they do not implicate the radiological concerns that are addressed in Part 60. The term "floodplain" still appears in §60.122(c)(1). However, rather than establishing any particular frequency as the means for defining its extent, the Commission will allow the factors specified in §60.122(a)(3) to be used in assessing the significance of flooding, whenever it may occur.

"Geologic repository." Clarifying change, to bring the terminology into line with common usage. The new definition includes only that portion of the geologic setting that provides isolation - not the entire geologic setting. The term, as defined, is considered to be synonymous with "repository" as defined at Section 2(18) of the Nuclear Waste Policy Act. <u>(The added clause "or may be used for" conforms to the statutory definition as well as the definition in existing Part 60).</u>

"Geologic setting." See <u>Terminology</u>, above. The phrase "spatially distributed" was superfluous and has been deleted.

"High-level radioactive waste." The Nuclear Waste Policy Act distinguishes between "high-level radioactive waste" and "spent nuclear fuel." These technical criteria are applicable equally to both categories. Accordingly, no change in the definition of high-level radioactive waste is required at this time.

"Important to safety." See <u>"Important to Safety,"</u> above.

§ 60.21(c)(8)

Section 60.21(c)(8) required a description of controls to restrict access. After permanent closure, monuments will be an important control. The paragraph has been amended to require that a conceptual design of such monuments be provided.

§ 60.21(c)(9) and § 60.21(c)(11)

Conforming changes required by elimination of the term "decommissioning."

§ 60.21(c)(13)

The changes in this paragraph reflect the revised definitions of "geologic setting," "site," "geologic repository," and "disturbed zone." No substantive change is intended.

§ 60.21(c)(14)

Conforming change reflecting limitation of "important to safety" to concerns related to the period of operations.

§ 60.21(c)(15)(i)

Editorial change limiting information on DOE organizational structure to that which pertains to construction and operation of the geologic repository operations area.

§ 60.21(c)(15)(ii)

[Conforming-change-from-quality-assurance-"program"-to-"organization";-and-consistent-with-changes-to-§60.21(c)(4).] Deleted. This provision was redundant with § 60.21(c)4. (Subsequent paragraphs have been renumbered.)

§ 60.21(c)(15)[~~(vii)~~] (vi)[§ 60.21(c)(15)(vii)].

Conforming change required by elimination of the term "decommissioning."

§ 60.21(c)(15)[~~(viii)~~] (vii)[§ 60.21(c)(15)(viii)].

Conforming change reflecting limitation of "important to safety" to concerns related to the period of operations.

§ 60.22 Filing and distribution of application.

Section 60.22(a) has been revised to conform to § 60.3(a). In both places, the rule now refers to receipt and possession of source, special nuclear, and byproduct material "at a geologic repository operations area."

The reference in § 60.22(d) to "geologic repository" has also been changed to "geologic repository operations area", as the latter term is a more precise designation of the HLW facility that is the subject of the proposed licensing action.

§ 60.31 Construction authorization.

The overall safety finding is related to the "geologic repository operations area" because that term refers to the HLW facility subject to NRC licensing authority. [This is also the reason for the change in § 60.31(a)(1)(ii).] In order to assure that the relevant features of the controlled area are considered in arriving at this finding, § 60.31(a)(2) now specifically refers to consideration of the "geologic repository." Because siting and design criteria are supplemental to performance objectives in Subpart E, § 60.31(a)(2) has been amended to provide for evaluation of the geologic repository's compliance with the performance objectives as well. The reference to Subpart F has been deleted; that subpart, which pertains to DOE's performance confirmation program, is now referenced in § 60.74.

or procurement or manufacture of components of the geologic repository operations area.

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Controlled area" means a surface location, to be marked by suitable monuments; extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure.

closure.

"Director" means the Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards.

"Disposal" means the isolation of radioactive wastes from the accessible environment.

"Disturbed zone" means that portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Engineered barrier system" means the waste packages and the underground facility.

"Geologic repository" means a system <u>which is intended to be used for, or may be used</u> for, the disposal of radioactive wastes in excavated geologic media. A geologic repository includes (1) the geologic repository operations area, and (2) the portion of the geologic setting that provides isolation of the radioactive waste.

"Geologic repository operations area" means a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

"Geologic setting" means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

"High-level radioactive waste" or "HLW" means (1) irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

"HLW facility" means a facility subject to the licensing and related regulatory authority of the Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat 1244).[1]

[1]These are DOE "facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such Act [the Atomic Energy Act]" and "Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive wastes generated by [DOE], which are not used for, or are part of, research and development activities."

structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

(15) The following information concerning activities at the geologic repository operations area:

(i) The organizational structure of DOE as it pertains to construction and operation of the geologic repository operations area including a description of any delegations of authority and assignments of responsibilities, whether in the form of regulations, administrative directives, contract provisions, or otherwise.

[~~(ii)--The-quality-assurance-organization-to-be-used-to-ensure-safety.~~]

[~~(iii)~~](ii) ***

[~~(vii)~~](vi) Plans for permanent closure and plans for the decontamination or dismantlement of surface facilities.

[~~(viii)~~](vii) Plans for any uses of the geologic repository operations area for purposes other than disposal of radioactive wastes, with an analysis of the effects, if any, that such uses may have upon the operation of the structures, systems, and components important to safety and the engineered and natural barriers important to waste isolation.

7. Section 60.22 is amended by revising paragraphs (a) and (d) to read as follows:

(c) Potentially adverse conditions.

The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may [e]affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system.

(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

A further source of uncertainty arises from the large number of different fission product radionuclides, each of which has a variety of solubilities and retardation factors. The latter uncertainties recall Chapter II and the Untreated Dilution Indices appearing in Figures 10, 11, and 12. By containing the wastes until the fission products are nearly depleted, these uncertainties can be greatly reduced.

In order to determine a [nominal]containment time requirement which can be expected to reduce these sources of uncertainty, it is necessary to consider how fission product inventories and heat generation rates, and near-field temperatures change as a function of time. Fission product inventories and their changes appear in Figures 1 through 12, and have the same general characteristic in each figure. Figures 1 through 3 show that the fission products no longer dominate the radioactivity of the high-level wastes after approximately 250 to 350 years, depending on the fuel cycle. It is seen in Figures 4, 5, and 6, that the rate at which total heat is generated by the waste decreases so that at least a 99% reduction in heat generation rate occurs within the first few hundred years for each of the waste types. At approximately 250 years, the fission products no longer dominate the heat generation rates for any of the fuel cycles considered. Repository temperatures may have peaked and become spatially relatively uniform by this time, or may require additional time, depending on parameters such as the thermal properties of the host rock and the design of the engineered barrier system. As seen in Figures 7 through 12, the toxicity of the fission products decreases by more than five orders of magnitude during the first 1,000 years and then remains essentially constant for the next 100,000 years. Thus, to a large extent, the uncertainties introduced by the heat generation rate and the fission product contributions to hazard can be compensated for by containment times in the range of [several-hundred] approximately 300 to 1,000 years. [However,-the-staff-recognizes-that] The interval [during] for which wastes should be contained will depend on such factors as the age and nature of the waste, the design of the engineered system, the properties of the geologic setting, and the uncertainties associated with all aspects of geologic disposal. Proper consideration for such factors must be a part of any containment requirement. Therefore, by compensating for several of the principal sources of uncertainty in assessing repository performance, a containment time of [several-hundred] 300 to 1,000 years is [appropriate] ordinarily sufficient to contribute to reasonable assurance that the EPA standard, as it pertains to anticipated processes and events, can be satisfied.

Achievability of Containment Requirement

As expressed more generally in the discussion of the achievability of release rates, the staff does not intend that the containment time requirement be achieved absolutely for all of the waste (i.e., absolute proof of zero release for 1000 years is not required). It is expected that containment of the waste will be substantially complete, with releases during the containment time limited to a small fraction of the inventory present. What is intended is that the waste package design have a high reliability, taking into account anticipated processes and events that could affect package performance. It is realized that a small fraction of the approximately 100,000 packages will be breached before 1000 years due to variations in materials, manufacturing processes, etc. that can only be estimated using statistical procedures. Similarly, a significant fraction of the packages may remain intact for much longer than 1000 years.

There has been considerable emphasis in the DOE program over the last several years on the research and development needed to design a long lived waste package. NRC has, in its own program, been reviewing DOE's R&D and has been performing assessments of the uncertainties involved in designing a waste package that could reasonably be expected to contain waste for 1000 years.

Brookhaven National Laboratory (Ref. 7-11) states that a multilayered metal container can provide containment for 1,000 years, as can carbon coated particles and high silica glass coated waste forms. Westinghouse has developed for DOE conceptual designs for titanium clad and self-shielded cast steel and cast iron containers which they consider will contain wastes for 1,000 years in basalt (Ref. 7-19). A report for the Electric Power Research Institute describes a container capable of retaining its integrity for 13,000 years (Ref. 7-20). While DOE has not yet proposed a waste package design, the NRC staff considers that the concepts being considered have promise and that a design objective for containment by the waste package of 1000 years is reasonable.

ENCLOSURE B

AFFIRMATION

RESPONSE SHEET

WM Record File ./0.5.3.1..
WM Dir. ....
WM Dep. Dir. ....
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WMHT..... WMHL M.G. ←
WMUR..... Others......

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: COMMISSIONER GILINSKY

SUBJECT: SECY-83-59 - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS

APPROVED xx DISAPPROVED______ ABSTAIN______

NOT PARTICIPATING______ REQUEST DISCUSSION______

COMMENTS:

We should keep the original definition of "Geologic repository" (page 8 of Enclosure C): "'Geologic repository' means a system which is intended to be used for, or may be used for the disposal of radioactive wastes ...". This will conform to the statutory definition of a repository.

VG

SIGNATURE

16 Mar 83

DATE

SECRETARIAT NOTE: PLEASE ALSO RESPOND TO AND/OR COMMENT ON OGC/OPE MEMORANDUM IF ONE HAS BEEN ISSUED ON THIS PAPER.

NRC-SECY FORM DEC. 80

ENCLOSURE C

AFFIRMATION

RESPONSE SHEET

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: COMMISSIONER AHEARNE

SUBJECT: SECY-83-59 - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS

APPROVED X DISAPPROVED ______ ABSTAIN ______

NOT PARTICIPATING ______ REQUEST DISCUSSION ______

COMMENTS:

as modified by attached comments

[signature]
SIGNATURE

3/9/83
DATE

SECRETARIAT NOTE: PLEASE ALSO RESPOND TO AND/OR COMMENT ON OGC/OPE MEMORANDUM IF ONE HAS BEEN ISSUED ON THIS PAPER.

NRC-SECY FORM DEC. 80

COMMISSIONER AHEARNE'S COMMENTS ON SECY-83-59

1. The staff states that the long-term performance requirements should not be tied to an ALARA principle, and the rule remains as it was when proposed. (Enclosure A, pages 14 & 15) However, the staff also states that "the proposed EPA standard calls for disposal systems to be selected and designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations." The staff concludes that "the Commission's rules will accommodate the underlying concerns of EPA, as they are articulated in the preamble to the Agency's proposed standards." (Footnote 5, Enclosure A, page 15.) Notwithstanding the remainder of Footnote 5, there appears to be a significant difference between EPA and the NRC with respect to ALARA, i.e., there is a considerable difference between the statement of Footnote 5 that "because of the measures that will be required to address the uncertainties, the Commission fully expects that actual releases are likely to be well below the upper bounds expressed in the EPA standard" and a statement that releases are ALARA. The "Supplementary Information" section of the proposed final rule should be revised to fully explain the differences between the EPA and NRC or the staff should get agreement from EPA that there are no differences. It also might be useful for OGC or OELD to explain the legal ramifications of this apparent ALARA disagreement in a separate paper to the Commission.

2. The staff states that "the numerical criteria for the individual barriers included in the rule are appropriate, insofar as anticipated processes and events are concerned...." The staff further states that "in order to meet the EPA standard as it applies to unanticipated processes and events, higher levels of individual barrier performance may be required." (Enclosure A, page 8.) It is not clear what the "criteria for higher levels of individual barrier performance" will be. It does appear that the EPA standard is controlling for unanticipated processes and events. Therefore it would be appropriate to explicitly state that with respect to unanticipated events the EPA standard is controlling rather than individual barrier performance objectives.

3. It is stated that the term "important to safety" has traditionally been linked to structures, systems, and components which must operate under accident conditions in a manner that will prevent serious offsite consequences. (Enclosure A, page 27.) In a November 20, 1981 memo, Harold Denton provided standard definitions for commonly-used safety classification terms. The definition of "important to safety" as provided by Denton is not consistent with the characterization provided in SECY-83-59. Denton indicates "important to safety" encompasses the broad class of plant features that contribute in important ways to safe operation and protection of the public in <u>all</u> phases and aspects of facility operation (i.e., normal operation and transient control as well as accident mitigation). NRR (and the NRC) has had a very difficult time in

trying to establish consistency in application of standard definitions for commonly-used safety-classification terms. The final rule should not counteract Denton's efforts. The definition used in the rule should be reviewed in light of the November 20, 1981 Denton memo. Any differences should be explained.

4. The proposed final rule states that structures, systems, and components are important to safety if, in the event they fail to perform their intended function, an accident could result which causes a dose commitment greater than 0.5 rem to the whole body or any organ of an individual in an unrestricted area. (§60.2 - Enclosure A, page 87) The staff indicates that the value of 0.5 rem is equal to the annual dose to the whole body of an individual in an unrestricted area that would be permitted under 10 CFR Part 20 for normal operations. The Supplementary Information section of the final rule package should mention that NRC revisions to Part 20 and EPA Clean Air Act standards may be significantly lower than 500 mr [Note that the drafts are].

5. Change definition of "Controlled Area" (§60.2 - Enclosure A, page 85) to read:

> "Controlled Area" means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the under ground facility, ..."

6. Delete §60.21(c)(15)(ii) on page 97 of Enclosure A. This information should be included with the description of the quality assurance program required by (§60.21(c)(4). (Page 96 of Enclosure A).

7. Enclosure G is intended to provide rationale for performance objectives in 10 CFR Part 60. However, the rationale for selecting the 300 year performance objective for the waste package (§60.113(a)(1)(ii)(A) is not covered in Enclosure G. The closest description is on page 73 of Enclosure G which mentions times in the range of "several hundred to 1,000 years". We should explicitly state why the 300 year figure was chosen.

AFFIRMATION

RESPONSE SHEET

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: COMMISSIONER ROBERTS

SUBJECT: SECY-83-59B - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS (SECY-83-59)

APPROVED X DISAPPROVED ______ ABSTAIN ______

NOT PARTICIPATING ______ REQUEST DISCUSSION ______

COMMENTS:

[signature]
SIGNATURE

4/21/83
DATE

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NRC-SECY FORM DEC. 80

AFFIRMATION

RESPONSE SHEET

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: COMMISSIONER GILINSKY

SUBJECT: SECY-83-59B - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS (SECY-83-59)

APPROVED ✓ DISAPPROVED______ ABSTAIN______

NOT PARTICIPATING______ REQUEST DISCUSSION______

COMMENTS:

V.G.

SIGNATURE

25 APR 83

DATE

SECRETARIAT NOTE: PLEASE ALSO RESPOND TO AND/OR COMMENT ON OGC/OPE MEMORANDUM IF ONE HAS BEEN ISSUED ON THIS PAPER.

AFFIRMATION

RESPONSE SHEET

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: COMMISSIONER AHEARNE

SUBJECT: SECY-83-59B - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS (SECY-83-59)

APPROVED X DISAPPROVED______ ABSTAIN______

NOT PARTICIPATING______ REQUEST DISCUSSION______

COMMENTS: As modified by attached

As modified by attached.

[signature]
SIGNATURE

5/6/83
DATE

SECRETARIAT NOTE: PLEASE ALSO RESPOND TO AND/OR COMMENT ON OGC/OPE MEMORANDUM IF ONE HAS BEEN ISSUED ON THIS PAPER.

NRC-SECY FORM DEC. 80

COMMISSIONER AHEARNE'S COMMENTS ON SECY-83-59B

1. The staff proposed changes to the explanation of the term "important to safety" do not highlight the fact that the term is used differently in Parts 50 and 60. I would prefer to use a different term such as "important to safe repository operations," in place of the term "important to safety." If the majority of the Commission disagrees, then I propose the following rewrite for the explanation of the term "important to safety" (Enclosure A, pages 26 and 27).

> Important to Safety. In response to public comments on Part 60, the NRC staff has adopted a numerical criterion for determining which structures, systems and components are important to safety. Structures, systems, and components are important to safety if, in the event they fail to perform their intended function, an accident could result which causes a dose commitment greater than 0.5 rem to the whole body or any organ of an individual in an unrestricted area.[1] The value of 0.5 rem is equal to the annual dose to the whole body of an individual in an unrestricted area that would be permitted under 10 CFR Part 20 for normal operations. The definition that has been adopted defines as important to safety, any system, structure or component whose failure to operate as intended could result in an annual dose commitment to an individual in an unrestricted area in excess of what would be permitted for normal operations of certain other activities licensed by NRC. Such systems, structures, and components would be subject to additional design requirements and to a quality assurance program to ensure that they performed their intended functions. The choice of 0.5 rem in this instance should not be construed as implying that it would be appropriate if applied to any other types of activities subject to regulation by the Commission. (The permissible annual dose in unrestricted areas--now 0.5 rem--is currently under review. The Commission contemplates that if this dose limit were to be revised, a corresponding change would be considered here.)
>
> The term "important to safety" applies solely to the functioning of structures, systems, and components during the period of repository operations. The proposed rule also applied the term to structures, systems, and components which must function in a particular way in order to meet the long-term isolation objective. The final rule includes design criteria that address long-term performance, but these are related to contributions to waste isolation instead of being tied to structures, systems, and components "important to safety." Similarly, the quality assurance requirements expressly apply to structures, systems, and components "important to waste isolation" as well as to those that are "important to safety" during operations.

---

[1] 10 CFR Part 50, Appendix A uses the term "important to safety" in a different context for nuclear power plants. The 10 CFR Part 60 definition does not supersede the 10 CFR Part 50 definition in nuclear power application.

2. It is presently stated in the Section by Section Analysis of Part 60 (Enclosure A to SECY-83-59) that the definition of "engineered barrier system" in Part 60 is synonymous with the term "engineered barriers" in the Waste Policy Act. Further discussion with the staff indicates this may not be the case. Therefore, replace Section by Section Analysis for "Engineered Barrier System" with the following (page 35 and 36 of Enclosure A):

> "Engineered barrier systems." This term refers to the system for which containment and release rate requirements are specified. It does not include the shafts and boreholes, and their seals. The proposed rule referred instead to "engineered systems," a term that was misleading because it could be understood to include shaft and borehole seals. However, the Commission recognizes that as used in the Nuclear Waste Policy Act of 1982, the related term "engineered barriers" might be construed to include shaft and borehole seals. The NRC will review whether the definition requires change in light of the Nuclear Waste Policy Act. Preliminary review does not indicate a need for change in this definition.

3. I have reviewed the staff's response (SECY-83-59B) to my previous comments on ALARA. I am in agreement with the staff's approach to consideration of ALARA. However, since we are commenting separately to EPA on its approach to ALARA, I would just mention this fact in Part 60, not give the details of our comments to EPA. I believe the staff's writeup on ALARA can be improved. Attached is a proposed replacement section on ALARA. (Replacement pages for pages 14, 14a, and 15 to SECY-83-59B)

> ALARA
>
> The notice of proposed rulemaking requested comment on "whether an ALARA principle should be applied to the performance requirements dealing with containment and control of releases." Some commenters believed that ALARA (as low as reasonably achievable) should be applied to all licensed activities, and that no exception should be made for geological repositories. Other commenters argued against incorporating ALARA, since the allowable releases under the EPA standard would already be so low as to eliminate any significant risk to public health and safety.
>
> Based in part upon the standard recently proposed by EPA, the Commission considers it reasonable to anticipate that the permissible amounts of radioactivity in the general environment will be established at a very low level. In fact, the statement of considerations accompanying EPA's proposed rule explains that EPA has chosen to propose disposal standards that limit the risks to future generations to a level no greater than the risks which those generations would be exposed to from equivalent amounts of unmined uranium ore and thus, any risks to future generations from disposal of high-level wastes would be no greater than, and probably much less than, risks which those generations would face if the wastes had not been created in the first place. Efforts to reduce releases further would have little, if any, demonstrable value commensurate with their costs.

The EPA limits require the performance of geologic repositories to be effective over a long period of time. There will always be substantial uncertainties in predicting the long-term performance of geologic repositories. The Commission will insist upon the adoption of a variety of design features, tests, or other measures in order to be able to conclude with confidence that the EPA standard is met. The result may be the same as if the Commission were to impose similar requirements in the name of keeping releases as low as reasonably achievable. Given the substantial uncertainties involved with predicting long term performance, the already low EPA limits and the already stringent geologic performance requirements, it is doubtful that the ALARA concept could be applied in a meaningful way.

When the Commission finds that certain measures are needed to improve confidence in dealing with uncertainties, it is making a substantial safety judgment. The same kinds of balancing that are undertaken in ALARA determinations may be appropriate. That is, if confidence in the performance of the geologic repository is sensitive to a particular source of uncertainty, it will be in order for the Commission to take into account both the significance of the factor involved and the costs of reducing or eliminating it.

In short, the Commission has concluded that the long-term performance requirements should not explicitly be tied to an ALARA principle, and the rule remains as it was when proposed. The Commission believes the concerns of the commenters in support of the ALARA approach will be largely accommodated in connection with its treatment of uncertainties in the course of the licensing process.

EPA's proposed rule (Part 191) indicates that appropriate measures must be taken, in light of the uncertainties involved in predicting repository performance, to assure that the "containment requirements" will be met. One of the measures identified by EPA would be the selection and design of disposal systems to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations. The Commission is recommending to EPA that the assurance requirements, including the ALARA provision, be omitted from the final rule. The Commission emphasizes that its rules accommodate the underlying concerns of EPA, as articulated in its statement of considerations, that measures must be taken to assure confidence that the numerical release limits will be met.

AFFIRMATION

RESPONSE SHEET

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: CHAIRMAN PALLADINO

SUBJECT: SECY-83-59B - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS (SECY-83-59)

APPROVED XX DISAPPROVED______ ABSTAIN______

NOT PARTICIPATING______ REQUEST DISCUSSION______

COMMENTS: as modified.

I approve SECY-83-59 as modified by SECY-83-59B including the changes suggested in Commissioner Ahearne's vote sheet of May 6, 1983. In regard to Commissioner Ahearne's comments, I would prefer to retain the term "important to safety" and incorporate the wording change suggested in his vote sheet as modified in the attached copy.

N. J. Palladino
SIGNATURE

5/13/83
DATE

SECRETARIAT NOTE: PLEASE ALSO RESPOND TO AND/OR COMMENT ON OGC/OPE MEMORANDUM IF ONE HAS BEEN ISSUED ON THIS PAPER.

NRC-SECY FORM DEC. 80

COMMISSIONER AHEARNE'S COMMENTS ON SECY-83-59B

1. The staff proposed changes to the explanation of the term "important to safety" do not highlight the fact that the term is used differently in Parts 50 and 60. I would prefer to use a different term such as "important to safe repository operations," in place of the term "important to safety." If the majority of the Commission disagrees, then I propose the following rewrite for the explanation of the term "important to safety" (Enclosure A, pages 26 and 27).

Important to Safety. In response to public comments on Part 60, the NRC ~~staff~~ has adopted a numerical criterion for determining which structures, systems and components are important to safety. Structures, systems, and components are important to safety if, in the event they fail to perform their intended function, an accident could result which causes a dose commitment greater than 0.5 rem to the whole body or any organ of an individual in an unrestricted area.[1] The value of 0.5 rem is equal to the annual dose to the whole body of an individual in an unrestricted area that would be permitted under 10 CFR Part 20 for normal operations, ~~The definition that has been adopted defines as important to safety, any system, structure or component whose failure to operate as intended could result in an annual dose commitment to an individual in an unrestricted area in excess of what would be permitted~~ the same as permitted for normal operations of certain other activities licensed by NRC. Such systems, structures, and components would be subject to additional design requirements and to a quality assurance program to ensure that they performed their intended functions. The choice of 0.5 rem in this instance should not be construed as implying that it would be appropriate if applied to any other types of activities subject to regulation by the Commission. (The permissible annual dose in unrestricted areas--now 0.5 rem--is currently under review. The Commission contemplates that if this dose limit were to be revised, a corresponding change would be considered here.)

replace with attached

~~The term "important to safety" applies solely to the functioning of structures, systems, and components during the period of repository operations. The proposed rule also applied the term to structures, systems, and components which must function in a particular way in order to meet the long-term isolation objective. The final rule includes design criteria that address long-term performance, but these are related to contributions to waste isolation instead of being tied to structures, systems, and components "important to safety." Similarly, the quality assurance requirements expressly apply to structures, systems, and components "important to waste isolation" as well as to those that are "important to safety" during operations.~~

---

[1] 10 CFR Part 50, Appendix A uses the term "important to safety" in a different context for nuclear power plants. The 10 CFR Part 60 definition does not supersede the 10 CFR Part 50 definition in nuclear power application.

In the final rule, the term "important to safety" applies solely to the functioning of structures, systems, and components during the period of operations prior to repository closure. The proposed rule had also applied this term to structures, systems, and components which must function in a particular way in order to meet the long-term isolation objective after repository closure. In the final rule, this latter group, which is intended to meet the design criteria that address long-term performance, is characterized as "important to waste isolation." Quality assurance requirements apply to structures, systems, and components equally whether they be "important to safety" or "important to waste isolation."

AFFIRMATION

RESPONSE SHEET

TO: SAMUEL J. CHILK, SECRETARY OF THE COMMISSION

FROM: COMMISSIONER ASSELSTINE

SUBJECT: SECY-83-59B - 10 CFR PART 60 -- DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES: TECHNICAL CRITERIA AND CONFORMING AMENDMENTS (SECY-83-59)

APPROVED x AS MODIFIED DISAPPROVED________ ABSTAIN________

NOT PARTICIPATING________ REQUEST DISCUSSION________

COMMENTS:

I agree with Commissioner Ahearne's proposed changes as modified by Chairman Palladino.

I would also revise the definition of high-level radioactive waste in Part 60 to conform to the definition of high-level waste in the Nuclear Waste Policy Act of 1982. This is consistent with the Commission's comments to EPA on their proposed high-level waste standards.

[signature]
SIGNATURE

5-18-83
DATE

SECRETARIAT NOTE: PLEASE ALSO RESPOND TO AND/OR COMMENT ON OGC/OPE MEMORANDUM IF ONE HAS BEEN ISSUED ON THIS PAPER.

NRC-SECY FORM DEC. 80