Department of Energy
Washington, DC 20585

MAY 27 1993

Mr. Joseph J. Holonich, Director
Repository Licensing & Quality Assurance
Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Holonich:

On December 14, 1990, the U.S. Department of Energy (DOE) transmitted its responses to the objections, comments, and questions presented in the U.S. Nuclear Regulatory Commission's (NRC) Site Characterization Analysis (SCA). On July 31, 1991, the NRC staff evaluated these responses, closing some comments and creating open items of the remainder. Comments 95, 105, and 115 pertained to Site Characterization Plan Section 8.3.5.13 (Total System Performance).

The DOE used discussions at the December 14-15, 1992, technical exchange on total system performance assessment to determine whether or not documentation could be provided to resolve the subject SCA open items. NRC staff in attendance also recognized the opportunity to address open items and encouraged DOE to produce such documentation.

Enclosures 1-3 of this letter summarize the administrative record with respect to these SCA comments and include additional documentation to provide the basis to resolve Comments 95, 105, and 115. With this submittal, the DOE considers these open items to be resolved.

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If you have any questions, please contact Chris Einberg of my office at (202) 586-8869.

Sincerely,

Dwight E. Shelor
Associate Director for
Systems and Compliance
Office of Civilian Radioactive
Waste Management

Enclosures:
1. Administrative Record for
   SCA Comment 95
2. Administrative Record for
   SCA Comment 105
3. Administrative Record for
   SCA Comment 115

cc: w/enclosures
C. Gertz, YMPO (w/o enclosure)
T. J. Hickey, Nevada Legislative Committee
R. Loux, State of Nevada
D. Bechtel, Las Vegas, NV
Eureka County, NV
Lander County, Battle Mountain, NV
P. Niedzielski-Eichner, Nye County, NV
W. Offutt, Nye County, NV
C. Schank, Churchill County, NV
F. Mariani, White Pine County, NV
V. Poe, Mineral County, NV
J. Pitts, Lincoln County, NV
J. Hayes, Esmeralda County, NV
B. Mettam, Inyo County, CA
C. Abrams, NRC

ENCLOSURE 1

SCA Comment 95 and DOE Response (12/14/90)

NRC Evaluation of DOE Response (7/31/91)

Additional Information Relevant to SCA Comment 95 Open Item

Section 8.3.5.13 Total System Performance

COMMENT 95

The underlying methodological logic that is used to develop and screen scenarios and its implementation in the SCP appears to be deficient for the generation of a CCDF representative of total system performance; therefore, this approach is unsuitable for guiding the site characterization program, even if allowances are made for the current lack of knowledge about the site and the expediencies required to develop the site characterization program.

BASIS

- Comment 94 on the CDSCP was addressed by providing more detail in additional text. However, as discussed in the points below, the new text does not resolve the comment. Although Question 46 on the CDSCP was answered in part, the text does not address important issues of mathematical robustness and does not provide confidence that site characterization will obtain data needed to analyze all the scenarios that need to be treated in the CCDF.

- With regard to the recommendation in CDSCP Comment 94: (1) the scenario selection and screening procedures articulated in the SCP do not contain explicit criteria or the justification for them; (2) the scenario selection and screening procedures are not systematic, nor do they provide assurance of completeness; and (3) the inappropriate formal use of expert judgment is discussed in comment 3.

- The five scenario classes listed in Table 8.3.5.13-3 are used to develop the performance allocation for total system performance (Table 8.3.5.13-8) that guides the site characterization program for resolution of Issue 1.1. Table 8.3.5.13-2 correlates the five scenario classes with 49 other scenario classes of unspecified origin (in column 2 of the Table), some of the 99 Ross scenario sequences, and some of the scenarios considered in the Decision Aiding Methodology. Neither the Tables nor the accompanying text provide a suitable relationship among the various sets of scenarios and scenario classes to show: (1) how these scenario classes relate to the discussions of construction the CCDF, and (2) how the particular set chosen is adequate for the purposes of site characterization.

- The "scenario classes" listed in Table 8.3.5.13-3 are used as the basis for performance allocation; however, because one scenario may fit into more than one of these groupings, they are not mutually exclusive and, therefore, not appropriate for development of a CCDF. Also, it is not clear that these groupings include all significant scenarios (another requirement of the CCDF). For example, the SCP adds 15 scenarios to the set of scenarios developed by Ross. Clearly, then, the Ross analysis was deemed incomplete; however, no analysis is provided to assure that the current set of scenarios is complete.

- As defined in the SCP, the "nominal scenario class" is so improbable as to be of marginal significance. It does not seem appropriate to plan site characterization based on a set of "scenarios" which are unlikely to even occur.

- As a practical matter it does not appear that DOE will be able to generate the joint distribution function F(V), or that the site characterization program will provide any input to define this distribution function given that the five "scenario classes" (A-E) which form the basis of performance allocation are defined in a manner inconsistent with the mathematical definitions of this text. Equation 8.3.5.13-6 defines the conditional CCDF for a "scenario." Equation 8.3.5.13-4 defines the basis of calculating the CCDF as the expectation integral given by equation 8.3.5.13-3. The expectation integral is defined in terms of the joint distribution function F(V), which is defined as the distribution over the entire set of state variables and their range for all eventualities. It does not appear that the use of the expectation integral as implied in equation 8.3.5.13-6 has a precise mathematical meaning, since the expectation integral has not been explicitly defined for a "scenario."

- The approach to defining scenarios used in the Ross report is to begin with a comprehensive list of events and processes that could contribute to release of radioactivity from a repository and screen these entities and their combinations for significance toYucca Mountain. An alternative approach is to look at the Yucca Mountain repository, to determine which subsystems are critical to waste isolation, and to define conditions or events that will compromise these subsystems; this is the central focus of most PRA. At the bottom of page 8.3.5.13-25 and in Table 8.3.5.13-2 the idea is articulated that some combination of these two approaches is being used to define scenarios for the purpose of guiding the site characterization effort. (Table 8.3.5.13-2 attempts to relate the Ross scenarios to scenarios defined on the basis of major barrier affected.) It is not clear how consistency, completeness, and mutual exclusivity of scenarios is achieved where a combination of approaches is used since this is conventionally assured by consistent use of one approach or another.

- The nominal scenario class, E, is cited Table 8.3.5.13-3 as: "Undisturbed and nominal performance of all barriers" and "Undisturbed performance of all natural barriers." However, on page 8.3.5.13-8 the text indicates that Ross scenarios related to flooding, geochemical change, undetected features, faulty waste emplacement, increase in recharge due to climate control, differential inelastic response to heating, nonelastic response to heating, temperature-driven fluid migration, local mechanical fracturing, corrosion, chemical reaction of waste package with rock, geochemical alteration, and microbial activity are all included in the nominal scenario class. The text broadly states that aggregating such diverse scenarios into the "nominal" scenario class is justified because site characterization will investigate a large range of conditions, features, and parameters sufficient to include these scenarios.

- The various processes and events, that form the bases of scenarios and sequences by which they can cause failure of barriers to the release of radionuclides, used in the Ross report are based on a list of 57 events and processes published by the International Atomic Energy Agency (IAEA, 1983). Although this listing is useful for some purposes, the NRC staff does not believe that this is an appropriate basis for developing scenarios pursuant to demonstrating compliance with 40 CFR 191. Unlike the European approaches to regulating a repository, the US approach is deeply rooted in the systems approach, wherein the term scenario has a very specific and constrained meaning. In particular, scenarios should not represent the response of the repository system to anticipated or unanticipated external events of environments; rather, scenarios should be limited to descriptions of the external constraints, in time, on the system.

- Page 8.3.5.13-44. Five "undetected features" are included in the set of "agents" used to estimate how many independent scenario classes must be considered. The NRC staff does not advise treating undetected features as scenarios. Instead, undetected features should be treated as uncertainties in the conceptual model or as alternative conceptual models to be resolved during site characterization.

RECOMMENDATIONS

- The approach to scenario analysis and how it is being employed to guide the site characterization program should be clarified or redone. In particular, as stated in the first Recommendation from CDSCP Comment 94, the methodology for scenario development and screening should (1) be systematic, and (2) provide assurance of completeness.

- In particular, the following aspects require correction:

  - Performance allocation and consideration of alternative conceptual models should be performed in the context of a reasonable number of real, mutually exclusive, important scenarios or scenario classes - not the objects listed in Table 8.3.5.13-3.

  - Consideration of sets of scenarios, sets of scenario classes, and sets of other objects derived in various references and other sources should be used considering their derivation and logical consistency.

REFERENCES

Ross, Benjamin. A First Survey of Disruption Scenarios for a High-Level Waste Repository at Yucca Mountain, Nevada, SAND85-7717. December 1987. Sandia National Laboratories.

IAEA. Concepts and Examples of Safety Analysis for Radioactive Waste Repositories in Continental Geological formations, Safety Series No. 58, Vienna, Austria, International Atomic Energy Agency, 1983.

RESPONSE

Several U.S. Nuclear Regulatory Commission (NRC) comments indicate concern related to incompleteness of the preliminary set of scenarios issued in Ross (1987) and included in the Site Characterization Plan (SCP). The example set of classes was also questioned. The logic discussion (SCP pages 8.3.5.13-125 and 126) points out the interdependence of site investigations and scenario development. The preliminary set of scenarios (Ross, 1987) should be viewed as a beginning. It is a list of possible release avenues based on evidence available at the time of writing, but is by no means comprehensive or final. Since publication in 1987, Ross has extended the list by adding scenarios related to gas-phase release. The U.S. Department of Energy (DOE) continues to work on scenario development and will do so as long as reasonable questions arise from site investigations or public concern.

The scenario course now being followed is derived from the SCP 8.3.5.13 information needs and activities. DOE believes scenarios have the potential to be the coordinating and integrating tool for site investigations, providing the statement of all known, credible potential release problems at the site. The scenario course also would serve as a guide to establish a record of technical arguments used to eliminate unimportant scenarios. The work is responsive to site investigation findings that DOE is familiar with and actively seeks input from Project Participants regarding other observations and insights into possible failure pathways.

Several methods were considered to assist in scenario construction. The event tree was selected for performing the detailed identification and screening of events and processes; these tasks are indispensable steps in scenario development. Eight basic initiating events or processes were identified as the (amendable) set important to postclosure performance assessment. The topics to be developed using event trees are:

1. Nominal Flow
2. Human Intrusion
3. Basaltic Volcanism
4. Tectonics
5. Climate Change
6. Other Human Activities
7. Gas Release
8. Closure of Repository.

Other issues have been identified that require resolution but that may require less extensive treatment.

Current strategy is implemented as follows: Using all information on site characteristics and investigations DOE is aware of, a "strawman" event tree is constructed. The tree for nominal flow includes processes and events to describe the entry of water through the surface, possible travel modes to the region of influence of the repository, mechanisms for releasing radionuclides from the engineered barrier system (EBS), and subsequent transport to the accessible environment. The disruptive trees include processes and events resulting in increased release by perturbations to nominal flow and by additional routes to the accessible environment. The tree, with an

explanation of its components, is distributed to project participants with a request for feedback to make the tree comprehensive, to eliminate insignificant portions (references requested), and to identify what is being worked on. Key participants, knowledgeable on the topic of the tree, are also consulted. The "strawman," expanded by the feedback, will produce a quasi-comprehensive event tree, containing nearly all known problems which need to be addressed during site characterization. Furthermore, since arguments for each cut on the tree will be documented, this methodical approach should prove valuable for license-application preparation. At this stage, a formal document containing the remaining scenarios (the surviving portions of the event tree) would be issued. The tree will continue to be updated as site characterization progresses, and to act as an outline of work left to be done and information needed.

The working set of scenarios will guide model development. As models are developed, they are used to screen the remaining scenarios on the basis of very low probability of occurrence or insignificant consequence. The current approach complies with the recommendations to be systematic and to provide assurance of completeness. As pointed out in this comment, the example set of classes in SCP Table 8.3.5.13-3 cannot be proved exhaustive, and the classes are not necessarily mutually exclusive. DOE believes rigorous classification of scenarios can be accomplished only after much of the modeling and much of site characterization has been done. Classification requires understanding of the controlling parameters of the models and the ranges of these parameters.

Hopefully these remarks respond meaningfully to this comment; this somewhat general discussion is provided because many of the concerns expressed in the comment have to do with the overall process of developing scenarios. The developments reported in the SCP guide site characterization, and the list of scenario classes is not the list that will eventually form the basis for a demonstration of compliance. To produce that final, exhaustive list is one of the tasks that requires site characterization, and it cannot be available to guide site characterization. The list in the SCP is thought to be reasonably complete, in that it covers releases currently thought to be potentially important. The scenario classes are not rigorously exclusive, but the object in guiding site characterization is to identify the phenomena that should be investigated, a task for which strict exclusivity of scenario classes is not absolutely necessary.

Several statements in the basis section of this comment ask for separate responses. The statement that the nominal scenario class is highly improbable does not agree with DOE expectations, because the sequences on which it is built are those that may be expected at the site. DOE would appreciate seeing the NRC analysis on which the statement is based. The SCP text is describing a different set of methods At Equation 8.3.5.13-6, from those described at Equation 8.3.5.13-4. The statement that "scenarios should be limited to descriptions of the external constraints, in time, on the system" is not consistent with DOE's use of the term "scenario." It also appears to be inconsistent with the use of the term in publications sponsored by the NRC: see, for example, the listing by Cranwell et al. (1982) of a scenario consisting of "reference site with repository but without other disruptions," a description of which must contain responses of the repository if the scenario is to be modeled. It is not clear whether this comment

reflects merely a matter of how the commenter uses the term "scenario" or whether it reflects a feeling that responses of the repository do not need to be modeled. The reference to a "very specific and constrained meaning" in the U.S. program, in contrast to the European program, may be valid, but the meaning that seems to be implied in this comment does not appear to be a consensus of the U.S. waste-management community. The presence or absence of undetected fractures is, of course, a matter for site characterization to resolve; the program will attempt to find the feature that could significantly affect releases of radionuclides.

REFERENCES:

Cranwell, R.M., R.V. Guzowski, J.E. Campbell, and N.R. Ortiz, 1982. Risk Methodology for Geologic Disposal of Radioactive Waste: Scenario Selection Procedure, SAND80-1429, Sandia National Laboratories, Albuquerque, New N.

Ross, B, 1987. A First Survey of Disruption Scenarios for a High-Level Waste Repository at Yucca Mountain, Nevada, SAND85-7717, Sandia National Laboratories, Albuquerque, New Mexico, December 1987.

Section 8.3.5.13 Total System Performance

SCA COMMENT 95

The underlying methodological logic that is used to develop and screen scenarios and its implementation in the SCP appears to be deficient for the generation of a CCDF representative of total system performance; therefore, this approach is unsuitable for guiding the site characterization program, even if allowances are made for the current lack of knowledge about the site and the expediencies required to develop the site characterization program.

EVALUATION OF DOE RESPONSE

- DOE recognizes that scenario development is an iterative process, stating that DOE "continues to work on scenario development and will do so as long as reasonable questions arise from site investigations or public concern." DOE's response provides some additional discussion of the process that DOE intends to use for scenario development.

- DOE's response suggests a general convergence of views regarding most of the subjects raised by the NRC staff in this comment. However, one significant issue is not addressed in DOE's response -- the NRC staff's recommendation for explicit criteria for development and screening of scenarios. DOE indicates that "project participants" will be requested to add to or subtract from a scenario event tree, apparently based on their subjective judgment of the significance of their additions or deletions. The NRC staff continues to believe that DOE should develop explicit criteria for such additions or deletions.

- The NRC staff considers this comment open. While DOE's views and those of the staff appear to be converging, an interaction is needed to continue progress toward resolution of differences. The NRC staff is particularly concerned about the absence of explicit criteria for scenario development and screening.

Supplemental Response to SCA Comment 95

At the requested interaction, which took place on December 14-15, 1992, the DOE and NRC representatives discussed in more detail the plans for scenario development. A particular point of discussion was the issue raised in the most recent NRC staff evaluation of the written DOE response to Comment 95: the value of "explicit criteria for development and screening of scenarios."

The participants in the interaction agreed that probability of occurrence and magnitude of consequences are both important criteria for this development and screening. Furthermore, they are "explicit" criteria. Some of the discussions centered around the desirability of expanding the definition of "explicit" to mean "highly quantitative" or "expressed in more detail." A few more detailed criteria appeared obvious, and the participants seemed to agree that they are already part of the development. For example, it seems reasonable to eliminate sequences of events and processes whose initial phenomena clearly have less than 1 chance in 10,000 of occurring in 10,000 years. And phenomena that do not lead to releases of radionuclides need not appear in scenarios.

The DOE, however, expressed concern that a rigid set of criteria, imposed early in the site characterization process, would prove to be an unacceptable basis. The DOE is reluctant to go beyond the obvious criteria until the technical community has gained more experience. The eventual goal for screening is to eliminate scenarios that do not contribute significantly to the complementary cumulative distribution function (or perhaps other regulatory performance measures) describing a repository system. After site characterization and performance assessment have progressed further, the technical community will understand site-specific CCDFs better. They will have agreed more completely on how to examine the contributions of different scenarios. Such understanding will enable them to develop criteria more authoritatively than they can now. The impact of repromulgated environmental standards from the EPA with respect to post-closure performance assessment and CCDF construction is still to be assessed.

At least for the near future, the DOE considers it prudent simply to retain scenarios that do not meet obvious criteria for elimination. Elaborate sets of criteria, if they eventually prove valuable, can be more usefully created later. In developing such criteria, the DOE would think it valuable to exchange information about them with the NRC, preferably at an early stage in their development.

ENCLOSURE 2

SCA Comment 105 and DOE Response (12/14/90)

NRC Evaluation of DOE Response (7/31/91)

Additional Information Relevant to SCA Comment 105 Open Item

Section 8.3.5.13 Total System Performance

COMMENT 105

Although DOE may incorporate material by reference in the licensing application and although scenarios already eliminated may not need to be treated in calculating the CCDF in the license application, sufficient data, and analyses, or justification should be accumulated during site characterization to substantiate the decision to eliminate these scenarios.

BASIS

- Page 8.3.5.13-46, 2nd paragraph states: "In general, the scenarios eliminated by Ross (1987) and those scenarios screened out as part of the DOE decision-aiding methodology (1986a) are assumed to be inapplicable at Yucca Mountain."

- The study by Ross was conducted to assist the Yucca Mountain Project; the decision-aiding methodology report was performed to assist the DOE in selecting sites to recommend for nomination by the President, under the NWPA.

- 10 CFR 60.21(c)(1)(ii)(C) requires that the SAR contain an evaluation of postclosure performance of the repository; this requirement mandates a justification of the anticipated and unanticipated processes and events (scenarios) used as the basis for estimating performance.

- 10 CFR 60.23 allows incorporation of material by reference in the license application; such incorporation by reference does not mean the conclusions of the references are exempt from challenge, review, and litigation during the licensing hearing.

- Elimination of certain scenarios, as in the cited references, may be appropriate for the purposes of site characterization; however, the justification for such eliminations must be included in the documentation for the SAR.

- The current NRC staff interpretation of 10 CFR 60 is that resolution of issues key to licensing and the technical basis supporting the resolution cannot be concluded prior to licensing, except by rulemaking, and then only when supported by a factual basis.

RECOMMENDATION

DOE should re-examine and re-evaluate the scenario screening process in the SCP and the proposed investigations in the SCP to assure that sufficient data will be obtained during the site characterization program to support the scenario screening presented in a complete, high-quality license application.

REFERENCES

DOE (U.S. Department of Energy), 1986. A Multiattribute Utility Analysis of Sits Nominated for Characterization for the First Radioactive-Waste Repository -- A Decision-Aiding Methodology, DOE/RW-0074, Washington, DC.

Ross, R., 1987. A First Survey of Disruption Scenarios for a High-Level-Waste Repository at Yucca Mountain, Nevada, SAND85-7117, Sandia National Laboratories, Albuquerque, NM.

RESPONSE

The U.S. Department of Energy agrees that the Safety Analysis Report will need to contain extensive discussions about scenario selection. This would take place using technical support documentation (TSD) where the data and analyses would be evolved from the studies set forth in Site Characterization Plan study plans. See also the response to Comment 1 regarding TSD. Provision for the discussion is allowed for in the scenario screening process (which is iterative); the process is discussed in Section 8.3.5.13 of the Site Characterization Report. As uncertainties are reduced with the acquisition of site data, the updated models would indicate priority data needs and detailed reasons for eliminating scenarios can be supplied.

Section 8.3.5.13 Total System Performance

SCA COMMENT 105

Although DOE may incorporate material by reference in the licensing application and although scenarios already eliminated may not need to be treated in calculating the CCDF in the license application, sufficient data, and analyses, or justification should be accumulated during site characterization to substantiate the decision to eliminate these scenarios.

EVALUATION OF DOE RESPONSE

- In its response, DOE agrees that the SAR will need extensive discussions about scenario selection. DOE refers to the discussion on technical support documentation (TSD) in the response to Comment 1 which, in the third paragraph on page 18 describes the TSD as consisting of technical reports and licensing documents that will synthesize data gathered in SCP studies and compile and interpret information acquired about the site. Also, in the discussion in Section 8.3.5.13 of the SCP, DOE refers to the iterative nature of the scenario screening process. The response relies primarily on the iterative nature of the process. As site data are acquired, updated models would indicate priority data needs and detailed reasons for eliminating scenarios.

- The point of NRC's comment lies in its basis as well as its recommendation. There is no reason to think that an iterative process would necessarily bring back scenarios that were eliminated at an early stage. Care must be taken in eliminating scenarios in a systematic manner that allows the data to be accumulated during site characterization to justify the decision to eliminate the scenarios.

- The NRC staff considers this comment open. Discussion at an interaction on scenario identification and screening would, in part, focus on this issue and would be a first step in bringing the issue to closure.

Supplemental Response to SCA Comment 105

At the requested interaction on scenario identification and screening, which took place on December 14-15, 1992, the DOE explained in more detail the plans for selecting scenarios. At this time, the project is involved in developing scenarios, and no scenarios have been selected. The DOE agreed with the NRC staff that an iterative process, simply because it was iterative, would not bring back previously eliminated scenarios. The decision-making for scenario selection must contain provisions for keeping track of the decisions and the justifications for them. The DOE, therefore, described the intended documentation of the scenario-selection process. These documents will provide the justification for decisions to add and to eliminate scenarios. They will present, either in themselves or by reference to other documents, the data and analyses underlying those decisions. Scenario-selection documentation may not be part of a total system performance assessment (TSPA) itself, but it will reside in a project or participant document that would be referenced to some future TSPA.

Summarized briefly, these documents begin with compilations of the events, features, and processes with which the scenario-development process will start. The initial publications will be available to all interested parties, and additional scenarios or reasons for deletions are all subject to the routine review and comment by NRC, the state, or other affected parties who are part of the current program. These documents serve not only the purpose of making the compilations as complete as possible, but also the purpose of keeping a record of the scenarios that have been suggested.

Then, as site characterization proceeds and some events or processes can be eliminated, scenario-selection documents will build on the original documents. These documents will explain the eliminations from the original compilations (and make additions, if additions are necessary). Because scenario-selection documents will be permanent records available to all interested parties, the trail of scenario construction and screening should be easily accessible. The DOE currently plans to seek technical scrutiny of these documents outside of the project.

The DOE plans to issue these documents in series that deal separately with major classes of features, events, and processes. For example, the phenomena associated with basaltic volcanism will be listed in a forthcoming report. The report will explain why it included those phenomena, will describe them as scenarios, and will point to the information needed for expanding or contracting the lists. Future work in selecting and screening scenarios that begins with basaltic volcanism will build on the report. Additional, easily available reports will describe the future work. Those later reports will include the reasoning--based on new data, new analyses, new insights--behind the elimination and addition of scenarios.

The DOE feels that this series of documents will demonstrate the systematic screening and elimination of scenarios. It will help to meet the concern shared by the NRC staff and the DOE staff that "care must be taken in eliminating scenarios." The DOE also feels that open review of its work and solicitation of the opinions of the technical community are the ways to achieve reasonable assurance in the completeness of the lists of important scenarios. The series of documents is to be the framework for such review and solicitation.

ENCLOSURE 3

SCA Comment 115 and DOE Response (12/14/90)

NRC Evaluation of DOE Response (7/31/91)

Additional Information Relevant to SCA Comment 115 Open Item

Section 8.3.5.13 Total System Performance

COMMENT 115

There is an incorrect statement that the CCDF can be expanded in terms of scenario classes as in Figure 8.3.5.13-2 only if the entities comprising the scenario classes are statistically independent.

BASIS

Page 8.3.5.13-13 (last paragraph). DOE states that "the formalism for expanding the CCDF in mutually exclusive scenario classes is nevertheless capable of being generalized to any number of such objects, provided that they are statistically independent entities ..." In fact, the formalism can also be applied to dependent entities, with the probability of S sub j computed by products of conditional probabilities.

RECOMMENDATION

State that the expansion of Figure 8.3.5.13-2 can be extended to any number of dependent events, with the probabilities being replaced by conditional probabilities. Discuss the problems involved in estimating or modeling the conditional probabilities.

RESPONSE

This comment makes a valid point. Although there are no plans to update the Site Characterization Plan, the concern can be addressed by adding the following paragraph after the first paragraph on page 8.3.5.13-13 of the Site Characterization Plan.

"The formalism just developed can also be extended to more general situations with some additional complexity. For example, the generalization to alternative models with more than two states is easily accommodated. A three-state alternative model would multiply the number of scenario classes by a factor of three rather than two. It is also possible to allow for correlations among events (and undetected features and alternative models). For example, suppose that there are two possible kinds of events, E^1 and E^2, as in Figure 8.3.5.13-2. The probability of event E^2 could depend upon the occurrence of event E^1 and still preserve mutual exclusivity and exhaustivity. Suppose the probability of event E^1 is p_1, as before, but the probability of event E^2 is given by p^2 if E^1 occurs and p^3 if E^1 does not occur. Then $P(S^1) = (1 - p^1)(1 - p^3)$, $P(S^2) = p^1(1 - p^2)$, $P(S^3) = (1 - p^1)p^3$, and $P(S^4) = p^1p^2$, with the scenario classes S^j defined as shown in Figure 8.3.5.13-2. It may be verified that the probabilities still add up to one and the scenario classes defined are still mutually exclusive. Even more complicated situations may be imagined, in which the order of occurrence of events E^1 and E^2 is important, for example. These extensions of the formalism can be developed in a straightforward manner using the elementary rules of probability."

Section 8.3.5.13 Total System Performance

SCA COMMENT 115

There is an incorrect statement that the CCDF can be expanded in terms of scenario classes as in Figure 8.3.5.13-2 only if the entities comprising the scenario classes are statistically independent.

EVALUATION OF DOE RESPONSE

- Currently, DOE is not planning to revise the SCP, but proposed a paragraph for addition to the SCP should it be updated in the future. The suggested paragraph (denoted by PAR 1) for inclusion on page 8.3.5.13-13 is almost correct when considered by itself (see below), but it should be inserted at a different place in the text, and the text needs additional modification. First, PAR 1 should be inserted after the paragraph beginning on the bottom of page 8.3.5.13-13 and continuing on page 8.3.5.13-14 (denoted by PAR 2), not before. Since PAR 2 deals with two-state alternative models based on independent objects and since PAR 1 deals with a generalization of this framework, PAR 1 should follow PAR 2. Second, the phrase "provided that they are statistically independent entities" in PAR 2 should be changed to indicate that statistical independence is not a necessary condition but rather a special case.

- The next to last sentence of PAR 1 implies that the order of occurrence of E^1 and E^2 is a further complication; in fact, the example is based on E^1 occurring, if it does occur, before E^2. A suggested replacement is as follows: "Even more complicated situations may arise, for example, where sometimes E^1 precedes E^2 and sometimes E^2 precedes E^1." Also the term "dependencies" should be used instead of "correlation," as it is the more general term. (It is possible for two events to be dependent but uncorrelated.)

- Following PAR 1, it should be noted that a model based on dependent objects presents additional complications in estimating the conditional probabilities.

- The NRC staff considers this comment open, because as explained above, the proposed resolution is incomplete.

Supplemental Response to SCA Comment 115

The DOE agrees with the text details suggested by the NRC response of July 31, 1991. However, the SCP is not going to be reissued. The DOE intent is to properly implement the formalism developed on pages 8.3.5.13-12 and 13, as suggested by the NRC staff in carrying out its performance assessment program. An expansion of the SCP's explanation follows.

The formalism just developed can be extended to more general situations with some additional complexity. The generalization to alternative models with more than two states is easily accommodated. A three-state alternative model would multiply the number of scenario classes by a factor of three rather than two. It is also possible to allow for dependencies among events (and undetected features and alternative models). For example, suppose that there are two possible kinds of events, E^1 and E^2, as in Figure 8.3.5.13-2. The probability of event E^2 could depend upon the occurrence of event E^1 and still preserve mutual exclusivity and exhaustivity. Suppose the probability of event E^1 is p_1, as before, but the probability of event E^1 is given by p_2 if E^1 occurs and p_3 if E^1 does not occur. Then

$$P(S^1) = (1-p_1)(1-p_3)$$

$$P(S^2) = p_1(1-p_2)$$

$$P(S^3) = (1-p_1)p_3$$

$$P(S^4) = p_1p_2$$

with the scenario classes S^1 defined as shown in Figure 8.3.5.12-2. It may be verified that the probabilities still add up to 1 and the scenario classes defined are still mutually exclusive. Even more complicated situations may arise: for example, situations where sometimes E^1 precedes E^2 and sometimes E^2 precedes E^1. These extensions of the formalism can be developed in a straightforward manner using the elementary rules of probability. Calculating conditional probabilities involves additional complications when the events to be combined have additional dependencies.