Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Total System Performance Assessment and Integration Features, Events, and Processes

May 15-17, 2001
Las Vegas, Nevada

Introduction and Objectives

This Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (TSPAI) is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review, and the U.S. Department of Energy (DOE) site recommendation decision. Topics within TSPAI KTI will be discussed in two separate technical exchanges. This first technical exchange focuses on the NRC review and comments regarding part of the scenario analysis subissue, specifically the screening of features, events, and processes (FEPs) from the performance assessment. Another technical exchange, currently scheduled for June 25-29, 2001, will focus on the remaining subissues within the TSPAI KTI.

Consistent with NRC regulations on prelicensing consultations and a 1992 agreement with the DOE, staff-level resolution can be achieved during prelicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during prelicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. The discussions recorded here reflect NRC's current understanding of the screening of FEPs within DOE's performance assessment. This understanding is based on all information available to date which includes limited, focused, risk-informed reviews of selected portions of recently provided DOE documents (e.g., Analysis and Model Reports (AMRs) and Process Model Reports (PMRs)). Pertinent additional information (e.g., changes in design parameters) could raise new questions or comments regarding a previously resolved issue.

Although the status of the TSPAI subissues will not be discussed in this meeting, NRC discussed the issue resolution definitions in the beginning of the meeting. Specifically, NRC stated that issues are "closed" if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

Enclosure

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, NRC and DOE reached a number of preliminary agreements which will be carried forward to the June 25-29, 2001, TSPAI Technical Exchange and Management Meeting. The preliminary NRC/DOE agreements made at the meeting are provided in Attachment 1. A table containing all the FEPs discussed during the meeting and their associated NRC/DOE agreed upon path forward is included in Attachment 2. The agenda and the attendance list are provided in Attachments 3 and 4, respectively. Copies of the presenters slides are provided in Attachment 5. Additional FEP comments, not discussed during this meeting (e.g., Unsaturated Zone Flow and Transport FEPs), will be addressed in the June technical exchange. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Opening Comments

In its opening comments, NRC provided a general overview of performance assessment and scenario analysis (see "Background for Total System Performance Assessment - Features, Events, and Processes Meeting" presentation given by James Firth). NRC stated that the performance assessment is one of many NRC safety requirements and is a systematic analysis of what could happen at a repository. NRC also defined some of the terms that would be used during the meeting, such as scenario, probability, consequence, scenario analysis, screening, and features, events, and processes. Finally, NRC stated that during the meeting it would address two main issues, specifically, whether DOE's list of FEPs is complete and whether DOE has an adequate technical basis to support the screening choice.

2) TSPAI KTI Subissue 2 - Scenario Analysis

DOE provided an overview of the FEP methodology, including the identification of FEPs, the classification of FEPs, and the screening of FEPs (see "Total System Performance Assessment and Integration Key Technical Issue Subissue 2 - Scenario Analysis" presentation given by Peter Swift and Geoff Freeze). DOE also discussed its electronic database and DOE's perspective on the status of the TSPAI acceptance criteria.

DOE stated that the objectives of the FEP methodology are to: (1) provide comprehensive documentation that potentially relevant FEPs have been considered, (2) identify the FEPs that should be included in the quantitative performance assessment scenario analysis, (3) document the bases for excluding FEPs from the performance assessment, and (4) map included FEPs to the performance assessment model. DOE discussed the basis for the current list of FEPs; specific sources include: (1) the Nuclear Energy Agency international database; (2) the Yucca Mountain Project literature; (3) DOE internal technical review; and (4) NRC review.

DOE then discussed the classification of FEPs; currently designated as primary and secondary FEPs. DOE stated that primary FEPs encompass a single process or event, or a few closely related or coupled processes. The primary FEPs are aggregated to the coarsest level at which a technically sound screening decision can be made while still maintaining adequate detail for analysis. Primary FEPs include all issues from underlying secondary FEPs. DOE further stated that the scope of a given primary FEP may be broader than that encompassed by associated secondary FEPs.

Next, DOE discussed the screening of FEPs. DOE stated that FEPs are screened based on regulatory criteria, probability, or consequence (conditional or probability weighted). DOE further stated that screening is performed at the primary FEP level. Based on the results from the Total System Performance Assessment - Site Recommendation, DOE stated that 152 out of 328 primary FEPs have been excluded from the performance assessment.

Lastly, DOE discussed its electronic FEP database and a general overview of the NRC acceptance criteria documented in Revision 3 of the TSPAI Issue Resolution Status Report (IRSR). DOE stated that the database tracks FEP identification and screening, and enhances transparency and traceability. DOE stated that the new database addressed all the FEP issues raised in Revision 3 of the TSPAI IRSR.

Following the DOE presentation, the NRC had a number of questions with regard to DOE's FEP methodology. NRC questioned DOE about the philosophy used for the difference between the scope of secondary FEPs and their associated primary FEP. DOE indicated that they used secondary FEPs from other projects, but that their intent was not to define new secondary FEPs. DOE stated that their intent is that primary FEPs contain all relevant technical information. DOE also stated that the underlying secondary FEPs, from which the primary FEPs were derived are artifacts of the database construction. A question was asked regarding how DOE adds FEPs to the database, specifically why DOE adds FEPs after they are introduced through a FEP AMR, rather than identifying the FEP and then to address the FEP in a later revision to a FEP AMR. DOE indicated that FEPs are added to the database when corresponding analyses indicate that additions are warranted. DOE was asked about how they tracked design assumptions used to screen FEPs from the performance assessment to make sure that the screening assumptions and the final design are consistent. DOE stated that design changes could affect screening arguments. DOE indicated that configuration management controls are adequate for pre-conceptual design, however, controls will adopt more rigor as the design advances.

3) NRC Positions on Treatment of FEPs

The NRC discussed its views and comments on FEPs screening methodology (see "FEP Screening Methodology: NRC Staff Views and Comments" presentation given by Michael Lee). NRC stated that proposed 10 CFR Part 63 (Part 63) requires a technical basis for either including or excluding those FEPs that might potentially affect the performance of a geologic repository at Yucca Mountain. However, proposed Part 63 does not specify the manner by which DOE should investigate FEPs. NRC staff then provided their perspective on four issues relating to scenario analysis:

1) Can design be used as a criterion to screen FEPs?

2) Can both qualitative and quantitative arguments be used to screen FEPs?

3) What is the time period of regulatory interest for any FEP screening methodology?

4) To what extent should a FEP resulting as a consequence of human-intrusion be factored into the stylized human intrusion calculation?

The NRC staff's views regarding these issues can be found in "NRC Comments on DOE Features, Events, and Processes - May 15-17, 2001, Technical Exchange" slides which are included in Attachment 5. Following this discussion, DOE questioned whether the final Part 63 would be consistent with the final Environmental Protection Agency (EPA) regulation (40 CFR 197) with regard to the inclusion of unlikely disruptive events in the human intrusion analysis. NRC stated that the final Part 63 would be consistent with the EPA rule in this regard.

Next, NRC presented its preliminary views and comments on the DOE FEP screening methodology. (NRC noted that most of its comments had been introduced as part of the discussions associated with Section 2, "TSPAI KTI Subissue 2 - Scenario Analysis.") Specifically, these comments were:

1) That the FEPs database did not appear to be complete;

2) That several areas had been identified where there may be a lack of correspondence between the scope of the AMRs and the FEPs database;

3) It was not clear that DOE has demonstrated or considered the extent of coupling between FEPs; and

4) The role of the FEP database in DOE decision-making was unclear.

In presenting these comments, the NRC staff noted that DOE was not expected to respond immediately; rather, it was anticipated that specific examples of the staff concerns and DOE responses thereto would be raised in the context of the subsequent discussions for each of the AMRs that would be taking place later in the technical exchange. Finally, NRC provided one general observation. Specifically, that the relegation of FEP attributes among more than one AMR could lead to (a) underestimation of importance of a FEP to performance; or (b) under-representation of the FEP in the performance assessment. Again, NRC stated that this issue will be further discussed in the NRC comments on the DOE FEPs AMRs.

In its overall response, DOE noted the following:

- DOE considers the FEPs database to be complete by virtue of the sources of information used to compile it. In general, DOE noted that practical considerations had driven internal decisions on the number and kind of primary FEPs chosen to represent the range of features, events, and processes believed to be present at Yucca Mountain. If there was a view by NRC staff that a particular FEP was missing, it was requested that it be identified so it could be evaluated by DOE for possible future consideration.
- To the extent that there may be discrepancies, DOE welcomed their identification.

- DOE believes that coupling between FEPs has been addressed by virtue of (a) the individual FEP screening arguments themselves; and (b) the appropriate process models intended to describe the FEPs of interest.

- The value of using a computerized database to manage FEPs information was discussed. However, DOE noted that the primary source of information for FEPs identification was the Nuclear Energy Agency database, project literature search, and the AMRs. Nevertheless, DOE did note that its thinking regarding the role of the FEPs database programmatically was still evolving, especially as elements of its overall performance assessment methodology and configuration management of the DOE design process. As part of its future program planning related to any potential license application submittal, DOE noted that it has not finalized the role of the database.

4) Discussion of NRC Comments on DOE FEPs

During this portion of the meeting, NRC and DOE discussed NRC comments related to the FEPs database and supporting FEPs AMRs. The NRC comments were broken down and discussed under the appropriate DOE FEPs AMR (see "NRC Comments on DOE Features, Events, and Processes - May 15-17, 2001, Technical Exchange" slides in Attachment 5). The specific FEPs discussed during this technical exchange, and the NRC/DOE agreed path forward for each related comment, are summarized in Attachment 2. Preliminary NRC/DOE agreements are discussed in Attachment 1 and reference the specific path forward information in Attachment 2. These preliminary agreements will be carried forward to the June 25-29, 2001, Technical Exchange and Management Meeting and will be included in the overall discussion of TSPAI Subissue 2.

During the meeting, NRC raised questions about the scope of several primary FEPs and about the differing level of detail encompassed by the primary FEPs. Rising from the discussions held during the meetings, NRC made the following observation.

Proposed Part 63 requires a systematic analysis of FEPs that might potentially affect the performance of a geologic repository at Yucca Mountain. Although it does not specify the manner by which FEPs should be investigated, proposed Part 63 requires that DOE "...provide the technical basis for either inclusion or exclusion of specific features, events, and processes...." The staff is interested in a transparent, traceable, and technically defensible investigative process that leads to a clear understanding of DOE's basis for FEP inclusion or exclusion. Based on the NRC staff review of the pertinent DOE documents, these attributes are not readily apparent for some FEPs. In addition, the level of information used to describe the scope of primary FEPs appears to vary. Therefore, the comprehensiveness of the FEPs list is not apparent. Specific examples were provided by the NRC during the technical exchange.

In response to this observation, the DOE acknowledged the importance of the FEPs to DOE's TSPA process and the FEP database to indicate the disposition of FEPs. DOE agreed with the NRC's concern, for the most part, and committed to clarify the FEP arguments in specific AMRs. DOE indicated that NRC should continue to focus on the primary FEPs and their associated arguments during its review, noting that the secondary FEPs are historical in nature. As a path forward, DOE also proposed to discuss improvements to the FEPs process at the June technical exchange, including a description of the method for adding new FEPs. In addition, at the June technical exchange, DOE indicated it would also discuss the role of FEPs versus models, how they fit together, and how they roll up in the TSPA. NRC agreed that this was an acceptable path forward and would clarify details in the telephone conversations preparing for the next technical exchange.

During the discussion of the NRC comments, DOE indicated that several FEPs had been excluded because of conservatism in the uncertainty range for TSPA parameters. NRC indicated that to be transparent, the TSPA disposition should indicate these FEPs are included in the performance assessment, instead of being excluded.

Two other issues were addressed during this part of the meeting. Specifically, that: (1) insufficient information is provided on propagation of uncertainties in spent nuclear fuel dissolution data, and (2) there has been insufficient use of alternative models for spent nuclear fuel dissolution. After discussing these two issues, DOE agreed to provide additional information in the appropriate AMRs (see Attachment 1 for preliminary agreement wording).

5) Public Comments

No public comments were made.

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Summary of the Resolution of the Key Technical Issue on Total System Performance Assessment and Integration Features, Events, and Processes

Subissue #	Subissue Title	Status	Preliminary NRC/DOE Agreements
2	Scenario analysis within the total system performance assessment methodology	N/A	1) Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 29, 32, 41, 43, 44, 47, 49, 50, 51, 53, 58, 67, 78, and 79. DOE will clarify the screening arguments, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY02 and FY03. 2) Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 19 (Parts 1, 2, and 6), 25, 26, 36, 37, 38, 39, 57, 60, and 61. DOE will provide the technical basis for the screening argument, as summarized in Attachment 2, for the highlighted FEPs. The technical basis will be provided in the referenced FEPs AMR and will be provided to the NRC in FY02 and FY03. 3) Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8) and 20. DOE will add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. The FEPs will be added to the appropriate FEPs AMRs and the AMRs will be provided to the NRC in FY02 and FY03.

			4) Provide a clarification of the description of the primary FEP. See Comments 24, 31, and 33. DOE will clarify the description of the primary FEPs, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY02 and FY03. 5) DOE needs to demonstrate how errors propagate in performance assessment from conservative (fast) rates of spent fuel dissolution. In addition, DOE needs to demonstrate that uncertainties in rates of spent fuel dissolution under low pH conditions are adequately represented in the performance assessment model, given the limited set of data. DOE will clarify propagation of uncertainties in spent fuel dissolution rates through TSPA in the In-package Chemistry Abstraction AMR, ANL-EBS-MD-000037 in FY02. DOE is conducting low pH flow-through experiments and will update the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 in FY02, as appropriate. In FY02, DOE will demonstrate in the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 that the CSNF models do not lead to optimistic results in the 10,000 year regulatory period. 6) DOE has alternative models for spent nuclear fuel dissolution (e.g., drip test results at ANL). DOE needs to clarify why the alternative models have not been incorporated in the DOE TSPA. DOE noted that Argonne National Laboratory Spent Nuclear Fuel drip tests corroborate the flow-through model. Other tests indicate that the model is bounding. This discussion in the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 will be clarified in FY02. In FY02, DOE will demonstrate in the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 that the models do not lead to optimistic results in the 10,000 year regulatory period.

Total System Performance Assessment and Integration
Features, Events, and Processes
Attachment 2

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
1	Generic	SZ		NRC stated that it is withdrawing the comment, no additional DOE action is required.
2	1.3.07.02.00	SZ	Water Table Rise	No additional DOE action is required.
3	2.2.10.03.00	SZ	Natural Geothermal Effects	This issue is addressed by existing DOE/NRC agreement (USFIC Subissue 5 Agreement 13). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated as necessary to reflect the results of this existing agreement.
4	1.2.06.00.00	SZ	Hydrothermal activity	This issue is addressed by existing DOE/NRC agreements (RT Subissue 1 Agreement 5 and Subissue 2 Agreement 10). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated as necessary to reflect the results of these existing agreements.
5	2.1.09.21.00	SZ	Suspension of Particles Larger than Colloids	DOE agreed to provide clarification for the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comments.
6	NA	SZ	NA	Initiation, tracking, resolution and closure of To Be Verified's in technical products are procedurally controlled per procedure AP-3.15Q. Resolution of this issue is being addressed at DOE and NRC Management meetings.
7	1.4.06.01.00	SZ	Altered soil or surface water chemistry	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comments. The AMR will also address the aggregate affects of this FEP on UZ and SZ.
8	1.2.04.07.00	SZ	Ashfall	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.
9	2.2.10.06.00	SZ	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/ dissolution)	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.
10	2.3.11.04.00	SZ	Groundwater discharge to surface	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.
11	1.3.07.01.00	SZ	Drought/water table decline	This issue is addressed by existing DOE/NRC agreements (RT Subissue 2 Agreement 8 and USFIC Subissue 5 Agreement 4). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated as necessary to reflect the results of these existing agreements and clarify the screening argument.
12	2.2.10.13.00	SZ	Density-driven groundwater flow (thermal)	This issue is addressed by an existing DOE/NRC agreement (USFIC Subissue 5 Agreement 13). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated to clarify the screening argument and to reflect the results of this existing agreement.
13	2.2.10.02.00	SZ	Thermal convection cell develops in Saturated Zone	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002.
14	1.2.09.02.00	SZ	Large-scale dissolution	No additional DOE action is required.
15	2.3.09.01.00	BIO	Animal Burrowing/Inclusion	NRC stated that it is withdrawing the comment, no additional DOE action is required.
16	2.3.13.01.10	Bio	Natural Ecological Development	No additional DOE action is required.
17	NA	Bio	NA	No additional DOE action is required.
18	1.4.07.01.00	Bio	Water management activities	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
19	Various	Bio	BDCF calculations	DOE will provide a technical basis in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 to address the NRC comment for FEP 2.3.11.04.00 (Groundwater Discharge to Surface), FEP 1.3.07.02.00 (Water Table Rise), and FEP 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere). No further action is required for FEP 3.2.10.00.00 (Atmospheric Transport of Contaminants) and FEP 1.2.04.01.00 (Igneous Activity). DOE agreed to provide clarification of the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011, for FEP 2.2.08.02.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone). DOE will add links to the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 for FEP 3.1.01.01.00 (Radioactive Decay and Ingrowth), and FEP 1.2.04.07.00 (Ashfall).
20	2.2.08.07.00	Bio	Radionuclide solubility limits in the geosphere	DOE will add this FEP to the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 and present the DOE discussion in the screening argument.
21	2.3.13.01.00	Bio	Biosphere characteristics	DOE agreed to provide clarification of the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 to address the NRC comment.
22	2.3.13.01.00	Bio	Biosphere characteristics	No additional DOE action is required.
23	2.3.11.04.00	Bio	Groundwater discharge to surface	No additional DOE action is required.
24	2.3.13.02.00	Bio	Biosphere transport	DOE agreed to clarify the description of the primary FEP in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011
25	2.4.07.00.00	Bio	Dwellings	DOE agreed to provide the technical basis for the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011.
26	3.3.08.00.00	Bio	Radon and daughter exposure	DOE agreed to provide the technical basis for the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011.
27	2.1.09.09.00	WP	Electrochemical effects (electrophoresis , galvanic coupling)	NRC stated that it is withdrawing the comment, no additional DOE action is required.
28	2.1.03.04.00	WP	Hydride cracking of waste containers	NRC stated that it is withdrawing the comment, no additional DOE action is required.
29	2.1.06.07.00	WP	Effects at Material Interfaces	This issue is addressed by an existing agreement (CLST subissue 6 Agreement 1). DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002, as necessary upon completion of the agreement item.
30	2.1.03.05.00	WP	Microbially mediated corrosion of waste container	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.
31	1.2.03.02.00	WP	Seismic vibration causes container failure	DOE agreed to clarify the description of the primary FEP in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
32	2.1.13.01.00	WF Misc WP	Radiolysis	DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 to address the NRC comment.
33	NA	WP	NA	DOE agreed to clarify the description of the primary FEP in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
34	2.1.03.02.00	WP	Stress corrosion cracking of Waste Containers	This issue is covered by an existing DOE/NRC agreement (CLST Subissue 2 Agreement 8). DOE will update the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 screening argument upon completion of the agreement.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
35	2.1.03.08.00	WP	Juvenile and early failure of waste containers	Manufacturing defects associated with the drip shield will be addressed during the resolution of an existing agreement item for the waste package (CLST Subissue 2, Agreement 7). The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be updated to reflect the results of this agreement. Mechanical integrity of the drip shield will be addressed during the resolution of an existing agreement item for the waste package (CLST Subissue 2, Agreement 6). The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be updated to reflect the results of this agreement. Rockfall effects on the drip shield will be addressed during the resolution of an existing agreement item for the waste package (CLST Subissue 2, Agreement 8). The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be updated to reflect the results of this agreement. The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be revised to address damage from improper quality control and emplacement of the drip shield. The criteria for damage to waste package during emplacement will be addressed by administrative procedures for emplacement operations that will be developed prior to operation of the facility.
36	2.1.09.03.00	WP	Volume increase of corrosion products	DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 to address the NRC comment.
37	2.1.07.05.00	WP	Creeping of metallic materials in the EBS	Treatment of creep of the drip shield will be addressed as part of an existing agreement related to drip shield rockfall analyses (CLST Subissue 2 Agreement 8). DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
38	2.1.11.05.00	WP EBS	Differing thermal expansion of repository components	DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 screening argument to address the NRC comment.
39	2.1.06.06.00	WP DE	Effects and degradation of drip shield	The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in existing agreements (CLST Subissue 2 Agreements 8 and 9). DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
40	2.1.02.21.00	Clad	Stress corrosion cracking of cladding	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.
41	2.1.02.20.00	WFClad	Pressurization from Helium production causes cladding failure	DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
42	2.1.08.07.00	EBS	Pathways for unsaturated flow and transport in the waste and engineered barrier system	This issue is addressed by an existing DOE/NRC agreement (ENFE Subissue 2 Agreement 6, 10, and 14). The Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 will be updated upon completion of these agreement items.
43	2.1.02.27.00		Localized corrosion perforation from fluoride	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
44	2.1.02.16.00	WFClad	Localized Corrosion (pitting) of cladding	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
45	2.1.02.19.00		Creep rupture of cladding	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.
46	2.1.02.24.00	WFClad	Mechanical failure of cladding	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
47	2.1.02.17.00	WFClad	Localized corrosion (crevice corrosion) of cladding	DOE agreed to provide clarification of the screening argument in the Clad Degradation – FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment using data relevant to the proposed repository.
48	2.1.01.04.00	WFMisc WP	Spatial heterogeneity of emplaced waste	Spatial variability that may affect degradation of the waste package will be addressed as part of the resolution of an existing agreement (CLST Subissue 1 Agreement 1). The scope of the agreement includes the evaluation of the range of chemical environments on the waste package.
49	2.1.02.15.00	WFClad	Acid corrosion of cladding from radiolysis	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
50	2.1.02.13.00	WFClad	General Corrosion of Cladding	DOE agreed to provide clarification of the screening argument in the Clad Degradation Features, Events and Processes Analysis/Model Report (ANL-WIS-MD-000008) to address the NRC comment.
51	2.1.02.14.00	WFClad	Microbially induced corrosion of cladding	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment. The new cladding local corrosion model will reference the In-Drift Microbial Communities AMR, ANL-EBS-MD-000038, which includes discussion of iron oxidizing bacteria. The *Clad Degradation - FEPs Screening Arguments*, ANL-WIS-MD-000008 AMR will be revised to be consistent with the updated Summary-Abstraction AMR.
52	1.2.04.04.00	WFMisc	Magma Interacts w/ Waste	NRC stated that it is withdrawing the comment, no additional DOE action is required.
53	2.1.02.22.00	WFClad	Hydride embrittlement of cladding	DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
54	2.1.09.02.00	EBS	Interaction w/ Corrosion products	This issue is addressed by an existing DOE/NRC agreements (ENFE Subissue 2 Agreement 6, 10, and 14). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be updated upon completion of these agreement items.
55	2.1.09.07.00	EBS Misc WF	Reaction Kinetics in Waste and EBS	This issue is addressed by an existing DOE/NRC agreements (ENFE Subissue 2 Agreement 5, 8, 11, and 12). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be updated upon completion of these agreement items.
56	2.1.07.06.00	EBS	Floor buckling	This issue is addressed by existing DOE/NRC agreements (RDTME Subissue 3 Agreements 2 – 13). DOE agreed to include the analysis of floor buckling for post-closure conditions, consistent with the site-specific parameters and loading conditions used to satisfy RDTME Subissue 3, Agreements 2-13. The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be revised to include this information.
57	1.1.02.03.00	EBS	Undesirable materials left	DOE agreed to provide the technical basis for the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 to address the NRC comment. This will include a technical basis for the use of the Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction. BABE00000-01717-2200-00007 Rev 04.
58	Various	EBS	NA	DOE agreed to provide clarification of the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 to address the NRC comment.
59	2.1.08.04.00	EBS	Cold traps	This issue is addressed by an existing DOE/NRC agreement (TEF Agreement Subissue 2 Agreement 5). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be revised upon completion of this agreement.
60	2.1.12.01.00	EBS	Gas generation	This issue is partially addressed by an existing DOE/NRC agreement (ENFE Subissue 2 Agreement 6). DOE agreed to provide the technical basis for the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 to address the NRC comment.
61	2.2.10.12.00	NFE UZ	Geosphere dry-out due to waste heat	DOE agreed to provide the technical basis for the screening argument in the Features, Events, and Processes in the *Features, Events, and Processes in UZ Flow and Transport*, ANL-NBS-MD-000001 to address the NRC comment.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
62	2.2.01.02.00	NFE	Thermal and other waste and EBS-related changes in the adjacent host rock	TM effects on fractures will be addressed by existing agreements between DOE and NRC (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work. Long term degradation of the host rock is addressed by existing agreements between DOE and NRC (RDTME Subissue 3 Agreement 11 and 19). DOE will provide an improved technical basis for this FEP by performing a postclosure drift deformation analysis that incorporates postclosure loads and rock properties using relevant information from existing agreements (RDTME Subissue 3 Agreements 2 – 13). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be revised to include this information.
63	2.1.09.12.00	NFE	Rind (altered zone) formation in waste, EBS and adjacent rock	This issue is addressed by existing agreements between DOE and NRC (ENFE Subissue 1 Agreement 3). *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
64	2.2.10.06.00	NFE	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/dis solution	This issue is addressed by existing agreements between DOE and NRC (ENFE Subissue 1 Agreement 3). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
65	2.1.11.02.00	NFE	Nonuniform heat distribution/edg e effects in repository	Repository wide non-uniform heating effects are the subject of existing DOE/NRC agreements (TEF Subissue 2 Agreement 5, RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work. THM continuum modeling will address non-uniform effects at a mountain scale. This information will be provided in the Coupled Thermal-Hydrologic-Mechanical Effects on Permeability Analysis and Model Report AMR, ANL-NBS-HS-000037.
66	2.2.06.01.00	NFE DE	Changes in stress due to thermal, seismic or tectonic effects	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 and the Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 will be revised upon completion of this work.
67	2.2.10.05.00	NFE	Thermo-mechanical alteration of rocks above and below the repository	DOE has planned work to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts, and thermal-hydrological/ thermal-hydrological -chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. In addition, THM continuum modeling will address thermal mechanical effects in rocks above and below the repository at a mountain scale in an update to the Coupled Thermal-Hydrologic-Mechanical Effects on Permeability Analysis and Model Report AMR, ANL-NBS-HS-000037. DOE will clarify the screening arguments in the *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 upon completion of this work.
68	1.2.02.01.00	NFE --	Fractures	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
69	2.2.01.01.00	NFE	Excavation and construction-related changes in the adjacent host rock	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
70	2.2.10.04.00	NFE	Thermo-mechanical alteration of fractures near repository	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
71	1.1.07.00.00	SYS	Repository design	No additional DOE action is required.
72	1.1.08.00.00	SYS	Quality control	No additional DOE action is required.
73	2.3.13.03.00	SYS Bio	Effects of repository heat on biosphere	No additional DOE action is required.
74	Various	SYS	Critically in waste and EBS	No additional DOE action is required.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
75	Various	DE	Excavation/ Construction Incomplete/ Closure Canister Failure(long term) Mechanical Degradation or Collapse of Drift Topography & Morphology	These issues will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.
76	Generic	DE	Hydrothermal activity	These issues will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.
77	2.1.07.02.00	DE	Mechanical degradation or collapse of drift	No additional DOE action is required.
78	1.2.03.02.00	WP DE	Seismic vibration causes container failure	Existing agreements from the Container Life and Source Term (Subissue 2 agreements 2 and 8), Repository Design and Thermal Mechanical Effects (Subissue 3 agreements 17 and 19) and Structural Deformation and Seismicity (Subissue 1 agreement 2 and Subissue 2 agreement 3) address related work. DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 and Features, Events, and Processes: Screening for Disruptive Events, ANL-WIS-MD-000005.
79	2.1.07.01.00	DE WP	Rockfall (Large Block)	Existing agreements from Repository Design and Thermal Mechanical Effects agreements (Subissue 3 agreements 17 and 19) and Container Life and Source Term (subissue 2 agreements 2, 3 and 8) address related work. DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 and Features, Events, and Processes: Screening for Disruptive Events, ANL-WIS-MD-000005.
80	2.3.02.02.00	Bio	Radionuclide Accumulation in Soil	These issues will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.

DOE-NRC Technical Exchange Meeting Agenda
TOTAL SYSTEM PERFORMANCE ASSESSMENT
FEATURES, EVENTS AND PROCESSES
Texas Station Hotel and Casino
Las Vegas, Nevada
May 15-17, 2001

OBJECTIVES:

Provide the basis to resolve open issues related to the Total System Performance Assessment and Integration Key Technical Issue. This Technical Exchange will focus on the DOE Scenario Analysis, particularly the screening of Features, Events and Processes from the Performance Assessment. Newly identified issues, resulting from NRC's review of DOE's technical documents, will be addressed.

TUESDAY – May 15, 2001

Time	Agenda Items
8:00 – 8:15 AM	Introduction/Objectives/Logistics – Opening Remarks (DOE/NRC)
8:15 – 8:30 AM	Description of Meeting Purpose and Background for the Meeting (NRC)
8:30 – 9:00 AM	TSPAI Subissue 2 – Scenario Analysis Presentations – Features, Events and Processes (FEPs) Database Construction (Freeze/Swift)
9:00 – 9:30 AM	TSPAI Subissue 2 – Scenario Analysis Presentation – Total System Performance Assessment Overview (Freeze/Swift) • FEPs identification • FEPs classification • FEPs screening
9:30 – 9:45 AM	BREAK
9:45 – 11:30 AM	NRC Positions on Treatment of FEPs (NRC)
11:30 – 12:30 PM	LUNCH
12:30 – 1:30 PM	Caucus
1:30 – 3:15 PM	Discussion of Saturated Zone related FEPs (Arnold/Eddebbarh)
3:15 – 3:30 PM	BREAK
3:30 – 4:30 PM	Discussion of Biosphere related FEPs (Tappen/Smith)
4:30 – 5:30 PM	Caucus
5:30 – 6:00 PM	Discussion of Caucus Results (DOE/NRC)
6:00 PM	Adjourn Day 1

Attachment 3

DOE-NRC Technical Exchange Meeting Agenda
TOTAL SYSTEM PERFORMANCE ASSESSMENT
FEATURES, EVENTS AND PROCESSES
Texas Station Hotel and Casino
Las Vegas, Nevada
May 15-17, 2001

WEDNESDAY – May 16, 2001

8:00 – 9:30 AM	Discussion of Waste Package and Drip Shield related FEPs (Pasu/Bennett/Lee)
9:30 – 9:45 AM	BREAK
9:45 – 10:45 AM	Discussion of Waste Form (Cladding, and Miscellaneous) related FEPs (Schenker/Siegmann/Stockman/Rechard)
10:45 – 11:15 AM	Uncertainties in Spent Fuel Dissolution and In-Package Chemistry (NRC)
11:15 – 11:45 AM	Alternative Conceptual Models for Spent Fuel Dissolution (NRC)
11:45 – 12:45 PM	LUNCH
12:45 – 1:45 PM	Discussion of Engineered Barrier System related FEPs (Mast)
1:45 – 2:45 PM	Discussion of TH and Coupled Processes related FEPs (Itamura)
2:45 – 3:00 PM	BREAK
3:00 – 4:00 PM	Discussion of TH and Coupled Processes related FEPs (Itamura) (DOE/NRC)
4:00 – 4:30 PM	Discussion of System Level and Criticality related FEPs (McGregor/Thomas/Rechard)
4:30 – 5:00 PM	Discussion of Disruptive Events related FEPs (McGregor/Quittmeyer)
5:00 – 6:00 PM	Caucus
6:00 PM	Adjourn Day 2

THURSDAY – May 17, 2001

8:00 – 8:30 AM	Discussion of Caucus Results (DOE/NRC)
8:30 – 9:30 AM	DOE Caucus to discuss proposed agreements
9:30 – 10:00 AM	Discussion of any proposed agreements (DOE/NRC)
10:00 – 10:30 AM	Closing Remarks/Public Comments
10:30 AM	Adjourn Meeting

KTI - TSPA/FEPs
Tuesday, May 15, 2001
Sign In Sheet

Name (Please Print)	Company	Phone #
SANDRA WASTLER	NRC	301-415-8733
JIM ANDERSEN	NRC	301-415-5717
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Mike Lee	NRC	301/415-6677
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Tae Ahn	NRC	301-415-5812
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Attachment 4

KTI - TSPA/FEPs
Tuesday, May 15, 2001
Sign In Sheet

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KTI - TSPA/FEPs

Tuesday, May 15, 2001

Sign In Sheet

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KTI - TSPA/FEPs
Tuesday, May 15, 2001
Sign In Sheet

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	Gordon Wittmeyer	CNWRA	210-522-5082
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	MICHAEL VALENTINE	DOE/YMP	702-794-1314
	LES WAGNER	OQA/NQS	702-794-1304
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	Carolyn Garden	BSC/B&A	295-5486
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KTI - TSPA/FEPs
Wednesday, May 16, 2001
Sign In Sheet

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KTI - TSPA/FEPs
Wednesday, May 16, 2001
Sign In Sheet

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KTI - TSPA/FEPs
Wednesday, May 16, 2001
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Bob Gamble	MTS/BAH	702-794-1440
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KTI - TSPA/FEPs
Thursday, May 17, 2001
Sign In Sheet

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Attachment 5

Slides from the Presentations

Background for Total System Performance Assessment Features, Events, and Processes Meeting

Las Vegas, Nevada
May 15-18, 2001

- Meeting will address part of the Department's of Energy's performance assessment.

- Performance Assessment is
  - Systematic analysis of what could happen at a repository. This means answering three questions: what can happen?, how likely is it?, and what can result?
  - One of many NRC safety requirements

- **Additional general information on performance assessment is available (see 11 by 17 inch color handout and poster)**
- **<u>Terms and definitions</u>**
    - **Scenario - another way of saying "what can happen?"**
    - **Probability - another way of saying "how likely?"**
    - **Consequence - another way of saying "what can result?"**
    - **Scenario analysis - an evaluation of what can happen**
    - **Screening - deciding whether to include a factor in a performance assessment**

Terms and definitions (continued)

- Features, Events, and Processes (FEPs) - factors that are necessary to describe what can potentially happen to the repository.

  - Examples include: climate, waterflow, rock chemistry, design of the repository, construction of the repository, strength of the waste containers and how well they resist corrosion, the nature of the waste, and natural events such as earthquakes and volcanoes.

- **Meeting will address the Department of Energy's scenario analysis in their performance assessment**
  - **List of features, events, and processes**
  - **Screening arguments used by the Department of Energy to exclude factors from their performance assessment**

- **The Nuclear Regulatory Commission's independent review of the Department of Energy's scenario analysis questions the Department of Energy's**
  - **List of features, events, and processes- is it complete?**
  - **Screening arguments - is there an adequate technical basis to support the screening choice?**

FEP SCREENING METHODOLOGY:

NRC STAFF VIEWS AND COMMENTS

U.S. DEPARTMENT OF ENERGY/
U.S. NUCLEAR REGULATORY COMMISSION
TECHNICAL EXCHANGE ON
TOTAL SYSTEM PERFORMANCE ASSESSMENT
Las Vegas, Nevada
May 14, 2001

Michael P. Lee
Division of Waste Management
Office of Nuclear Materials Safety and Safeguards
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GOALS OF SCREENING METHODOLOGY FOR FEATURES, EVENTS, AND PROCESSES (FEPs): NRC STAFF VIEWS

- Proposed 10 CFR Part 63 requires a systematic analysis of FEPs that might potentially affect the performance of a geologic repository at Yucca Mountain

- Proposed regulation specifies consideration of those FEPs that could materially affect compliance with the overall system performance objective or have potentially adverse effects on performance

  - Events with annual probabilities less than 10^{-8} can be excluded

- However, proposed Part 63 does not specify the manner by which DOE should investigate FEPs

  - Purpose of FEPs screening process is to show clearly both:

    1. What has been considered, and

    2. What has been excluded from any performance assessment calculation

NRC EXPECTATIONS REGARDING DOE SCREENING METHODOLOGY[1] FOR FEPs

- DOE can screen FEPs using whatever method(s) it chooses
- In general, method should include:
  - Adequate technical justification
  - Well-documented
- In particular, method should:
  - Be thorough
  - Provide correct characterization and treatment of FEPs as singular or universal
  - Have sound probabilistic calculus
  - Consider FEP representativeness and variability

---

[1] November 5-6, 1997, NRC/DOE Technical Exchange on TSPA.

GOALS FOR TODAY'S PRESENTATION AND DISCUSSION

- Assess DOE's progress in the implementation of its FEP screening methodology

- Provide additional clarification from NRC staff on:

  1. Use of design as a screening criterion
  2. Use of qualitative and quantitative arguments to screen FEPs
  3. Time period of regulatory interest for FEPs consideration
  4. Treatment of FEPs in the stylized human intrusion calculation

- Provide staff views on other specific issues

NRC STAFF RESPONSE TO QUESTIONS

ISSUE 1
Can design be used as a criterion to screen FEPs?

NRC STAFF RESPONSE

- DOE can screen FEPs (or FEP classes) based on a proposed design concept
  - Consistent with overall risk-informed, performance-based philosophy to proposed Part 63
  - Screening can be based on either:
    1. Probability, or
    2. Consequence
- DOE will need to demonstrate that the particular design feature can perform its intended mitigation function over the time period of regulatory interest
- For supporting screening arguments, probability values for component failure or events potentially leading to the failure of the design feature, range, and distributions or relevant variables and/or boundary assumptions should be:
  - Technically defensible
  - Account for uncertainty and variability
- Reference to "yet-to-be developed" quality assurance (QA) arguments may be appropriate during pre-licensing
  - Any such QA procedures will need to be developed considering proposed screening arguments

ISSUE 2

Can both qualitative and quantitative arguments be used to screen FEPs?

NRC STAFF RESPONSE

- DOE is required to provide the technical basis for:
  - FEPs considered for the performance assessment, but excluded
  - FEPs included in the performance assessment
- DOE may use qualitative arguments as long as they provide sufficient justification to show that the FEP has been screened appropriately
- DOE may decide that quantitative information is necessary to provide the information necessary to show that a FEP has been screened appropriately
- Decide whether there is sufficient field, experimental, and/or analogue information and data to adequately support FEP screening arguments (probability or consequence)
  - Alternatively rely on informal expert judgement, peer review, formal expert judgment, or some other decision-making
  - FEP characteristics likely to influence whether qualitative arguments would suffice
- Ultimately, DOE decision should be risk-informed

ISSUE 3
What is the time period of regulatory interest for any FEP screening methodology?

NRC STAFF RESPONSE

- Proposed Part 63 does not require or suggest any analyses beyond 10,000 years

- Should DOE choose to conduct analyses beyond 10,000 years, the Department is expected to rely on well-documented screening arguments

ISSUE 4
To what extent should a FEP resulting as a consequence of human-intrusion be factored into the stylized human intrusion calculation?

NRC STAFF RESPONSE

- NRC's proposed regulation at Part 63 would require that DOE evaluate the ability of the proposed repository to limit radiological exposures due to stylized human intrusion drilling scenario
  - Provide insight into the degree in which the ability of the repository would be degraded by intrusion
  - Reduce unlimited speculation regarding the nature of the calculation itself
- In the spirit of both the intent and nature of the "stylized" calculation itself, staff do not expect DOE to conduct an exhaustive review of screened FEPs
- DOE is expected to:
  - Describe a reasonable suite of human intrusion-related FEPs sufficient to evaluate repository resilience
  - Identify those FEPs where the screening argument may be substantively affected by the intrusion
  - Document its decision-making on ultimate treatment in calculation

NRC STAFF COMMENTS

COMMENT 1
DOE's FEP data base does not appear to be complete

WHAT IS NEEDED
DOE needs to prepare a comprehensive list of FEPs that are present or may occur during the time period of regulatory interest

OBSERVATIONS

- FEPs database is a key feature in any potential DOE license application
  - Describes what was evaluated (transparency)
  - Documents ultimate decision-making (traceability)
  - Helps to ensure complete and high-quality license application
- In some instances, the staff have identified a number of "missing" FEPs that are not implicitly or explicitly addressed in DOE's FEP data base
- In some instances, use of broad FEP class definitions (i.e., Primary FEPs) as screening tool does not clearly convey what DOE did consider

COMMENT 2
Several areas have been identified where there may be a lack of correspondence between the scope of the AMRs and the FEPs database

WHAT IS NEEDED
DOE's comprehensive list of FEPs should be consistent with the features, events, and processes evaluated in the AMRs

OBSERVATIONS

- FEPs database as a key feature in any potential DOE license application
  - Describes what was evaluated (transparency)
  - Documents ultimate decision-making (traceability)
  - Helps to ensure complete and high-quality license application
- Correspondence between the FEPs database and the analyses described/ documented in AMRs should be improved

COMMENT 3
It is not clear that DOE has not demonstrated or considered the extent of coupling between FEPs

WHAT IS NEEDED
In the context of FEP screening, DOE should describe the extent of coupling between the pertinent physicochemical processes at the site as part of its rationale for screening FEPs

OBSERVATIONS
- DOE relying on the use of predictive models to estimate future repository performance

- Predictive models used in the screening do not appear to rely on an adequate understanding of the physicochemical processes present at the site as well as their potential interaction with engineered components of any potential repository

COMMENT 4
The role of the FEP database in DOE decision-making is unclear

WHAT IS NEEDED
A demonstrated vertical integration between FEPs, process-level models, and TSPA computational modules

OBSERVATIONS

- DOE documentation of its decision-making regarding FEPs is unclear
  - See Comment Nos. 1 and 2

COMMENT 5
Several of the screening arguments for the initial list of FEPs are incomplete (i.e, inadequate or classified as "yet-to-be-verified")

WHAT IS NEEDED
It is necessary to outline verification plans for those FEPs or supporting assumptions considered "yet-to-be-verified"

OBSERVATIONS

- Screening arguments for Primary FEPs should be valid for corresponding Secondary FEPs
- Screening arguments for **excluded** FEPs need to be adequate
- For those **included** FEPs, it should be clear they are being incorporated into the performance assessment
- Lack of detail or insufficient information to support DOE screening arguments

NRC STAFF OBSERVATION

OBSERVATION 1

Relegation of FEP attributes among more than one AMR could lead to (a) underestimation of importance of FEP to performance (e.g., screening); or (b) under representation of the FEP in the performance assessment itself

WHAT IS NEEDED

DOE will need to (a) develop an appropriate rationale for FEPs screening; and (b) appropriately incorporate included FEPs in its performance assessment

OBSERVATIONS

- Feature, Event, or Process is the ultimate unit of interest
- Screening arguments can be probability- or consequence-based
- To the extent that a FEP occurs in more than one AMR, it needs to be treated in those AMRs in a manner that is consistent with its affect on performance of the repository system
- By virtue of FEP division among more than one AMR, there is the potential for under-representation of an included FEP within the performance assessment

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Total System Performance Assessment and Integration Key Technical Issue Subissue 2 - Scenario Analysis

Presented at:
DOE/NRC Technical Exchange on Features, Events and Processes

Presented by:
Peter Swift
Geoff Freeze

May 15-17, 2001
Las Vegas, NV

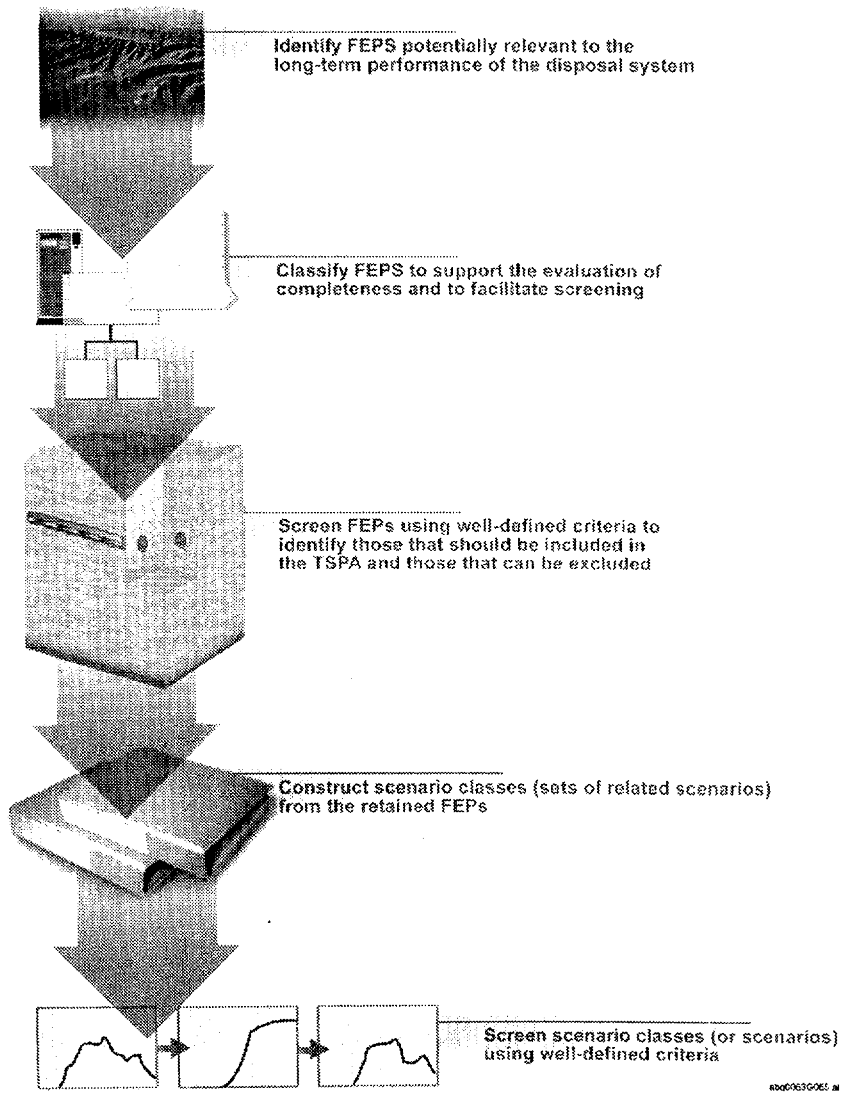
YUCCA MOUNTAIN PROJECT

Outline

- Summary of Feature, Event, and Process (FEP) Methodology
- Identification of FEPs
- Classification of FEPs
- Screening of FEPs
- Electronic Database
- Status of Total System Performance Assessment & Integration Issue Resolution Status Report (IRSR) Revision 3 Acceptance Criteria
- Summary

Summary of FEP Methodology

- Scenario analysis for Total System Performance Assessment is based on a five step process that is consistent with the approach described in NRC Total System Performance Assessment & Integration Issue Resolution Status Report Rev 3
  - Identification of FEPs
  - Classification of FEPs
  - Screening of FEPs
  - Constructing Scenarios*
  - Screening Scenarios*



* Not discussed in this presentation

Summary of FEP Methodology (cont.)

- Objectives of the FEP methodology
  - Provide comprehensive documentation that potentially relevant FEPs have been considered
  - Identify the FEPs that must be included in the quantitative Total System Performance Assessment scenario analysis
  - Document the basis for FEPs excluded from the Total System Performance Assessment
  - Map how included FEPs have been modeled

Summary of FEP Methodology (cont.)

- **FEP methodology and implementation documented in:**
  - Total System Performance Assessment - Site Recommendation Technical Report
    - TDR-WIS-PA-000001 Rev 00 ICN 1 (Sec. 2.1.1 and 2.1.2)
  - FEP Database Technical Report
    - TDR-WIS-MD-000003, *The Development of Information Catalogued in Rev. 00 of the YMP FEP Database,* Rev 00 ICN 1
    - FEP Database is included on Compact Disk in Appendix B of this report
- **FEP screening arguments documented in:**
  - FEP Analysis/Model Reports (11)

List of FEP Analysis/Model Reports

Unsaturated Zone Flow and Transport (UZ)	ANL-NBS-MD-000001 REV 01A
Saturated Zone Flow and Transport (SZ)	ANL-NBS-MD-000002 REV 01
Biosphere (Bio)	ANL-MGR-MD-000011 REV 01
Disruptive Events (DE)	ANL-WIS-MD-000005 REV 00 ICN 01
Waste Package Degradation (WP)	ANL-EBS-PA-000002 REV 01
Waste Form Miscellaneous (WF Misc)	ANL-WIS-MD-000009 REV 00 ICN 01
Waste Form Cladding (WF Clad)	ANL-WIS-MD-000008 REV 00 ICN 01
Waste Form Colloid (WF Col)	ANL-WIS-MD-000012 REV 00 ICN 01
Near Field Environment (NFE)	ANL-NBS-MD-000004 REV 00 ICN 01
Engineered Barrier System (EBS)	ANL-WIS-PA-000002 REV 01
System-Level and Criticality (SYS)	ANL-WIS-MD-000019 REV 00

Identification of FEPs

- 1261 FEPs from Nuclear Energy Agency international database
  - Canada, Sweden, Switzerland, United Kingdom, Waste Isolation Pilot Plant
- 292 site-specific FEPs from Yucca Mountain Project literature
  - e.g., 1988 Site Characterization Plan (SCP)
- 95 additional FEPs from internal technical review
  - Technical Area Workshops
  - Analysis/Model Reports

Identification of FEPs (cont.)

- 8 additional FEPs from external review
  - 2 - NRC Near Field Environment audit (Pickett and Leslie 1999, Section 3.3.1)
    - » 2.1.08.14.00 (Condensation on underside of drip shield)
    - » 2.2.10.14.00 (Mineralogic dehydration reactions)
  - 2 - Unsaturated and Saturated Flow Under Isothermal Conditions Key Technical Issue meeting, 2000
    - » 2.2.07.18.00 (Film flow into drifts)
    - » 2.2.07.19.00 (Lateral flow from Solitario enters drifts)
  - 3 - Igneous Activity Key Technical Issue meeting, 2000
    - » 1.2.04.07.01 (Soil leaching following ashfall)
    - » 2.3.02.02.10 (Soil leaching to groundwater)
    - » 2.4.07.00.10 (Evaporative coolers)
  - 1 - Structural Deformation and Seismicity Issue Resolution Status Report, 1999
    - » 1.2.02.02.17 (Faulting exhumes waste package)

Classification of FEPs

- **152 Classification entries added to 1656 FEP entries from previous slide**
  - Based on the Nuclear Energy Agency hierarchical structure
  - 4 Layers, 13 Categories, 135 Headings
- **1656 FEP entries from previous slide mapped to appropriate Headings**
  - All related FEPs grouped together under same Heading
- **Further hierarchical classification of site-specific FEP entries into Primary and Secondary FEPs to facilitate efficient screening**

Classification of FEPs (cont.)
Examples of Layers, Categories and Headings

Layers	Categories	Headings
0. Assessment Basis	0.1 Assessment Issues and Assumptions	0.1.01 Impacts of concern 0.1.02Timescales 0.1.03 Spatial domain 0.1.04 Repository assumptions 0.1.05 Future human action assumptions 0.1.06 Future human behavior assumptions 0.1.07 Dose response assumptions 0.1.08 Aims of the assessment 0.1.09 Regulatory requirements and exclusions 0.1.10 Model and data issues
1. External Factors	1.1 Repository Issues	1.1.01 Site investigation 1.1.02 Excavation/construction 1.1.03 Emplacement of wastes 1.1.04 Closure and sealing 1.1.05 Records and markers 1.1.06 Waste allocation 1.1.07 Design 1.1.08 Quality control 1.1.09 Schedule and planning 1.1.10 Administrative control of site 1.1.11 Monitoring 1.1.12 Accidents and unplanned events 1.1.13Retrievability
	1.2 Geologic Processes and Effects	1.2.01 Tectonic movements 1.2.02 Deformation 1.2.03Seismicity 1.2.04 Volcanic activity 1.2.05 Metamorphism 1.2.06Hydrothermal activity 1.2.07 Erosion and sedimentation 1.2.08Diagenesis 1.2.09 Saltdiapirism and dissolution 1.2.10 Hydrologic response to geologic changes

Classification of FEPs (cont.)

- Steps in the Classification of Primary and Secondary FEPs
  - Map each FEP to the most relevant Heading
  - Identify groups of related FEPs under each Heading
  - From each group
    - Identify a most "representative" FEP (the Primary FEP)
    - Examine the remaining FEPs (the Secondary FEPs) to ensure that they are subsumed in or redundant to the Primary FEP
  - For each Primary FEP, prepare a site-specific FEP description
    - Expand the originator description, if necessary, to ensure that it is site-specific
    - Include all aspects of Secondary FEPs

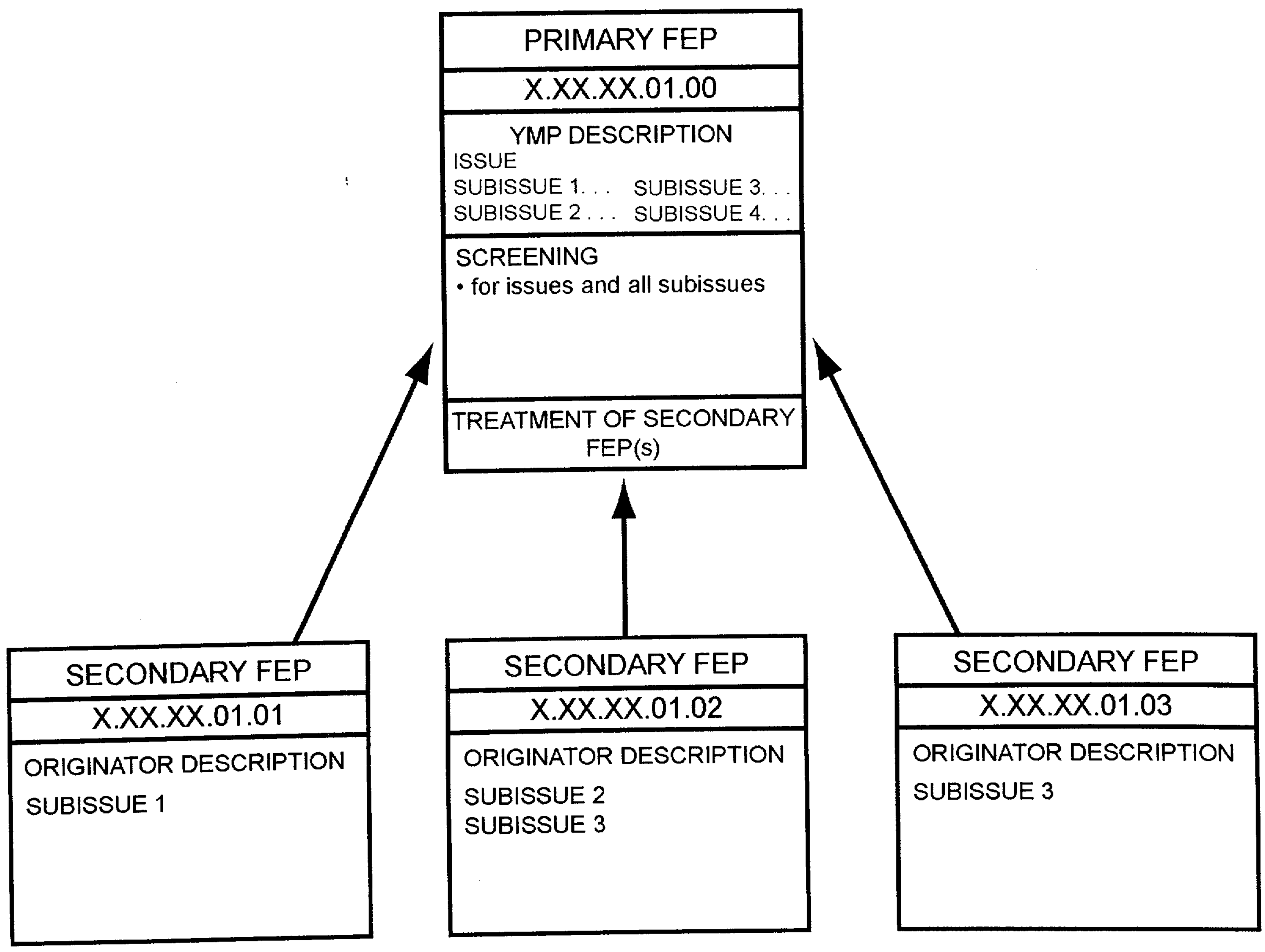
Classification of FEPs (cont.)

- **Primary FEPs**
  - Encompass a single process or event, a few closely related or coupled processes
  - Aggregated to the coarsest level at which a technically sound screening decision can be made while still maintaining adequate detail for analysis
- **Secondary FEPs**
  - Redundant to a Primary FEP
  - FEPs specific to another program
  - Better captured or subsumed in another similar FEP

Classification of FEPs (cont.)

- Relationship of Primary FEP to Secondary FEP
  - Primary FEPs include all issues from underlying Secondary FEPs
  - Secondary FEPs mapped to a Primary FEP and addressed by the Primary FEP screening discussion
  - Subset of secondary FEPs for a given Primary FEP may not envelop the entire scope of the Primary FEP

Classification of FEPs (cont.)



Summary of FEP Identification and Classification

- Comprehensive list of FEPs developed based on iterative internal and external reviews
- 1808 entries in FEP Database Rev 00 ICN 01
  - 112 Classification entries
    - 4 Layers, 13 Categories, 95 Headings
    - 40 additional Headings also classified as Primary FEPs
  - 328 Primary FEP entries
    - including the 40 Headings
  - 1368 Secondary FEP entries
- Database is open to new FEPs
  - Potential new FEPs are introduced via FEP Analysis/Model Reports

Screening of FEPs

- **Screening Criteria**
  - Regulatory
    - FEPs that are inconsistent with proposed regulations (10 CFR 63, 40 CFR 197) may be excluded (screened out) from Total System Performance Assessment
  - Probability
    - Proposed regulations (10 CFR 63.114(d), 40 CFR 197.40) state that FEPs with a probability less than 1 in 10,000 over 10,000 years (~ 10^{-8} per year) may be excluded from Total System Performance Assessment
  - Consequence
    - Proposed regulations (10 CFR 63.114(e,f), 40 CFR 197.40) state that FEPs whose exclusion would not significantly change the expected annual dose may be excluded from Total System Performance Assessment

Screening of FEPs (cont.)

- **Implementation of Regulatory Screening Criteria**
  - DOE uses "regulatory criteria" that are not identified as criteria by the Total System Performance Assessment & Integration Issue Resolution Status Report, but which are defined by proposed regulation
    - e.g., the regulation defines criteria used to screen FEPs for human intrusion, biosphere, and others
- **Implementation of Probability Screening Criteria**
  - Where appropriate, uses a quantitative probability calculation
  - DOE treats "not credible" as a variant of low probability
    - "not credible" low probability screening typically does not use a quantitative probability calculation

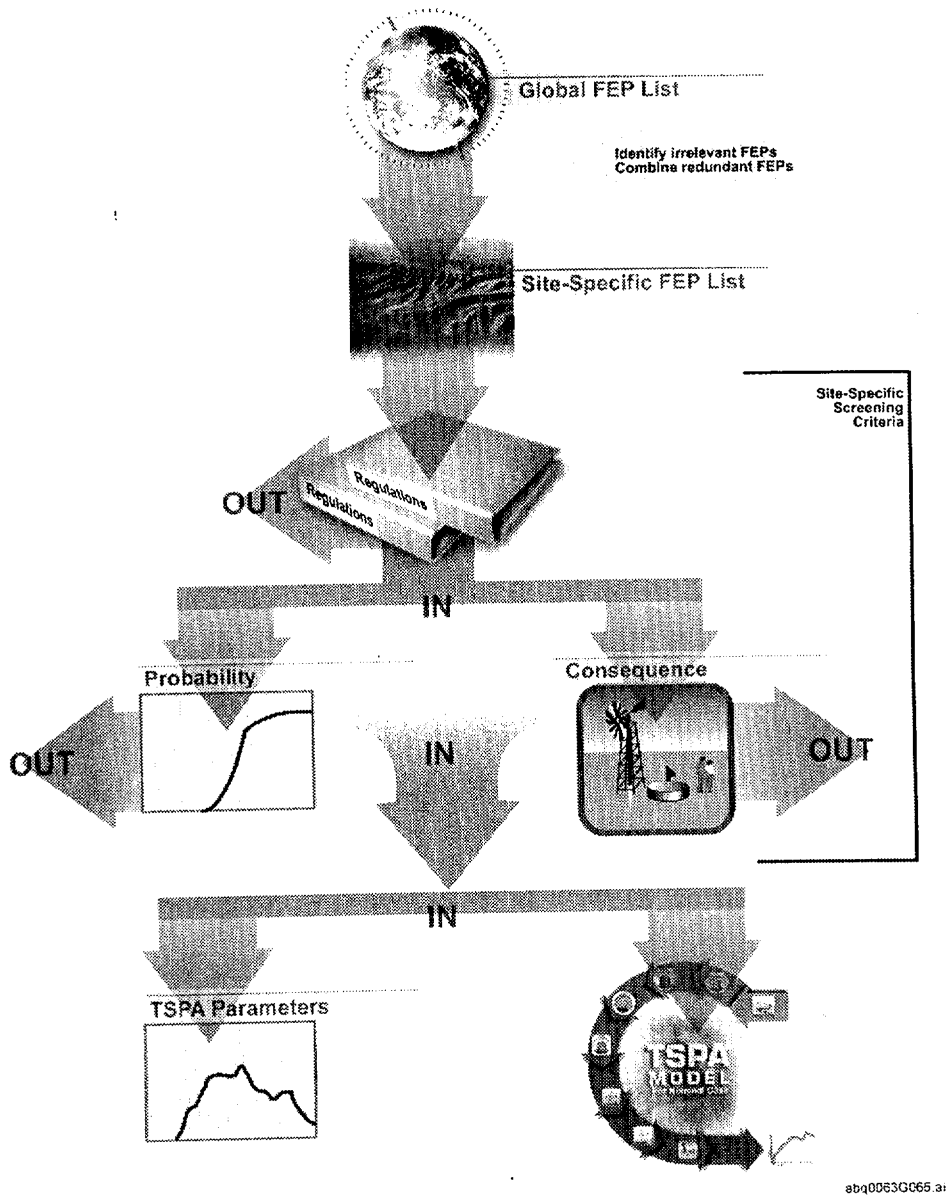
Screening of FEPs (cont.)

- **Implementation of Consequence Screening Criteria**
  - may evaluate impact on intermediate performance measures
  - may use deterministic and in some cases bounding analyses
    - sensitivity studies
  - may use models and codes external to the Total System Performance Assessment
  - may rely on varying levels of analysis
    - reasoned (qualitative) arguments based on literature
    - quantitative analyses
    - site characterization or modeling outside of Total System Performance Assessment
    - Total System Performance Assessment sensitivity analysis

Screening of FEPs (cont.)

- **Screening performed at the Primary FEPs level**
  - **Each Primary FEP has a site-specific description**
  - **Secondary FEP entries have issues that are addressed by overlying Primary FEP descriptions**

Screening of FEPs (cont.)

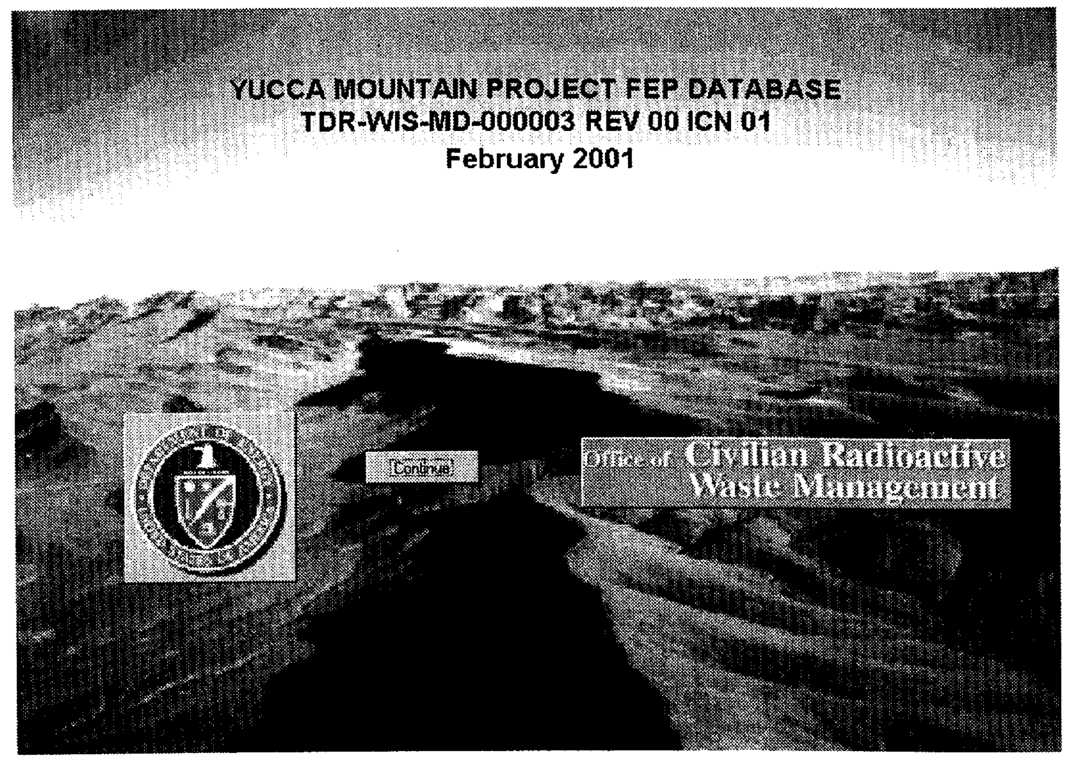


Summary of FEP Screening

- **328 Primary FEPs screened for Total System Performance Assessment - Site Recommendation (see TDR-WIS-PA-000001 Rev 0 ICN 1 Appendix B)**
  - 68 FEPs Included
  - 108 FEPs Partially Included
    - some aspects included, some aspects excluded
      - » (2.1.02.23.00) - Cladding unzipping included for wet oxidation, excluded for dry oxidation
    - included in one domain, excluded in another domain
      - » (2.2.08.07.00) - Radionuclide solubility limits in geosphere included in Saturated Zone, excluded in Unsaturated Zone
    - some aspects not relevant to Yucca Mountain Project may be excluded
  - 152 FEPs Excluded
    - low probability, low consequence, regulation

The Electronic FEP Database

- **Microsoft Access application**
  - Windows 95, 98, and NT
- **Custom toolbar features**
  - multiple views
  - searching
  - sorting
  - filtering
  - directory "tree"



The Electronic FEP Database (cont.)

- **September 1999 - Rev 00B (1786 entries)**
  - preliminary placeholder screening discussions
  - proposed primary - secondary FEP relationships
  - distributed to NRC at FEPs Appendix 7 meeting
- **June 2000 - Rev 00 ICN 00 (1797 entries)**
  - screening discussions from Rev 00 ICN 0 of FEP Analysis/Model Reports for "with backfill" design
  - primary - secondary FEP relationships confirmed by subject matter experts in FEP Analysis/Model Reports
- **February 2001 - Rev 00 ICN 1 (1808 entries)**
  - screening discussions and FEP relationships updated from revisions or ICNs to FEP Analysis/Model Reports for "no backfill" design
  - screening discussions strengthened through regulatory and technical review

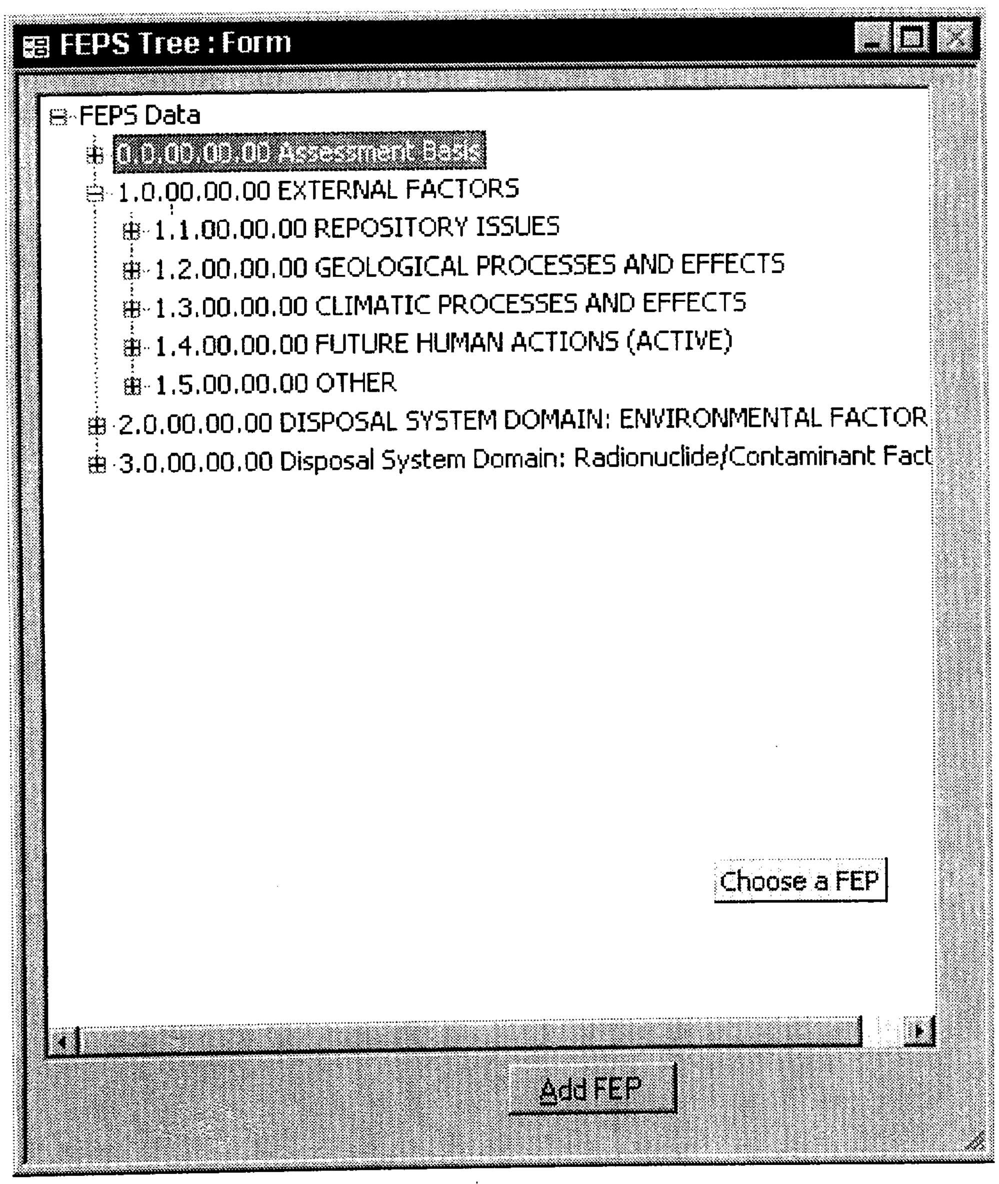
The Electronic FEP Database (cont.)

- **Database is a tool for:**
  - **Tracking FEPs identification and screening**
  - **Enhancing transparency and traceability**
- **Development of the FEPs Database is documented in TDR-WIS-MD-000003 Rev 00 ICN 1, *The Development of Information Catalogued in REV 00 of the YMP FEP Database***
- **Contains 1808 entries**
- **Technical defensibility of screening arguments is documented in FEP Analysis/Model Reports, which are accessible from the database through hyperlinks**

The Electronic FEP Database (cont.)

- **Each FEP entry includes 22 fields of data/text Key fields are:**
  - YMP FEP Database Number
  - FEP Name
  - FEP Class (primary, secondary, etc.)
  - YMP Primary FEP Description
  - Screening Decision (include or exclude)
  - Screening Argument (for excluded FEPs)
  - TSPA Disposition (for included FEPs)
  - Treatment of Secondary FEP(s)

The Electronic FEP Database (cont.)



The Electronic FEP Database (cont.)

FEPS - [YMPFEPs - Directory View]

File Edit View Insert Format Records Tools Window Help

Directory | BIO WFClad WFCol WFMisc SZ UZ NFE DE SYS EBS WP

YMP FEP Database - Directory View

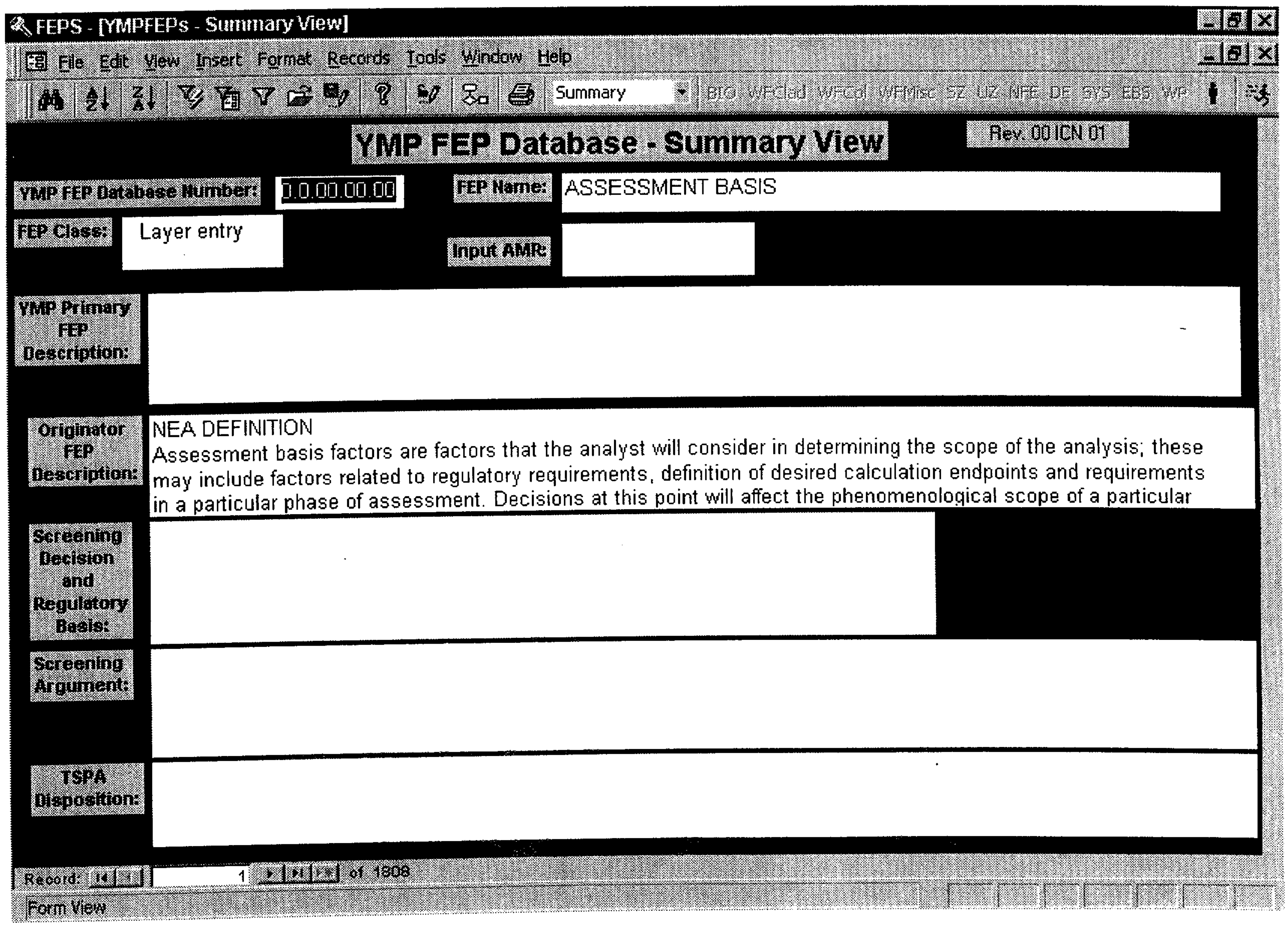
Rev. 00 ICN 01

YMP FEP Database No.	FEP Name	Input AMR	FEP Class	Screening Decision and Regulatory Basis
0.0.00.00.00	ASSESSMENT BASIS		Layer entry	
0.1.00.00.00	ASSESSMENT ISSUES AND ASSUMPTIONS		Category entry	
0.1.01.00.00	Impacts of Concern		Heading entry	
0.1.02.00.00	Timescales of concern	SYS	Primary entry	SYS—Included in the TSPA–SR—Does not satisfy a screening criterion.
0.1.03.00.00	Spatial domain of concern	SYS	Primary entry	SYS—Included in the TSPA–SR—Does not satisfy a screening criterion.
0.1.04.00.00	Repository Assumptions		Heading entry	
0.1.05.00.00	Future human action assumptions		Heading entry	

Record: 1 of 1808

Ready

The Electronic FEP Database (cont.)



Status of TSPA&I IRSR Rev. 3 Acceptance Criteria

- NRC Acceptance Criterion
  - The License Application contains a comprehensive list of FEPs that are present or might occur in the Yucca Mountain region (YMR) consistent with the site characterization data and includes those FEPs that have the potential to influence repository performance
- DOE Basis for Closure
  - TDR-WIS-MD-000003 documents development of FEPs list
  - Initial FEP list is based on both general international issues and site-specific issues, including Site Characterization Plan
  - Comprehensiveness of FEP list based on:
    - Combination of bottom-up (FEPs identification) and top-down (Nuclear Energy Agency structure) systems
    - Review by subject matter experts and external reviewers for potential new FEPs
    - Initial FEPs list supplemented with an additional 95 site specific and 8 external

Status of TSPA&I IRSR Rev. 3 Acceptance Criteria

- **NRC Acceptance Criterion**
  - The classification of the initial FEP list into categories of FEPs is comprehensive, clearly documented, and technically complete
- **DOE Basis for Closure**
  - Explicit discussion of relationship of Secondary FEPs to Primary FEPs provided in FEP Analysis/Model Reports and in *Treatment of Secondary FEP(s)* database field
  - Site specific description created to capture Secondary FEP issues (*YMP Primary FEP Description* field in database)
  - Preliminary classification of FEPs (within the hierarchical structure of layers, categories and headings) reviewed in 2 iterations by subject matter experts
  - TDR-WIS-MD-000003 documents classification of FEPs list

Status of TSPA&I IRSR Rev. 3 Acceptance Criteria

- **NRC Acceptance Criterion**
  - FEPs that are excluded from the Performance Assessment for the Yucca Mountain repository are identified and sufficient technical basis is provided for the exclusion
- **DOE Basis for Closure**
  - Screening criteria based on proposed regulations (10 CFR 63, 40 CFR 197)
  - FEPs screening performed by subject matter experts and documented in FEP Analysis/Model Reports
  - FEP Analysis/Model Reports subjected to iterative technical and regulatory review to strengthen the technical bases for screening

Status of TSPA&I IRSR Rev. 3 Acceptance Criteria

- **NRC Concern**
  - To achieve transparency and traceability, DOE needs to improve documentation to achieve completeness and uniqueness
- **DOE Basis for Closure**
  - NRC Issue Resolution Status Report concerns were based on review of a draft FEPs Database and initial revisions of the FEP Analysis/Model Reports
  - DOE has implemented the following improvements:
    - FEP Analysis/Model Reports updated to reflect current design and improved screening arguments
    - TDR-WIS-MD-000003 Rev 00 ICN 1, documents FEP origins, classification, and screening processes
    - Database field *Input AMR* lists source for screening technical basis
    - Database provides hyperlinks to FEP Analysis/Model Reports

Summary

- The Primary FEPs collectively capture the issues relevant to postclosure performance of the potential Yucca Mountain repository
- Included FEPs provide the basis for Total System Performance Assessment scenario analysis
- Total System Performance Assessment & Integration Issue Resolution Status Report Revision 3 Acceptance Criteria are being addressed

Summary (cont.)

- FEP Analysis/Model Reports and Database have been improved to reflect:
  - current design
  - iterative regulatory and technical reviews
  - enhanced functionality of the database
- The electronic FEP Database facilitates
  - Easy tracking of FEPs screening arguments
  - Enhanced transparency and traceability of issues to and from Total System Performance Assessment
- FEP identification and screening updated as new information is obtained or design changes occur in support of any potential License Application

BACKUP SLIDES

The Electronic FEP Database

- **FEPs are organized using a FEP Database number for each FEP having the form**
  - L.C.hh.pp.ss
    - L = Layer
    - C = Category
    - hh = Heading
    - pp = Primary FEP
      - » where L.C.hh is the overlying Heading
    - ss = Secondary FEP
      - » where L.C.hh.pp is the overlying Primary FEP

Layers, Categories and Headings

Layers	Categories	Headings (*)
0. Assessment Basis	0.1 Assessment Issues and Assumptions	0.1.01 Impacts of concern 0.1.02 Timescales 0.1.03 Spatial domain 0.1.04 Repository assumptions 0.1.05 Future human action assumptions 0.1.06 Future human behavior assumptions 0.1.07 Dose response assumptions 0.1.08 Aims of the assessment 0.1.09 Regulatory requirements and exclusions 0.1.10 Model and data issues
1. External Factors	1.1 Repository Issues	1.1.01 Site investigation 1.1.02 Excavation/construction 1.1.03 Emplacement of wastes 1.1.04 Closure and sealing 1.1.05 Records and markers 1.1.06 Waste allocation 1.1.07 Design 1.1.08 Quality control 1.1.09 Schedule and planning 1.1.10 Administrative control of site 1.1.11 Monitoring 1.1.12 Accidents and unplanned events 1.1.13 Retrievability
	1.2 Geologic Processes and Effects	1.2.01 Tectonic movements 1.2.02 Deformation 1.2.03 Seismicity 1.2.04 Volcanic activity 1.2.05 Metamorphism 1.2.06 Hydrothermal activity 1.2.07 Erosion and sedimentation 1.2.08 Diagenesis 1.2.09 Salt diapirism and dissolution 1.2.10 Hydrologic response to geologic changes

Layers, Categories and Headings

Layers	Categories	Headings (*)
1. External Factors (cont.)	1.3 Climatic Processes and Effects	1.3.01 Climate change, global 1.3.02 Climate change, regional 1.3.03 Sea level changes 1.3.04 Periglacial effects 1.3.05 Glacial and ice sheet effects 1.3.06 Warm climate effects 1.3.07 Hydrologic response to climate change 1.3.08 Ecological response to climate change 1.3.09 Human response to climate change
	1.4 Future Human Actions (Active)	1.4.01 Human influences on climate 1.4.02 Inadvertent/deliberate human actions 1.4.03 Un-intrusive site investigation 1.4.04 Drilling activities 1.4.05 Mining and other underground activities 1.4.06 Surface environment 1.4.07 Water management (wells, reservoirs) 1.4.08 Social developments 1.4.09 Technological developments 1.4.10 Remedial actions 1.4.11 Explosions and crashes
	1.5 Other	1.5.01 Meteorite impact 1.5.02 Species evolution 1.5.03 Miscellaneous (earth tides)

Layers, Categories and Headings

Layers	Categories	Headings (*)
2. Disposal System Domain: Environmental Factors	2.1 Wastes and Engineered Features	2.1.01 Inventory 2.1.02 Waste form 2.1.03 Waste container 2.1.04 Backfill 2.1.05 Seals, cavern/tunnel/shaft 2.1.06 Other features (drip shield, invert) 2.1.07 Mechanical processes and conditions 2.1.08 Hydrogeologic processes and conditions 2.1.09 Geochemical processes and conditions 2.1.10 Biological processes and conditions 2.1.11 Thermal processes and conditions 2.1.12 Gas sources and effects 2.1.13 Radiation effects 2.1.14 Nuclear criticality
	2.2 Geologic Environment	2.2.01 Excavation disturbed zone 2.2.02 Host rock 2.2.03 Geologic units, other 2.2.04 Discontinuities, large scale 2.2.05 Contaminant transport pathways 2.2.06 Mechanical processes and conditions 2.2.07 Hydrogeologic processes and conditions 2.2.08 Geochemical processes and conditions 2.2.09 Biological processes and conditions 2.2.10 Thermal processes and conditions 2.2.11 Gas sources and effects 2.2.12 Undetected features 2.2.13 Geological resources 2.2.14 Nuclear criticality

Layers, Categories and Headings

Layers	Categories	Headings (*)
2. Disposal System Domain: Environmental Factors (cont.)	2.3 Surface Environment	2.3.01 Topography 2.3.02 Soil 2.3.03 Aquifers / water-bearing features, near surface 2.3.04 Lakes, rivers, streams, springs 2.3.05 Coastal features 2.3.06 Marine features 2.3.07 Atmosphere 2.3.08 Vegetation 2.3.09 Animal populations 2.3.10 Meteorology 2.3.11 Hydrologic regime and water balance 2.3.12 Erosion and deposition 2.3.13 Ecological / biological / microbial systems
	2.4 Human Behavior	2.4.01 Human characteristics 2.4.02 Adults, children, infants 2.4.03 Diet and fluid intake 2.4.04 Habits, non-diet-related 2.4.05 Community characteristics 2.4.06 Food and water processing and preparation 2.4.07 Dwellings 2.4.08 Wild / natural land and water use 2.4.09 Rural / agricultural land and water use 2.4.10 Urban / industrial land and water use 2.4.11 Leisure and other uses of environment

Layers, Categories and Headings

Layers	Categories	Headings (*)
3. Disposal System Domain: Radionuclide / Contaminant Factors	3.1 Contaminant Characteristics	3.1.01 Radioactive decay and ingrowth 3.1.02 Chemical/organic toxin stability 3.1.03 Inorganics 3.1.04 Volatiles 3.1.05 Organics 3.1.06 Noble Gases
	3.2 Contaminant Release / Migration Factors	3.2.01 Dissolution, precipitation, crystallization 3.2.02 Speciation and solubility 3.2.03 Sorption / desorption processes 3.2.04 Colloids 3.2.05 Chemical/complexing agents, effect on transport 3.2.06 Microbiological / plant-mediated processes 3.2.07 Water-mediated transport 3.2.08 Solid-mediated transport 3.2.09 Gas-mediated transport 3.2.10 Atmospheric transport 3.2.11 Animal, plant, microbe mediated transport 3.2.12 Human-action-mediated transport 3.2.13 Food chains, uptake of contaminants in
	3.3 Exposure Factors	3.3.01 Drinking water, food, drugs, concentrations in 3.3.02 Environmental media, concentrations in 3.3.03 Non-food products, concentrations in 3.3.04 Exposure modes 3.3.05 Dosimetry 3.3.06 Radiological toxicity / effects 3.3.07 Non-radiological toxicity / effects 3.3.08 Radon exposure

* some heading descriptions are paraphrased

NRC Comments on DOE Fe...ures, Events and Processes
May 15-17, 2001 Technical Exchange

SATURATED ZONE

Scenario Analysis

c	AC	Comment	Source
1	AC2	General comment on Saturated Zone flow and transport FEPs: The SZ FEPs AMR (CRWMS M&O, 2001) tends to neglect issues associated with transport in the alluvium. Several screening arguments focus on aspects other than those in the alluvium that might be influenced by those FEPs (dissolution, for instance). Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ
2	AC2	FEP 1.3.07.02.00 (Water table rise). According to the SZ FEPs AMR (CRWMS M&O, 2001), this FEP is included on a preliminary basis because higher flow rates are included through the varying flux inputs included in the model. The screening argument is based on the assumption that the SZ model can effectively capture short circuits and changes in flow paths as a result of water table rise. Since the model is only calibrated to current conditions, it is difficult to discern how sensitivity analyses are adequate for screening. Moreover, it is known that as a result of higher water table elevations, springs have discharged within the 20 km radius in the past. Given the uncertainties associated with groundwater pathways, why aren't the effects of spring discharge (for example, at 9S and 1S) considered in the analysis? Thermal effects could also influence water table elevations and spring discharge, yet these are not considered either. Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ
3	AC2	FEP 2.2.10.03.00 (Natural geothermal effects). The SZ FEPs AMR (CRWMS M&O, 2001) states that this FEP is included because the current geothermal gradient is included in the SZFT model. However, this discussion does not address the potential for spatial and temporal variation in that gradient, which is part of the FEP description. Resolution of this issue is necessary to address the issue of changes in the geothermal gradient in FEP 2.2.10.13.00 [Density-driven groundwater flow (thermal)]. Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ
4	AC2	FEP 1.2.06.00.00 (Hydrothermal Activity). In the SZ FEPs AMR (CRWMS M&O, 2001), this item is excluded on the basis of low consequence. For SZ transport, the argument is that the adopted Kd distributions account for possible lithologic changes and thermal effects, with reference to CRWMS M&O (2000). However, the latter AMR does not provide a clear technical basis that the Kds were derived in such a fashion. In addition, though the screening argument is based on low consequence, there is a reference at the conclusion of the Supplemental Discussion to the low probability of hydrothermal activity (CRWMS M&O, 2001). Resolution of this issue is necessary to address the issue of changes in the geothermal gradient in FEP 2.2.10.13.00 [Density-driven groundwater flow (thermal)]. The DOE should provide a stronger technical basis for the assertion that possible hydrothermal effects on Kd values are accounted for in TSPA. References: CRWMS M&O. *2000. Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada; CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ

5	AC2	FEP 2.1.09.21.00 (Suspension of Particles Larger than Colloids). The SZ FEPs AMR (CRWMS M&O, 2001a) states that these particles will be included and treated as colloids. However, this FEP is not addressed in the UZ FEPs AMR (CRWMS M&O, 2000) and is noted as excluded under two other model components in the FEPs database (CRWMS M&O, 2001b). Furthermore, it is not clear how the effects of particles are included with colloids. This FEP should be addressed under the UZ Flow and Transport PMR and the integration of its disposition across the EBS, UZ, and SZ should be clarified. References: CRWMS M&O. 2001a. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada; CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01A.. Las Vegas, Nevada; CRWMS M&O. 2001b. *Yucca Mountain FEP Database.* TDR-WIS-MD-000003 REV00 ICN01. Las Vegas, Nevada.	SZ
6	AC2	Assumptions labeled as To-Be-Verified were found in the following reports: *FEPs in Thermal Hydrology and Coupled Processes.* ANL-NBS-MD-000004 REV 00 ICN1. 2001 *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 00. 2000 *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. 2001 It is necessary to disclose plans to verification.	SZ THER UZ
7	AC2	FEP 1.4.06.01.00 (Altered soil or surface water chemistry). This FEP is excluded for UZ on the basis of low probability (CRWMS M&O, 2000), but is not addressed by DOE under SZ. The probability argument is not supported by a calculation or estimate. This FEP is possibly relevant for SZ2 because of possible changes in groundwater chemistry. Reference: CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01A,, Las Vegas, Nevada.	SZ
8	AC2	FEP 1.2.04.07.00 (Ashfall). DOE assumes that ashfall blankets the region between the repository and the compliance boundary. Radionuclides associated with ashfall are then assumed to be transported instantaneously into the SZ. DOE presented only the case for uniform distribution. Moreover, parameter values and models used in the Ashfall analysis are not clear. Some parameters used in the model are not well documented and other parameters such as the number of waste packets that fail are not viewed as conservative. DOE should provide additional bases for the choice of models and parameters used to screen this FEP. Reference: CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ

9	AC2	FEP 2.2.10.06.00 [Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution)]. This FEP is excluded on the basis of low consequence (CRWMS M&O, 2001) with reference to the screening argument for FEP 2.2.7.10.00 in the UZ FEPs AMR (CRWMS M&O, 2000a). The argument that repository thermal effects on SZ radionuclide transport will be minimal is based on a TBV assumption (CRWMS M&O, 2000a). There is no explicit technical basis presented that rock alteration or temperature effects on geochemical properties and processes will negligibly affect SZ transport. In addition, it is asserted in the SZ FEPs AMR (CRWMS M&O, 2001) that any such effects would be within the bounds of uncertainty ranges established for transport properties such as Kd. However, the relevant AMR (CRWMS M&O, 2000b) does not provide a clear technical basis that this is the case. DOE's current technical justification is considered inadequate. The Department should provide additional technical justification for exclusion. Same comment applies to FEP 2.2.10.08.00 (Thermo-chemical alteration of the saturated zone) <u>References</u>: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2000a. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01A. Las Vegas, Nevada CRWMS M&O. 2000b. *Unsaturated Zone and Saturated Zone Transport Properties.* ANL-NBS-HS-000019 REV 00. Las Vegas, Nevada.	SZ
10	AC2	FEP 2.3.11.04.00 (Groundwater discharge to surface). Excluded in the SZ FEPs AMR on the basis of low consequence (CRWMS M&O, 2001). Modeling shows that spring discharge within the 20-km radius is not likely, yet past discharges have occurred within the 20-km radius (e.g., paleospring deposits at 9S and 1S). See discussion of water table rise FEP 1.3.07.02.00. Any screening argument that spring discharges are outside of the proposed compliance area is insufficient. Additional technical justification is required to fully exclude this FEP. <u>Reference</u>: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ
11	AC2	FEP 1.3.07.01.00 (Drought/water table decline). According to the SZ FEPs AMR (CRWMS M&O, 2000b), this FEP is excluded due to low consequence. DOE states that "a lower water table could result in less travel through the alluvial aquifer and as a result, less sorption and retardation of the contaminant plume." However, no evidence is presented that precludes a watertable decline. Current flow models assume that groundwater flow through the saturated alluvium is relatively shallow. As water tables decline, how will flow through the alluvium be affected? Is it possible that a larger component of flow will be through the deep carbonate system? Will the upward gradient observed at some locations be affected? Are there distinct pathways that are dependent on the elevation of the water table? It is likely that the transport times will stay the same or increase due to water table decline, but the exclusion argument provided seems insufficient. Additional technical justification is required to fully exclude this FEP. <u>Reference</u>: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada. CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada	SZ

12	AC2	FEP 2.2.10.13.00 [Density-driven groundwater flow (thermal)]. The SZ FEPs AMR (CRWMS M&O, 2001a) addresses this FEP in two parts: repository-induced effects ("excluded" low consequence) and natural geothermal effects ("include"). Exclusion of repository effects on flow based on DOE analyses is accepted. Natural effects are included only to the extent that the "natural geothermal gradient" is applied in the SZFT model. However, changes in thermal gradients are excluded on the basis of low consequence, with reference to FEPs 1.2.06.00.00 and 1.2.10.02.00 (CRWMS M&O, 2001a). A clear technical basis is not provided under these FEPs that all possible changes in thermal gradients will be localized. The screening argument for 1.2.06.00.00 focuses on geochemical effects (see separate entry), while 1.2.10.02.00 is focused on highly localized igneous intrusions. How these arguments apply to 2.2.10.13.00 is not entirely clear. References: CRWMS M&O, *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, NV, TRW Environmental Safety Systems, Inc., 2001a.	SZ
13	AC2	FEP 2.2.10.02.00 (Thermal Convection Cell Develops in SZ). DOE indicates that temperatures at the watertable are expected to approach 80-degrees Celsius. The DOE further points out that the resulting concern is that thermally driven water flow in the upper tuff aquifer could increase groundwater velocities relative to the system without heat sources. Additional justification for exclusion is necessary. Reference: CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ
14	AC2	FEP 1.2.09.02.00 (Large-scale dissolution). This FEP is excluded (CRWMS M&O, 2001) from the TSPA-SR abstraction of radionuclide transport and flow in the saturated zone on the basis of low consequence. In the DOE screening argument, potential dissolution of the carbonate aquifer materials is discussed. However, there is no mention of the calcite/carbonate that may exist in the saturated zone alluvium. Since retardation of radionuclides such as Np in the alluvium is, in part, explained by larger Kds due to the presence of calcite, an analysis of changes in the calcite concentration of alluvium seems warranted. This dissolution process may not be "large-scale" as defined, but certainly may be a response caused by a carrier plume of differing chemistry (said to be included in the model). A wetter climate may also result on dissolution of the alluvial calcite. Reference: CRWMS M&O, *Features, Events, and Processes in SZ Flow and Transport.* 2001. ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	SZ

BIOSPHERE

Scenario Analysis

c	AC	Comment	Source
15	AC2	Biosphere FEP AMR states that FEP 2.3.09.01.00 (Animal Burrowing/Inclusion) can be excluded because calculation of dose to animals is not required by the regulation. However, FEP should be listed as included because one of the secondary FEPs is ingestion of radionuclides by animals. Ingestion of radionuclides by livestock leads to dose to the critical group through the ingestion pathway. This pathway is included in the Biosphere modeling. FEP status is just inaccurate. <u>Reference</u>: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
16	AC2	FEP 2.3.13.01.10 (Natural Ecological Development) has a FEP description that is really a rationale for exclusion. Similar problem exists with FEP 3.3.04.03.05 (Irradiation). <u>Reference</u>: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
17	AC2	Screening criteria used by DOE in the biosphere FEP AMR (CRWMS M&O, 2001), in lieu of final regulations, derive from a Revised Interim Guidance report (RIG, Dyer, 1999). These criteria were excerpted, in 1999, from NRC proposed regulations in 10 CFR Part 63; however, the criteria are incomplete when compared to actual proposed NRC regulation. In the biosphere FEP AMR, DOE cites the RIG criteria to screen specific FEPs and cites the proposed Part 63 criteria for other FEPs, when all FEPs could be screened using the proposed Part 63 rule. It is unclear the purpose of establishing and citing a second set of 'regulatory' criteria since, ultimately, DOE should demonstrate compliance with NRC regulations. Referring to both the proposed Part 63 rule and the RIG criteria as regulations (as done in the Biosphere FEP AMR) is incorrect. <u>References</u>: Dyer, J.R. 1999. *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 1, July 22, 1999) for Yucca Mountain, Nevada.* Letter from J.R. Dyer (DOE/YMSCO) to D.R. Wilkins (CRWMS M&O), September 3, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New NRC Regulations for Yucca Mountain (Revision 01)". CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO

18	AC2	Biosphere FEP AMR indicates that any future changes in FEP 1.4.07.01.00 (Water Management Activities) can be excluded based on the proposed 10 CFR Part 63. This FEP includes well pumping from an aquifer as a water management activity. The conclusion that changes to water management activities may be excluded is not supportable by the regulation. The draft regulation indicates that the behaviors and characteristics of the farming community shall be consistent with current conditions of the region surrounding the Yucca Mountain site and that climate evolution shall be consistent with the geologic record. As the climate becomes wetter and cooler, the farming community is likely to pump less water out of the aquifer, consistent with sites analogous to the predicted future climate of Yucca Mountain. This reduction in pumping would not be considered a change in the behavior or characteristics of the critical group since the community would still be raising similar crops using similar farming methods. Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
19	AC2	DOE has selected a subset of the full FEPs list as applicable for biosphere screening in the biosphere FEP AMR report. Some FEPS that are potentially applicable to BDCF calculations (that should at least be considered for screening) have not been included in the scope of the Biosphere FEP AMR. These include: FEP 2.3.11.04.00 (Groundwater Discharge to Surface), FEP 1.3.07.02.00 (Water Table Rise), FEP 3.2.10.00.00 (Atmospheric Transport of Contaminants), FEP 1.2.04.01.00 (Igneous Activity) FEP 2.2.08.02.00 (Groundwater Chemistry/Composition in UZ and SZ) (i.e., chemical species can impact dose coefficient selection), FEP 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere), FEP 3.1.01.01.00 (Radioactive Decay and Ingrowth), and FEP 1.2.04.07.00 (Ashfall). Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
20	AC2	FEP Database does not indicate that FEP 2.2.08.07.00 (Radionuclide Solubility Limits in the Geosphere) is relevant to the biosphere. This FEP is relevant for limiting the quantity of radioactive material that can leach radionuclides out of the soil or tephra deposit in the biosphere compared to the quantity of radionuclides that would be predicted to leach out of the deposit using only leach rate limits. Reference: YMP FEP Database Rev 00 ICN01	BIO YMP FEP Database REV00 ICN01
21	AC2	FEP 2.3.13.01.00 (Biosphere Characteristics) screening argument indicates YM region lacks permanent surface water. Is this statement consistent with the geologic record of past climate change in the area? Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
22	AC2	FEP 2.3.13.01.00 (Biosphere characteristics) includes a secondary FEP for Plants (FEP 2.3.13.01.07), but not one for animals, yet plants and animals are both listed in the FEP description (CRWMS M&O, 2000). Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO

23	AC2	FEP 2.3.11.04.00 (Groundwater discharge to surface) screening argument states that surface discharge will not impact the annual dose without providing a reason why (e.g., low concentration, low exposure times etc). The screening argument that spring discharges are outside of the proposed compliance area is insufficient. The proposed 10 CFR Part 63 does not preclude residents of the farming community located at the proposed compliance point to visit spring areas to the south. The Ash Meadows area, for example, is a national park with facilitated access points and soils rich in minerals precipitated from groundwater discharge. Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
24	AC2	FEP 2.3.13.02.00 (Biosphere Transport) contains only two secondary FEPs related to surface water, gas, and biogeochemical transport processes. The YMP FEP description and the originator FEP description are different and call into question whether the focus of this FEP is transport processes, alterations during transport, or both. Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	BIO
25	AC2	FEP 2.4.07.00.00 (Dwellings) includes a secondary FEP, household cooling, which has an inappropriate screening argument. The screening argument indicates that since the use of an evaporative cooler would only increase the inhalation and direct exposure pathways, and these pathways are only minor contributors to the current dose conversion factors, the use of evaporative coolers can be screened. However, the direct exposure and inhalation dose from evaporative coolers is the result of significantly different processes than the direct exposure and inhalation dose from radionuclides deposited on soils and could have a more significant dose impact. Reference: CRWMS M&O, 2001. Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP) (ANL-MGR-MD-000011, REV 01)	BIO
26	AC2	Biosphere FEP AMR report states that FEP 3.3.08.00.00 (Radon and Daughter Exposure) is screened as excluded on the basis that the parent radionuclide (Th-230) will not reach the critical group in 10,000 years in the base case scenario. This rationale, however, does not apply to the direct release scenario where transport times are much shorter. References: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01. CRWMS M&O. 2000. *Disruptive Event Biosphere Dose Conversion Factor Analysis*. ANL-MGR-MD-000003, REV 00.	BIO

WASTE PACKAGE AND DRIP SHIELD

Scenario Analysis

c	AC	Comment	Source
27	AC2	FEP 2.1.09.09.00 (Electrochemical effects [electrophoresis, galvanic coupling] in waste and EBS Electrochemical effects may establish an electric potential within the drift or between materials in the drift and more distant metallic materials that could affect corrosion of metals in the EBS and waste. It is excluded based on low consequence assuming that galvanic coupling between the inner and outer container or the outer container and the drip shield will not lead to accelerated corrosion. The effect of galvanic coupling between the Ti drip shield and steel components of the EBS (drift support, rock bolts, gantry rail, etc) should be included because it may enhance hydrogen entry in the drip shield and therefore hydride cracking (see FEP 2.1.03.04 on hydride cracking). Reference: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	WP
28	AC2	FEP 2.1.03.04.00 Hydride cracking of waste containers *Excluded* low consequence for both drip shield and waste package Hydrogen induced cracking of the Alloy 22 waste package outer barrier is not expected at repository temperatures that are predicted o be 186C. Heating waste package in the range of 540 C for extended periods can result in ordering that substantially increases the susceptibility to hydride cracking. Hydride absorption of Ti alloys for the drip shield based on passive corrosion rates that do not consider accelerated corrosion rated from the presence of fluoride The technical basis for the minimum concentration of hydrogen absorbed in order to observe hydrogen embrittlement or hydrogen induced cracking is not well supported by DOE investigations Reference: CRWMS M&O. 2001. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	WP
29	AC2	FEP 2.1.06.07.00 (Effects at Material Interfaces). The basic chemical processes that occur at phase boundaries (principally liquid/solid) are included in others FEPs. Solid/solid contact either does occur or could occur between the drip shield and the invert and/or backfill (if included in the YMP design), between the waste package and the invert and/or backfill (if included in the YMP design); between the pedestal and the waste package and/or drip shield; and between the waste form and any of the other EBS component materials. Since these materials are all relatively inert, no solid/solid interaction mechanisms have been identified that are significant relative to the basic seepage water induced corrosion of the EBS components and hence this FEP is excluded on the basis of low consequence. However, interfaces between solid phases in contact with an aqueous phase can accelerate degradation processes such as crevice corrosion of WP or galvanic coupling of drip shield to steel components (see FEP 2.1.03.01.00 and 2.1.03.04.00). Reference: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	WP

30	AC2	FEP: 2.1.03.05.00 Microbially mediated corrosion of waste container *Included* for waste package *Excluded* for drip shield low consequence Quantitative data on microbially influenced corrosion of drip shield materials such as Ti grades 7 and 16 are not available from the literature. If microbially influenced corrosion of the drip shield occurs it would not have an effect on dose. Accelerated corrosion rates of drip shield have been evaluated in the TSPA-SR and shown not to have an affect on dose. <u>Reference</u>: CRWMS M&O, 2001. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	WP
31	AC1	There is no FEP addressing the response of the drip shield to static loads and seismic excitation. It is necessary to account for the degradation of the capability of the drip shield to avoid water infiltration due to the interaction of seismic excitation with dead loads (such as those caused by rock fall or naturally occurring backfill) on the drip shield, and it is recommended to add a new FEP. FEP 1.2.03.02.00 (Seismic vibration causes container failure) assesses the effect of ground motion on the waste package and drip shield, without consideration of possible pre-existing static loads. The Screening argument for FEP 2.1.06.06.00 (Effects and degradation of drip shield) in (CRWMS M&O, 2001) states that A... seismic activity will not induce SCC of the waste packages or drip shields, regardless of magnitude, since a sustained tensile stress is required for SCC and an earthquake is only temporary in nature (CRWMS M&O 2000q, Section 5, Assumption 1).@ The above assumption does not account for the possibility of static loads affecting the drip shield and possibly, the waste package. <u>References</u>: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, NV. CRWMS M&O. 2000q. *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Steel Structural Material.* ANL-EBS-MD-000005 REV 00 ICN 01. Las Vegas, NV.	WP
32	AC2	FEP 2.1.13.01.00 (Radiolysis) is excluded based on low consequence. Screening argument considers only radiolysis of water to produce hydrogen and oxidants. No consideration of the formation of nitric acid resulting from radiolysis in presence of air. Spent fuel is expected to have higher dissolution rates at lower pH, thus ignoring nitric acid may underestimate radionuclide release. Potential production of nitric acid from radiolysis of N_2 in air should be considered. Necessary to consider potential effect of acid environments on the corrosion of Alloy 22 and Ti. Alpha, beta, gamma and neutron irradiation of air saturated water can cause changes in chemical conditions (Eh, pH, and concentration of reactive radicals) and positive shifts in corrosion potential due to the formation of hydrogen peroxide. DOE, on the bases of experimental work concluded that radiolysis will not lead to localized corrosion of Alloy 22. However, additional work by the DOE is necessary to complete the evaluation of the critical potentials related to localized corrosion of Alloy 22. <u>Reference</u>: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada. CRWMS M&O, 2001. *FEPs screening of processes and issues in drip shield and waste package degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	WP MiscWF
33	AC1	FEP(s) related to the effect of trace metal cations on Alloy-22 and Ti corrosion and stress corrosion should be added to database, given results recently reported by Barkatt and Gorman (2000). <u>Reference</u>: A. Barkatt and J.A. Gorman, Tests to Explore Specific Aspects of the Corrosion Resistance of C-22, Nuclear Waste Technical Review Board Meeting, August 1, 2000, Carson City, NV, 2000.	WP

34	AC2	FEP 2.1.03.02.00 (Stress corrosion cracking of Waste Containers) *Included* *Excluded* drip shield- low consequence "...Source of stress for cracks is due to cold work stress and cracks caused by rockfall However these cracks tend to be tight (i.e., small crack opening displacement) and fill with corrosion products and carbonate minerals. These corrosion products will limit water transport through the drip shield and thus not contribute significantly to overall radionuclide release rate from the underlying failed waste packages... " Screening argument for drip shield is weak. Simplified calculations by DOE indicate cracks will take considerable time to fill with corrosion products (*Stress corrosion cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Steel Structural Material* ANL-EBS-MD-000005). Cracks that develop in the DS may propagate and/or "open up" when subjected to subsequent loads caused by rockfall/drift collapse and/or seismic excitation allowing significant ground water infiltration through the drip shield. Reference: CRWMS M&O. 2001. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	WP
35	AC2	FEP 2.1.03.08.00 Juvenile and early failure of waste containers *Included* Manufacturing and welding defects in waste container degradation analysis *Excluded* Manufacturing defects in drip shield degradation analysis, early failure of Waste package and drip shield from improper quality control during the emplacement "Major effect of pre-existing manufacturing defects is to provide sites for crack growth by stress corrosion cracking. Tensile stress is required to have stress corrosion cracking. Because all fabrication welds of DS are fully annealed prior to emplacement, drip shield are not subject to stress corrosion cracking earthquakes are insignificant to cause stress corrosion cracking (stresses are temporary in nature)" "Manufacturing defects in the drip shield and early failures of the Waste package and drip shield from improper quality control during emplacement can be excluded based on negligible consequence to dose" The bases for this assessment is that slap down analysis of a 21-PWR waste package resulted in stresses in the waste package material that were less than 90 percent of the ultimate tensile strength. The impact energy associated with emplacement error is substantially less than that expected in a vertical tip over, emplacement errors are "not expected to result in any damage." The results of the Slap-down analysis is cited as the screening analyses of several FEPs. The damage reported in the Slap down analyses is concerning. While the impact energy of emplacement errors may be substantially less than those experienced int eh slap-down analyses, a proper assessment of the extent of Waste package damage as a result of emplacement errors should be performed. Reference: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	WP

36	AC2	FEP 2.1.09.03.00 (Volume increase of corrosion products). The presence of WP corrosion products with higher molar volume than the uncorroded material that may change the stress state in the material being corroded is excluded in the case of WP based on low consequence. However, it may have an effect on corrosion processes such as SCC of outer container after its initial breaching that may affect radionuclide release (see FEP 2.1.03.07.00, Mechanical Impact on the Waste Container and Drip Shield). The possibility of additional sources of stress arising from the formation of corrosion products should be evaluated in regard to SCC. See comment for FEP 2.1.11.05.00 (Differing thermal expansion of repository components). Reference: CRWMS M&O 2000, *FEPs Screening of Process and Issues in Drip Shield and Waste Package Degradation*, ANL-EBS-Pa-000002 Rev. 00 ICN 01	WP
37	AC2	FEP 2.1.07.05.00 (Creeping of metallic materials in the EBS) has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). Although DOE correctly points out in their screening argument (CRWMS M&O, 2001b) that " the deformation of many titanium alloys loaded to yield point does not increase with time," (American Society for Metals International 1990, p. 626), it still does not specifically address the potential for creeping of titanium grades 7 and 24. For example, some titanium alloys have been shown to creep at room temperatures (Ankem, S., et al., 1994). Creeping of the titanium drip shield subjected to dead loads caused by fallen rock blocks and/or drift collapse could significantly reduce the clearance between the drip shield and waste package over time. As a result, the drip shield may cause substantial damage to the waste package during its dynamic response to subsequent seismic loads. In addition, creeping could potentially cause separation of the individual drip shield units. References: American Society for Metals International. 1990. Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, Specific Metals and Alloys. Volume 2 of Metals Handbook. 10th Edition. Metals Park, Ohio: American Society for Metals; Ankem, S., C.A. Greene, and S. Singh. 1994. Time Dependent Twinning During Ambient Temperature Creep of a Ti-Mn Alloy. Scripta Metallurgica et Materialia, Vol 30, No 6, pp 803-808; CRWMS M&O. 2001a. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	WP
38	AC2	FEP 2.1.11.05.00 (Differing thermal expansion of repository components) has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). The technical basis for excluding differing thermal expansion effects on repository performance is not comprehensive nor adequate. For example, according to the screening arguments (CRWMS M&O, 2001b), " the difference in temperature between the inside of the waste package inner barrier (316NG) and the outside of the waste package outer barrier (Alloy 22) never exceeds 2°C. As an illustrative example, using the coefficients of thermal expansion for the two materials discussed above [i.e., Alloy 22 and 316NG] and a bounding 5°C (or 5 K) temperature difference between them, the calculated strain is $2.15A10^{-5}$ m/m. This strain is so small that thermal expansion of waste package barriers will result in a negligible effect on expected mean dose rate. A ~1 mm gap will prevent the resultant stress due to the differing thermal expansion coefficients of the waste package materials from reaching a critical level that could lead to stresses in the waste package barriers. The Waste Package Operation Fabrication Process Report (CRWMS M&O, 2000[a], Section 8.1.8) requires a loose fit between the outer barrier (Alloy 22) and the inner shell (316NG stainless steel) to accommodate the differing thermal expansion coefficients, and so this FEP can be excluded for the waste packages based on low consequence to the expected annual dose." The quoted rationale is not technically correct and does not address the limited clearance between the inner and outer barriers of the waste package in the axial direction, which may be as small as 2-mm according to design drawings (CRWMS M&O, 2000b). In addition, the differential thermal expansion between various invert components and the drift wall (which they are attached to) has not been addressed.	WP EBS

		<u>Excluded</u> - low consequence (CRWMS M&O. 2001a; 2001b). Peak temperature of Waste package 278 with backfill and 176EC without backfill with 0.5 meter spacing and 50-yr ventilation. Screening argument is that the temperature differential between inner type 316NG barrier and outer Alloy 22 barrier is 5EC and the corresponding strain of 2.15 H 10'5 m/m. This calculation is performed using difference between thermal expansion coefficients for 316NG and Alloy 22 using the maximum expected temperature difference between the waste package barriers. There will be at least a 1 mm gap between the barriers no thermal stresses are predicted. <u>The calculation should use a temperature of the waste package rather than the difference between waste package barriers</u>. The clearance between the inner type 316NG and the outer Alloy 22 is specified in the waste package design and fabrication process report to be 0 to 4 mm (CRWMS M&O. 2000a). It is implicit that this clearance is specified at ambient temperature (i.e. 25EC) because (i) no temperature is specified and (ii) the outer Alloy 22 waste package outer barrier will be heated to 700 F (371EC) for inner 316NG cylinder installation. Using a temperature of 186EC the calculated strain is 7.99 H 10'4 m/m. For waste package with clearance gaps of 1 mm or less at 25EC, thermal stresses will occur as a result of the difference in thermal expansion. <u>References</u>: CRWMS M&O. 2000a. *Waste Package Operations Fabrication Process Report.* TDR-EBS-ND-000003 REV 01. Las Vegas, Nevada CRWMS M&O. 2000b. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada CRWMS M&O. 2001a. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01	
39	AC2	FEP 2.1.06.06.00 (Effects and Degradation of Drip Shield). Excluded based on low consequence (CRWMS M&O, 2000a). The drip shield is an important component of the EBS and its function and degradation is explicitly considered in the TSPA. The degradation of the drip shield due to corrosion processes is considered directly in the model abstraction for WP degradation, whereas remaining aspects of drip shield behavior are considered as part of the EBS analysis. A secondary FEP is FEP 2.1.06.06.01, Oxygen embrittlement of Ti drip shield, which is a subset of the Primary FEP and DOE argues that is explicitly considered in the screening argument discussion. No discussion is presented but it is noted that this issue is most relevant to mechanical failure of the drip shield, which is discussed under FEP 2.1.07.01.00, rockfall, and FEP 2.1.07.02.00, mechanical degradation or drift collapse. Although physical and chemical degradation processes have been included for consideration in the TSPA code, their effects on the ability of the drip shield to withstand dead loads (caused by drift collapse and/or fallen rock blocks), rock block impacts, and seismic excitation is not accounted for in the screening arguments (CRWMS M&O, 2001a,b). In (CRWMS M&O, 2000b, p. 29, 64) it is stated that the impact of rockfall on the degraded drip shield has been screened out from the TSPA-SR until more detailed structural response calculations for the drip shield under various rock loads are available. No references are provided in this document as to when and where these analyses will be available. <u>References</u>: CRWMS M&O 2000a, FEPs Screening of Process and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 Rev. 00 ICN 01 CRWMS M&O. 2000b. *AMR EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001 REV 00. Las Vegas, NV; CRWMS M&O. 2001a. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	WP

WASTE FORM

Scenario Analysis

c	AC	Comment	Source
40	Model Abstraction AC1 Model Abstraction AC 5	FEP 2.1.02.21.00 (Stress corrosion cracking [SCC] of cladding). Included but only the SCC caused by fission products that operates from the inside out of the cladding (FEP 2.1.02.21.01). The occurrence of SCC caused by the action of chemical or salts present inside the WP and acting from the outside in, even that is considered in another secondary FEP (FEP 2.1.02.21.02), it is not discussed in the screening arguments. Therefore, no justification is offered in the database for the exclusion of SCC occurring from the outside in. In the Table 2 of the Clad Degradation B FEPs Screening Arguments. ANL-WIS-MD-000008 REV 00, ICN 01, this secondary FEP is listed as included. <u>Reference</u>: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
41		FEP 2.1.02.20.00 (Pressurization from helium production causes cladding failure). Included as a process of internal gas pressure buildup that increases the cladding stress contributing to delayed hydride cracking (DHC) and strain (creep??) failures. The wording could be more precise in the text where it is clarified that helium production from alpha decay is the main source of pressure buildup. <u>Reference</u>: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
42		FEP 2.1.08.07.00 (Pathways for unsaturated flow and transport in the waste and engineered barrier system) evaluates unsaturated flow and radionuclide transport that may occur along preferential pathways in the waste and EBS. The DOE indicates that preferential pathways are already "included" via "a series of linked one dimensional flowpaths and mixing cells through the EBS, drip shield, waste package and into the invert (CRWMS M&O, 2000)." Staff are concerned that preferred pathways in the EBS are not being evaluated at the appropriate scale. Water has been observed to drip preferentially along grouted rock bolts in the ECRB, for example, demonstrating that the introduced materials themselves can influence the location of preferred flow pathways. Interactions with engineered materials, such as cementitious and metallic components, can have a significant effect on evolved water and gas compositions. Because the FEP description states that "Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating [preferential] pathways", staff expect the screening arguments to be based on an evaluation of these topics (ENFE IRSR Rev. 03). <u>Reference</u>: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	MiscWF
43	Model Abstraction AC1 Model Abstraction AC 5	FEP 2.1.02.27.00 (Localized corrosion perforation from fluoride). Included because fluoride is present in YM waters and zirconium corrodes in environments containing fluoride. It is argued that localized corrosion caused by fluoride is included in the model abstraction for cladding degradation to account for modeling uncertainty of the in-package chemistry since conditions for corrosion induced by fluoride were considered more likely to occur relative to other processes examined. <u>Reference</u>: CRWMS M&O. 2000. *Clad Degradation-Summary and Abstraction,* ANLBWISBMDB000007 REV 00 ICN01. Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD

44	Model Abstraction AC1 Model Abstraction AC 5	FEP 2.1.02.16.00 (Localized corrosion [pitting] of cladding). Included because localized corrosion by pits could produce penetration of cladding. Even though localized corrosion is included in the CSNF cladding degradation model abstraction, the effect of chloride ions as pitting promoters is not considered in the analysis of localized corrosion done by the DOE. It is stated that pitting corrosion is promoted by concentrated chloride and fluoride solutions at very low pHs and very high oxidation potentials, but these conditions are not predicted to occur in the bulk solution inside WPs. However, it accepted that certain processes such as MIC, galvanic coupling, radiolysis in a humid environment, and evaporation may generate locally concentrated solutions of aggressive species or pH decreases that a model for localized corrosion is necessary. Reference: CRWMS M&O, *2000. Clad Degradation-Local Corrosion of Zirconium and its Alloys under Repository Conditions,* ANL-EBS-MD-000012, REV 00, Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
45		FEP 2.1.02.19.00 (Creep rupture of cladding) Included as perforation mechanism for the CSNF cladding degradation component. Distribution of cladding temperatures and hoop stresses used to evaluate the propensity to hydride reorientation and embrittlement (see FEP 2.1.02.22.00) should be consistent with those for creep and SCC calculations. References: CRWMS M&O. *2000. Initial Cladding Condition,* ANL-EBS-MD-000048 REV 00 ICN01. Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation-Summary and Abstraction,* ANLBWISBMDB000007 REV 00 ICN01. Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
46		FEP 2.1.02.24.00 (Mechanical failure [of cladding]). Included as a failure process resulting from external stresses such as ground motion during earthquakes assuming a frequency of 1.1 x10^{-6} events/year that cause failure of all cladding that is available for unzipping. On the contrary, cladding failure arising from rock fall is not included in the model abstraction assuming integrity of the WP for 10,000 years (See FEP 2.1.07.01.00). Reference: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
47	AC2	FEP 2.1.02.17.00 (Localized corrosion [crevice corrosion] of cladding). Excluded based on low probability of occurrence. Experimental evidence is cited to indicate that crevice corrosion has not been observed in zirconium alloys exposed to chloride solutions, including NRC /CNWRA results. There is a need to develop a better understanding of localized corrosion of zirconium alloys before confirming this conclusion because the data are limited. In the report on Clad Degradation- Local Corrosion of Zirconium and Its Alloys Under Repository Conditions, ANL-EBS-MD-000012, Rev 00 it is noted that crevice corrosion may occur in the presence of fluoride ions. References: CRWMS M&O, 2000.*Clad Degradation-Local Corrosion of Zirconium and its Alloys under Repository Conditions,* ANL-EBS-MD-000012 REV 00, Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
48	AC2	FEP 2.1.01.04.00 (Spatial Heterogeneity of Emplaced Waste). Waste placed in Yucca Mountain will have physical, chemical, and radiological properties that will vary. The effect of spatial heterogeneity of the waste on repository-scale response is excluded based on low consequence but the heterogeneity within a waste package is implicitly included in the evaluation of in-package temperature used to determine perforation of the CSNF cladding. However, spatial variability that may affect degradation of engineering barrier, such as conditions leading to crevice corrosion vs passive corrosion of outer container, is not considered in this FEP. Reference: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	MiscWF

49	AC2	FEP 2.1.02.15.00 (Acid corrosion of cladding from radiolysis). Included as part of localized corrosion model on the basis that the formation of HNO_3 and H_2O_2 ions(sic) by radiolysis can enhance corrosion of cladding. It is stated, however, that zirconium has excellent corrosion resistance to HNO_3 and concentrated H_2O_2. The arguments are poorly worded stating that radiolysis is not expected to occur until WP failure and then the gamma dose will be very low to produce sufficient HNO_3 and H_2O_2 to promote general corrosion but localized corrosion could be possible. The argument of local acidic pH causing localized corrosion of cladding is in contradiction with experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, it is in contradiction with arguments to screen out pitting corrosion by chloride anions (See FEP 2.1.02.16.00). In the Basis for Screening undue consideration is given to alkaline conditions arising from concrete liner whereas possibility of very acidic conditions (pH < 2) are not discussed. Reference: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
50	AC2	FEP 2.1.02.13.00 (General corrosion of cladding) Excluded based on low probability of occurrence. Although general corrosion of cladding could expose large areas of irradiated fuel matrix and produce hydrides it is argued that it is a very slow process. The arguments are based on extrapolation to low temperatures at test data obtained at temperatures above 250°C and in measurements of oxide thickness from specific fuel rods after reactor operation and exposure to water in reactor pool storage. Reference: CRWMS M&O, 2000. *Clad Degradation - FEPs Screening Arguments.* ANL-WIS-MD-000008 REV00 ICN01. Las Vegas, Nevada (This reference is consistent with updated Database as quoted and valid for all FEPs on cladding); CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
51	AC2	FEP 2.1.02.14.00 (Microbially induced corrosion of cladding). Included as part of localized corrosion model on the basis that microbial activity may induce local pH decreases and the local acidic environment may produce multiple penetrations of the cladding. It is stated, however, that MIC resulting from sulfide produced by sulfate reducing bacteria (SBR) and organic acid producing bacteria is not expected to occur due to resistance of zirconium to these species. The arguments are poorly worded stating that MIC is not expected to occur (not probable or credible) because microbial activity is screened out at the scale of the repository model as a significant bulk process. The argument of local acidic pH causing localized corrosion of cladding is in contradiction with experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, it is in contradiction with arguments to screen out pitting corrosion by chloride anions (See FEP 2.1.02.16.00). Screening arguments for inclusion or exclusion should be consistent with screening decisions for related FEPs (See FEP 2.1.02.15.00). A third group of bacteria iron oxidizers should be considered in the analysis too (see CLST IRSR Rev. 3). Reference: CRWMS M&O, 2000. *Clad Degradation - FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	CLAD
52	AC2	FEP 1.2.04.04.00 (Magma Interacts with Waste) includes in the WFMisc screening argument a citation of a 1996 document to indicate the igneous activity is not a significant contributor to risk. Although they do not end up trying to screen IA, DOE's estimates of the consequences of volcanism have increased by many orders of magnitude in the last 5 years, and it is now considered the only risk during the regulatory period. DOE should be careful about citing out of date documents for their screening arguments, especially on consequence. Reference: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	MiscWF

53	AC2	FEP 2.1.02.22.00 (Hydride embrittlement of cladding). Excluded based on low probability of occurrence. DOE screening argument states that the in-package environment and cladding stresses are not conductive to hydride cracking. The NRC staff believes that reorientation of pre-existing hydride and embrittlement depend on temperature in addition to the required stresses. Clarification is needed on the cladding temperature and stress distributions used in the analysis. <u>References</u>: CRWMS M&O. 2000. *Hydride Related Degradation of SNF Cladding Under Repository Conditions*, ANL-EBS-MD-000011 REV 00. Las Vegas, Nevada CRWMS M&O, 2000. *Clad Degradation - FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada. Several secondary FEPs are listed related to various processes leading to hydrogen entry into the cladding are listed below: FEP 2.1.02.22.01 (Hydride embrittlement from zirconium corrosion [of cladding]). Excluded due to low probability of occurrence because the hydrogen pickup as a result of cladding corrosion is very low due to the low corrosion rate and the relatively small pickup fraction. The experimental hydrogen pickup fraction is given ans it is argued that the corrosion rate is very low. The conclusion attained by the DOE regarding failure of cladding as a result of hydrogen pickup due to general corrosion is acceptable However, the screening arguments can be better justified using quantitative arguments for the corrosion rate under disposal conditions. FEP 2.1.02.22.02 (Hydride embrittlement from WP corrosion and hydrogen absorption [of cladding]). Excluded due to low probability of occurrence because the hydrogen generated by corrosion of WP and WP internals and present as a molecule in gas or dissolved in water is not directly absorbed by the cladding. It is argued on the basis of experimental data that hydrogen absorption occurred through the reaction with water and not from the dissolved molecular hydrogen. The conclusion attained by the DOE regarding failure of cladding as a result of absorption of hydrogen gas generated by corrosion of WP materials is acceptable. However, the screening arguments can be better organized. FEP 2.1.02.22.03 (Hydride embrittlement from galvanic corrosion of WP contacting cladding) Excluded due to low probability of occurrence because corrosion of WP internals will not result in hydriding of cladding. It is argued using some experimental data as basis that galvanic coupling to carbon steel will not be conducive to hydrogen charging because corrosion products will interrupt the electrical contact. It is claimed also that the Ni content both in Zircaloy 2- and -4 is not sufficient to induce the necessary hydrogen charging. The conclusion attained by the DOE regarding failure of cladding as a result of hydrogen entry due to galvanic coupling with internal components of the WP is in general acceptable However, the screening arguments could be better supported by more relevant experimental data. FEP 2.1.02.22.04 (Delayed hydride cracking [of cladding]) Excluded due to low probability of occurrence. The analysis is based on the use of calculated values for the distribution of the stress intensity factor which are compared with the threshold stress intensity for irradiated Zircaloy-2. The conclusion attained by the DOE regarding failure of cladding as a result of DHC is acceptable. However, the DOE analysis of DHC is based on material properties of cladding containing mostly circumferential hydrides. DOE need to provide cladding temperatures and stress distributions and demonstrate that are insufficient to cause hydride reorientation. FEP 2.1.02.22.05 (Hydride reorientation [of cladding]) Excluded due to low probability of occurrence because tested fuel rods did not exhibited hydride reorientation at stresses higher than those expected at the repository temperatures. It is argued, in addition, that with hydride reorientation stresses will be insufficient for hydride embrittlement and clad failure. Therefore hydride reorientation has not been included in the model abstraction for cladding degradation._DOE agreed to provide updated documentation on the distribution of cladding temperatures and hoop stresses, critical parameters needed to evaluate the propensity to hydride reorientation and embrittlement. See primary FEP (FEP 2.1.02.22.00). FEP 2.1.02.22.06 (Hydride axial migration [of cladding]). Excluded based on low probability since it is unlikely that sufficient hydrogen can be moved to the cooler ends of the fuel rods because of a lack of large temperature gradients in the WPs. Based on studies for storage up to 90 years, it is concluded that the temperature gradients are not sufficient to induce redistribution of hydrides._The conclusion attained by the DOE regarding redistribution of hydrides caused by temperature gradients is acceptable. The screening arguments, however, should include the combined effects of stress and temperature.	CLAD

		FEP 2.1.02.22.07 (Hydride embrittlement from fuel reaction [causes failure if cladding]). Excluded based in low probability of occurrence because hydride embrittlement from fuel reaction (???) is only observed in BWRs and a high temperature steam environment is require for failure propagation, conditions which are unlikely even after WP failure. The conclusion is acceptable because it is not a credible failure mechanism. However, the screening arguments are to say the least, confusing.	

ENGINEERED BARRIER SYSTEM FEPS

Scenario Analysis

c	AC	Comment	Source
54	AC2	FEP 2.1.09.02.00 (Interaction with corrosion products) was excluded in the EBS (except for colloid-related effects) on the basis of low consequence (CRWMS M&O. 2001). As noted in the NRC/DOE technical exchange on ENFE, changes in seepage water chemistry resulting from interactions with engineered materials and their corrosion products were not adequately addressed in (CRWMS M&O, 2000).Water has been observed to drip preferentially along grouted rock bolts in the ECRB, for example, demonstrating that the introduced materials themselves can influence the location of preferred flow pathways. Seepage waters that have interacted with engineered materials and their corrosion products, can have a significant effect on evolved water and gas compositions. References: CRWMS M&O. 2000. *EBS Physical and Chemical Environmental Model AMR*,ANL-EBS-MD-000033 REV 01. Las Vegas, Nevada; CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	EBS MiscWF
55	AC2	FEP 2.1.09.07.00 (Reaction kinetics in waste and EBS). Consideration of chemical reactions, such as radionuclide dissolution/ precipitation reactions and reactions controlling the reduction-oxidation state is included by considering reaction kinetics in the in-package equilibrium model but excluded based on low consequence for the EBS. However, these [processes may affect the composition of the near field environment, particularly for trace elements, and the effect on corrosion of container materials could be indirect and should be considered. Adequate technical bases have not been provided to demonstrate that the combination of transport processes and reaction kinetics in the EBS will not adversely impact performance by altering the composition of water contacting the drip shield and waste package Reference: CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada. CRWMS M&O. 2000. *Miscellaneous Waste Form FEPs* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	EBS MiscWF
56		FEP 2.1.07.06.00 (Floor Buckling) has been excluded (CRWMS M&O, 2001) and *EBS Radionuclide Transport Abstraction* (CRWMS M&O, 2000) based on analyses documented in *Repository Ground Support Analysis for Viability Assessment* (CRWMS M&O, 1998), which indicate that floor heave from thermal-mechanical effects would not exceed about 10 mm. However, to address concerns raised by NRC staff about the appropriateness of the thermal-mechanical properties used in DOE calculations (such as the analyses cited above), the DOE has agreed to revise its assessment of floor buckling [RDTME Agreement 3.9 (DOE/NRC Technical Exchange on RDTME, February 6B8, 2001, Las Vegas, Nevada)]. Note that screening argument relies on analyses that DOE has agreed to revise to address outstanding NRC concerns in RDTME Agreements 3.2B3.13 (RDTME Technical Exchange, February 6B8, 2001, Las Vegas, Nevada). References: CRWMS M&O. 1998. *Repository Ground Support Analysis for Viability Assessment.* BCAA00000-01717-0200-0004 Rev 01. Las Vegas, Nevada CRWMS M&O. 2000. EBS Radionuclide Transport Abstraction AMR. ANL-WIS-PA-000001 Rev 00. Las Vegas, Nevada CRWMS M&O. 2001. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	EBS

57	AC2	FEP 1.1.02.03.00 (Undesirable materials left) is screened out on the basis of low consequences (CRWMS M&O, 2000). Although a report cited by the DOE (CRWMS M&O, 1995b) provides an analysis of acceptable upper bounds on materials introduced into the repository, no analysis has been conducted to determine if the current design will meet these limits. An assumption that the limits will be adhered to during the preclosure period is considered inadequate to exclude this FEP. DOE should provide adequate technical basis for the effect of introduced materials on water chemistry <u>Reference</u>: CRWMS M&O. 1995b. Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction. BABE00000-01717-2200-00007 Rev 04. Las Vegas, NV, 1995b CRWMS M&O. 2000. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	EBS
58	AC2	Screening arguments were labeled with the word <u>*Preliminary*</u> in *Features, Events, and Processes: Screening for Disruptive Events.* ANL-WIS-MD-000005 REV 00 ICN1. 2001. {FEPs 2.1.07.01.00 [Rockfall (Large Block)]; 1.2.02.01.00 (Fractures); 1.2.02.02.00 (Faulting); 1.2.03.01.00 (Seismic activity); etc} *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. 2001. Attachment I includes 61 FEPs arguments that are considered preliminary. It is stated that "future modeling and analysis efforts may enhance these considerations, and in this sense they are preliminary." It is necessary to disclose plans to release of more solid screening arguments.	EBS DE
59	AC2	FEP 2.1.08.04.00 (Cold Traps). Emplacement of waste in the drifts creates thermal gradients within the repository that may result in condensation forming on the roof of the drifts or elsewhere in the EBS, leading to enhanced dripping on the drip shields, waste packages, or exposed waste material. This FEP is excluded on the basis of low consequence (CRWMS M&O, 2001). The DOE's Multiscale Thermohydrologic Model (MSTHM) does not account for mass transport along the length of drifts. The only MSTHM submodel that includes thermal hydrology (i.e. mass transport) is a cross-section of a drift so it accounts for potential condensation only along the radial axis. <u>References</u>: CRWMS M&O. 2001. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV01. Las Vegas, Nevada.	EBS
60	AC2	The exclusion of 2.1.12.01.00 (Gas generation); and 2.1.12.05.00 (Gas generation from concrete) is unacceptable, because adequate technical bases have not been provided to justify the characterization of chemical environments in the EBS in terms of bulk water and gas compositions. The possibility of existence of local heterogeneity in gas composition in the drift, altering the chemistry of the DS/WP environment and adversely impacting repository performance should be explored. Local variations in the efficiency of advection/diffusion processes, relative to reaction rates, should be evaluated. <u>References</u>: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada. CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	EBS MiscWF

THERMAL HYDROLOGY AND COUPLED PROCESSES

Scenario Analysis

c	AC	Comment	Source
61	AC2	FEP 2.2.10.12.00 (Geosphere dry-out due to waste heat). Necessary to develop screening argument for this FEP under scope of UZ Flow and Transport FEP AMR. Elevated thermal effects on shallow infiltration due to changes in soil water content were not addressed for this FEP. DOE study of a natural thermal gradient on YM addresses this FEP (CRWMS M&O, 1998). This FEP is screened as included in (CRWMS M&O, 2001) for issues related to Near Field Environment, but does not address the effects of the FEP on infiltration. References: CRWMS M&O. 1998. *Final Report: Plant and Soil Related Processes along a Natural Thermal Gradient at Yucca Mountain, Nevada.* B00000000-01717-5705-00109 Rev 00. Las Vegas Nevada. CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001REV 00. Las Vegas, Nevada. CRWMS M&O, 2001. *FEPs in Thermal Hydrology and Coupled Processes.* ANL-NBS-MD-000004 REV 00 ICN01. Las Vegas, Nevada.	THER UZ
62	AC2	FEP 2.2.01.02.00 (Thermal and other waste and EBS-related changes in the adjacent host rock). Excluded - Low consequence (TM effects). Excluded - Low Probability (THC and backfill effects). Changes in host rock properties result from thermal effects or other factors related to emplacement of the waste and EBS, such as mechanical or chemical effects of backfill. Properties that may be affected include rock strength, fracture spacing and block size, and hydrologic properties such as permeability. The screening argument did not consider mechanical degradation of the rock mass, such as fracture-wall rock alteration owing to long-term exposure to heat, moisture, and atmospheric conditions. Such degradation would increase the severity of mechanical failure, e.g., (Ofoegbu G.I., 2000). However, DOE is expected to reevaluate its assessment of long-term mechanical degradation to satisfy outstanding DOE/NRC agreements (RDTME Agreements 3.11 and 3.19). In the analyses, it is necessary to account for long-term mechanical degradation of the host rock mass in its assessment of drift degradation, rockfall, and changes in hydrological properties; and their effects on repository performance. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada. Ofoegbu G.I. 2000. *Thermal-Mechanical Effects on Long-Term Hydrological Properties at the Proposed Yucca Mountain Nuclear Waste Repository.* CNWRA 2000-03. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.	THER
63	AC2	FEP 2.1.09.12.00 (Rind (altered zone) formation in waste, EBS, and adjacent rock). Included (THC model). Excluded - Low consequence (TH model, effects on transport). Thermo-chemical processes alter the rock forming the drift walls mineralogically. These alterations have hydrologic, thermal and mineralogic properties different from the current country rock. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	THER

64	AC2	FEP 2.2.10.06.00 (Thermo-chemical alteration (solubility speciation, phase changes, precipitation/dissolution)). Excluded - Low Consequence. Changes in the groundwater temperature in the far-field, if significant, may change the solubility and speciation of certain radionuclides. This would have the effect of altering radionuclide transport processes. Relevant processes include volume effects associated with silica phase changes, precipitation and dissolution of fracture-filling minerals (including silica and calcite), and alteration of zeolites and other minerals to clays. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	THER
65	AC2	FEP 2.1.11.02.00 (Nonuniform heat distribution/edge effects in repository). Included (TH and THC aspects) Excluded - Low consequence (TM effects). Temperature inhomogeneities in the repository lead to localized accumulation of moisture. Uneven heating and cooling at repository edges lead to non-uniform thermal effects during both the thermal peak and the cool-down period. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	THER
66	AC2	FEP 2.2.06.01.00 [Changes in stress (due to thermal, seismic, or tectonic effects) change porosity and permeability of rock]. Excluded - Low consequence. Excluded - Low probability (one secondary FEP not relevant to YMP) (CRWMS M&O, 2001). Even small changes in the fracture openings cause large changes in permeability. The rock deforms according to the rock stress field. Changes in the groundwater flow and in the temperature field will change the stress acting on the rock which will in turn change the groundwater flow. FEP 2.2.06.01.00 [Change in stress (due to thermal, seismic, or tectonic effects) change porosity and permeability of rock] was excluded as having low consequence to dose (CRWMS M&O, 2000a). However, the DOE analyses used to support the screening argument (CRWMS M&O, 2000b) did not consider water-flux diversion toward a drift from the adjacent pillar caused by increased aperture of subhorizontal fractures in the pillar from thermal-mechanical response. Such flux diversion would cause increased water flow to the drifts and potentially significant effects on dose. References: CRWMS 1.2.02.01.00 M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada. CRWMS M&O. 2000a. *Features, Events, and Processes: Screening for Disruptive Events.* ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, NV. CRWMS M&O. 2000b. AMR *Fault Displacement Effects on Transport in the Unsaturated Zone* (ANL-NBS-HS-000020 Rev 00. Las Vegas, NV.	THER DE
67	AC2	FEP 2.2.10.05.00 (Thermo-mechanical alteration of rocks above and below the repository). Thermal-mechanical compression at the repository produces tension-fracturing in the PTn and other units above the repository. These fractures alter unsaturated zone flow between the surface and the repository. Extreme fracturing may propagate to the surface, affecting infiltration. Thermal fracturing in rocks below the repository affects flow and radionuclide transport to the saturated zone. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	THER

68	AC2	FEP 1.2.02.01.00 (Fractures). Included (seepage). Excluded - Low consequence (permanent effects). Generation of new fractures and re-activation of preexisting fractures may significantly change the flow and transport paths. Newly formed and reactivated fractures typically result from thermal, seismic, or tectonic events. Thermally induced changes in stress may result in permeability changes between drifts that could act to divert flow towards drifts. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	THER
69	AC2	FEP 2.2.01.01.00 (Excavation and construction-related changes in the adjacent host rock). Included (initial effects on seepage). Excluded - Low consequence (permanent THC and TM effects). Stress relief, leading to dilation of joints and fractures, is expected in an axial zone of up to one diameter width surrounding the tunnels. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	THER
70	AC2	FEP 2.2.10.04.00 (Thermo-Mechanical alteration of fractures near repository). This FEP was excluded as having low consequence to dose (CRWMS M&O, 2001, 2000). See discussion under FEP 2.2.06.01.00. Heat from the waste causes thermal expansion of the surrounding rock, generating compressive stresses near the drifts and extensional stresses away from them. The zone of compression migrates with time. References: CRWMS M&O. 2001. Features, Events, and Processes in Thermal Hydrology and Coupled Processes. ANL-NBS-MD-000004 Rev 00 ICN01. Las Vegas, Nevada CRWMS M&O. 2000. Features, Events, and Processes in UZ Flow and Transport. ANL-NBS-MD-000001 REV 00. Las Vegas, Nevada.	THER

SYSTEM-LEVEL AND CRITICALITY

Scenario Analysis

c	AC	Comment	Source
71	AC2	FEP 1.1.07.00.00 (Repository Design), specifically secondary FEP 1.1.07.05.00 (Access Tunnels and Shafts). Staff considers that, although this FEP was originally specified for the WIPP emplacement geometry, it is sufficiently general to require inclusion at the YMP. Reference: CRWMS M&O. 2000. *Features, Events, and Processes: System Level and Criticality.* ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.	SYS
72	AC2	FEP 1.1.08.00.00 (Quality Control), specifically secondary FEPs 1.1.08.00.01 - 1.1.08.00.04 (Poorly constructed repository, material defects, common cause failures, poor quality construction). Staff considers that, although there are quality control procedures in place to prevent performance degradation related to these secondary FEPs, it remains possible that defects and failures are not recognized. Reference: CRWMS M&O. 2000. *Features, Events, and Processes: System Level and Criticality.* ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.	SYS
73	AC2	FEP 2.3.13.03.00 (Effects of repository heat on biosphere) is screened as excluded on the basis of low consequence but the screening analysis states that the repository heat effect on the biosphere is included in the uncertainty analysis of the shallow infiltration model. The shallow infiltration model accounts for vegetation and soil water content changes caused by climatic change. However, there are two important points that contradict the inclusion of repository heat effects: (1) the changes caused by the repository heat pulse act in the opposite direction of the vegetative changes made for monsoonal and glacial transition climates (repository heat leads to decrease in perennial shrubs, whereas both of those climate change possibilities lead to increased vegetation cover); and (2) the Analysis of Infiltration Uncertainty AMR (ANL-NBS-HS-000027) does not incorporate repository heat pulse in its determination of parameter variation or uncertainty. Reference: CRWMS M&O. 2000. *Features, Events, and Processes: System Level and Criticality.* ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.	SYS
74	AC2	FEP 2.1.14.01.00 (Criticality in waste and EBS) was preliminarily excluded in the Document (CRWMS M&O, 2000) based on low probability. A preliminary screening status was assigned because the criticality calculations were not complete for (i) DSNF following igneous intrusion and (ii) near-field and far-field criticality of all waste types following igneous disruption. The excluded screening status will be regarded unacceptable until concerns on the calculation of the probability for criticality are addressed. Since the probability of criticality depends on the presence of a breach of the waste package barriers, most of the discussion of criticality probability is focused on the probability of waste package failure. DOE has referenced the document, *Probability of Criticality in 10,000 Years* (CRWMS M&O, 2000g) for addressing the criticality probability due early failure by stress corrosion cracking, waste package damage following igneous intrusion, and seismic events. DOE has referenced the screening argument for rockfall (2.1.07.01) for screening the damage to the waste package and drip shield from seismically-induced rockfall. [R. Benke/M. Rahimi] In general, DOE needs to address the concerns raised on the waste package related FEPS, Mechanical Disruption FEPS, and the issues raised at the CLST technical exchange before it can conclude that there is no waste package breach before 10,000 years. [M. Rahimi] The concerns on the probability calculation in the document, Probability of Criticality in 10,000 Years (CRWMS M&O, 2000b) are: - The conclusion of waste package failure probability of 2.7×10^{-11} due to stress corrosion cracking (SCC), based on the equation in Section 6.1.1, is contrary to the TSPA results which indicate the first waste package failure, using the upper-bound curve, due to SCC at	SYS

		approximately 10,000 years. [M. Rahimi] - The screening argument for FEP 1.2.03.02.00 (Seismic Vibration Causes Container Failure), fails to consider the appropriate combinations of dead loads (caused by drift collapse and/or fallen rock blocks), rock block impact, and seismic excitation or the ability of these loads to initiate cracks and/or propagate preexisting cracks. - The screening argument for seismic events does not consider the indirect effects, such as causing dents which could aid in the collection and channeling of water or tilting the waste packages, which would result in the greater height of the water within the waste package. Seismic shaking, combined with a sloped waste package, may also allow materials to accumulate at one end of a waste package and form a more reactive geometry. [M. Rahimi] - The screening argument for seismically-induced rockfall damaging the drip shield and waste package includes several deficiencies as documented in the staff review of the *Drift Degradation Analysis* (CRWMS M&O) Analysis Model Report (AMR) and FEP 2.1.07.01 Furthermore, the analysis of the effects of rockfall on the drip shield, referenced in FEP 2.1.07.01 fails to consider (i) the temperature effects on mechanical material behavior, (ii) seismic motion of the supporting invert, (iii) point load impacts, (iv) appropriate material failure criteria, (v) material degradation processes, (vi) multiple rock block impacts, and (vii) boundary conditions that account for the potential interactions between the drip shield and gantry rails. Consequently, DOE has not adequately demonstrated that the drip shield has been designed to withstand 6, 10, or 13-MT rock block impacts. Other concerns related to the impact of rockfall on the WP are reflected in the comments on the related FEPs. [M. Rahimi] - The calculation does not fully consider mechanisms that could result in accelerated degradation of the fuel during an igneous event, such as burning of Zircaloy or creep of the fuel at high temperatures. [D. Galvin] - The analysis of damage to Zone 2 waste packages (CRWMS M&O, 2000b) fails to consider long term exposure to high temperatures changing the microstructure of Alloy 22 and reducing the mechanical strength of the material (e.g., Rebak et al., 1999) or the differences in thermal expansion between the inner alloy 316 NG SS and Alloy 22 (ASME, 1998) causing significant hoop-stress on waste package walls, in addition to the internal pressurization effects analyzed in CRWMS M&O (2000b). Analyses in CRWMS M&O (2000b) also do not consider potentially adverse chemical reactions, such as sulfidation reactions, in response to magmatic degassing or contact with basaltic magma. These processes could cause a more significant breach than the 10 cm^2 hole currently assumed for waste packages located in DOE Zone 2 during basaltic igneous events. [D. Galvin] - The calculation does not consider any changes to drift by the magma, such as magma solidifying in the lower part of the drift, causing ponding above and around the waste package. or fractures forming in the cooled magma that may provide preferential pathways to the waste package. Finally, the unsaturated flow may be modified by the presence of 1170 degree C magma so current parameters may no longer be valid. [D. Galvin] - The Criticality Probability document is inconsistent when discussing the water content of the magma in Section 5.3.2. The text indicates that the magma would consist of a very conservative 5 weight percent water content, but Table 5-1 lists the water content as only 0.05 weight percent. The computer files provided with the document that contained the actual calculations used a more realistic water content of 1.6%. A water content of 5 weight percent would clearly be very conservative, but justification needs to be provided if a lower water content is utilized in the calculations. [D. Galvin] <u>References</u>: CRWMS M&O. 2000. Features, Events, and Processes: System-Level and Criticality, ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada: CRWMS M&O. CRWMS M&O. 2000b. Probability of Criticality in 10,000 Years, CAL-EBS-NU-000014 REV 00. Las Vegas, Nevada: CRWMS M&O. ASME, *B&PV Code, Section II, Part D B Properties.* 1998. Rebak, R.B., T.S.E. Summers, and R.M. Carranza. Mechanical properties, microstructure, and corrosion performance of C-22 alloy aged at 260EC to 800EC. *Materials Research Society, Boston Meeting, Paper QQ 14.4.* 1999.	

DISRUPTIVE EVENTS

Scenario Analysis

c	AC	Comment	Source
75	AC1	A number of FEPs that could potentially influence the evolution of an igneous event intersecting the repository have not been identified as being relevant for disruptive events. These include: FEP 1.1.02.00.00 (Excavation/Construction) - changes to the rock around the repository due to excavation and construction could affect dike/repository interactions and influence how a dike behaves near the surface. Additionally, repository features such as ventilation shafts could provide a path to the surface that would bypass the repository. FEP 1.1.04.01.00 (Incomplete Closure) - if the design of the repository includes a seal at the end of the drifts strong enough to contain magma which is relied upon for performance calculations, failure to complete these seals could significantly affect repository performance. FEP 2.1.03.12.00 (Canister Failure (Long-Term)) - for intrusive volcanism, credit is taken for the waste packages remaining mostly intact other than an end cap breach following magma interactions. The only waste package failure mechanism that is investigated to take this credit is internal gas pressure buildup. Other waste package failure mechanisms such as differential expansion of the inner and outer waste packages and phase changes in the Alloy 22 due to the long term exposure to elevated temperatures are not considered. FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) - could affect magma-repository interactions and affect the dose as a result of an igneous event. FEP 2.3.01.00.00 (Topography and Morphology) - the topography may affect dike propagation near the surface and dike propagation probably should be discussed under this FEP.	Database DE
76	AC1	Detailed processes related to the interaction of the ascending dike with the repository drift are not described as FEPs. Instead, the FEP database includes only general categories like "Magma interacts with waste" and "Igneous Activity". This very high level treatment of the igneous FEPs likely has caused the DOE to miss many of the FEPs that are relevant to repository/dike interactions and interactions between magma and waste packages and fuel, particularly for Type 2 waste package failures (waste packages that fail, but whose contents are not removed by the event) and the determination of the number of waste packages affected. FEPs related to magma/repository interactions that are not included in the FEP database include: mechanical and fluid dynamics at the dike tip; fragmentation; vesiculation; plume dynamics; effect of drip shield on magma/repository interactions; geologic factors; threshold flow characteristics; gas segregation; alternate models of vent formation; effects of air shafts and drifts; consideration of flow segregation; localization of magma; recirculation of magma; and evolution of flow conditions. Canister/magma interactions that appear to have been missed include hoop stress due to differential expansion of the inner and outer waste packages; melting of materials; thermal shock; and phase changes in the Alloy 22 due to the long-term exposure to elevated temperatures. Fuel/magma interactions that may have been missed could include: cladding burning at high temperatures in the presence of air; cladding/fuel chemical reactions causing damage to the fuel form (no credit is taken for cladding); dissolution of fuel in magma; mechanical shear; oxidation (during and post-eruption); reworking of spent fuel in conduit; and evolution of flow conditions.	Database DE
77	AC2	FEP 2.1.07.02.00 (Mechanical degradation or collapse of drift) has been excluded (CRWMS M&O, 2001,a,b) based on (CRWMS M&O, 2000), which indicates that the emplacement drifts would essentially maintain their integrity through the period of regulatory concern. DOE is expected to revise the *Drift Degradation Analysis* to satisfy RDTME Agreements 3.17 and 3.19 (DOE/NRC Technical Exchange on RDTME, February 6B8, 2001, Las Vegas, Nevada).	DE

		At this stage, the screening argument is considered closed-pending given the existence of the RDTME Agreements 3.17 and 3.19. It should be noted, however, that the current state of knowledge on unsupported openings in fractured rock indicates that majority of drifts are likely to collapse soon after cessation of maintenance. This opinion is consistent with the conclusion of the DOE expert panel on drift stability (Brekke, T.L., et al, 1999) and to recent analyses of the behavior of unsupported drifts in fractured rock during seismic loading from an earthquake (Hsiung, S.M., et al., 2001). Drift collapse could have implications on temperature, chemistry, seepage into drifts, and drip shield performance. <u>References</u>: Brekke T.L., E.J. Cording, J. Daemen, R.D. Hart, J.A. Hudson, P.K. Kaiser, and S. Pelizza. 1999. *Panel Report on the Drift Stability Workshop, Las Vegas, Nevada, 9B11 December, 1998.* Yucca Mountain Site Characterization Project CRWMS M&O. 2000.*Drift Degradation Analysis* AMR. ANL-EBS-MD-000027 Rev 01. Las Vegas, Nevada CRWMS M&O. 2001a. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, Nevada Hsiung S.M. and G.-H. Shi. 2001. Simulation of earthquake effects on underground excavations using discontinuous deformation analysis (DDA). To appear in *Proceedings 38th U.S. Rock Mechanics Symposium*, Washington, DC: 7B10 July, 2001.	
78	AC2	FEP 1.2.03.02.00 (Seismic Vibration Causes Container Failure). The Seismic Vibration Causes Container Failure FEP has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). The screening argument cites preliminary seismic analyses of the drip shield and waste package as the basis for this screening decision (CRWMS M&O, 2000a). Because these analyses were not available at the time of this review, it is not clear as to whether the appropriate combinations of dead loads (caused by drift collapse and/or fallen rock blocks), rock block impacts, and seismic excitation were considered. Moreover, the ability of these loads to initiate cracks and/or propagate preexisting cracks may not have been adequately addressed. In addition, DOE has not demonstrated that the drip shield, pallet, and/or waste package will respond in a purely elastic manner when subjected to the aforementioned loading conditions. The screening argument for this FEP also states that " it does not appear credible that the drip shield would be breached, because the drip shield has been designed to withstand up to a 6-MT rockfall." based on the rockfall on drip shield analyses performed by the DOE (CRWMS M&O, 2000b). DOE, however, has not adequately demonstrated that the drip shield has in fact been designed to withstand 6-MT rock blocks {see the comments on FEPs 2.1.07.01.00 [Rockfall (large block)], 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift), and 2.1.07.05.00 (Creeping of metallic materials in the EBS) for additional discussion relevant to rockfall and seismic analyses}. <u>References</u>: CRWMS M&O 2000a. Input Request for Seismic Evaluations of Waste Packages and Emplacement Pallets. Input Transmittal 00230.T. Las Vegas, Nevada; CRWMS M&O 2000b. Rock Fall on Drip Shield. CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada; CRWMS M&O.2001a. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada; CRWMS M&O.2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01	DE WP

79	AC2	FEP 2.1.07.01.00 [Rockfall (Large Block)]. The effects of Rockfall (Large Block) on the drip shield and waste package has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a-c). The *Drift Degradation Analysis* (CRWMS M&O, 2000a) Analysis Model Report (AMR) indicates that thermal loading, seismicity, and time-dependent mechanical degradation of the host rock would have minor effect on the integrity of the drifts through the entire period of regulatory concern. However, several deficiencies associated with this analysis were identified by the NRC staff at the NRC/DOE RDTME technical exchange [see the comments on FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) for additional discussion pertaining to the DOE rockfall analyses]. As was pointed out at the ÇLST and RDTME technical exchanges, the rockfall on drip shield analyses (CRWMS M&O, 2000b) did not consider (i) the temperature effects on mechanical material behavior, (ii) seismic motion of the supporting invert, (iii) point load impacts, (iv) appropriate material failure criteria, (v) material degradation processes, (vi) multiple rock block impacts, and (vii) boundary conditions that account for the potential interactions between the drip shield and gantry rails. Consequently, DOE has not adequately demonstrated that the drip shield has been designed to withstand 6, 10, or 13-MT rock block impacts. Because the framework for the invert is constructed from carbon steel, their potential degradation may affect the orientation of the waste packages over time. In other words, the invert floor cannot be expected to keep the waste packages in a horizontal position for the entire regulatory period. As a result, rock block impacts on the waste package may occur at angles that are not perpendicular to the waste package longitudinal axis. Angled rock block impacts near the closure lid welds may have significantly different results than nonangled impacts. This is a new scenario that has not presented to DOE. Mechanical failure of cladding due to rockfall is excluded based on low probability because rockfall on intact WP will not cause rod failure (CRWMS M&O, 2000c). Main screening argument is based on intact WP. However, the discussion is confusing because arguments based on the presence of backfill are also used in quantitative estimates. Although the conclusion can be acceptable due to presence of intact WP, the screening arguments should be improved on the bases of appropriate calculations. <u>References</u>: CRWMS M&O. 2000a. Drift Degradation Analysis AMR. ANL-EBS-MD-000027 Rev 01. Las Vegas, Nevada CRWMS M&O. 2000b. Rock Fall on Drip Shield. CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada CRWMS M&O. 2000c. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada. CRWMS M&O. 2001a. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O.2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, Nevada CRWMS M&O.2001c. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01	DE WP CLAD

Source Acronyms:

SZ:
CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.

UZ:
CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 00. Las Vegas, Nevada.

EBS:
CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.

SYS:
CRWMS M&O. 2000. *Features, Events, and Processes: System Level and Criticality.* ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.

CLAD:
CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.

MiscWF:
CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.

WP:
CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.

THER:
CRWMS M&O. 2001. *FEPs in Thermal Hydrology and Coupled Processes.* ANL-NBS-MD-000004 REV 00 ICN01. Las Vegas, Nevada.

DE:
CRWMS M&O. 2000. *Features, Events, and Processes: Screening for Disruptive Events.* ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, NV.

BIO:
CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.

Database:
YMP FEP Database Rev 00 ICN01

DOE Discussion Topics for May 15-17, 2001 Features, Events and Processes Technical Exchange

Errata

1. NRC Comments (Items Nos. 15, 40, 42, 43 and 45) were withdrawn and are not included in the DOE Discussion Topics.

2. NRC Comments and DOE Discussion Topics (Items Nos. 75 and 76) will not be discussed at this Technical Exchange, but will be discussed at the May 18, 2001 Igneous Activity Appendix 7 Meeting, Las Vegas, NV.

3. DOE Discussion Topics (Items Nos. 82 and 83) are not included in the NRC Comment table and therefore, will not be discussed during the Technical Exchange.

4. DOE Discussion Topic (Item No. 80) is not included in the NRC Comment table but will be discussed during the Technical Exchange.

5. DOE Discussion Topic entries that have duplicate numbering (e.g., Item Nos. 9 and 53) address the same primary or similar secondary features, events and processes. The NRC Comment table will dictate which or if all entries are discussed during the Technical Exchange.

6. NRC Comments and DOE Discussion Topics will be combined and issued as a single table following the Features, Events and Processes Technical Exchange.

DOE Discussion Topics for May 15-17, 2001 Features, Events and Processes Technical Exchange

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
1	Generic	SZ		Arnold (S&A)	Screening arguments for the Saturated Zone Features, Events and Processes are focused on those components of the Saturated Zone system to which the feature, event and process is most relevant (e.g., the thermal convection cells due to repository heat in the volcanic aquifer). The issue of dissolution in the alluvium is discussed in more detail in response to NRC comment on Feature, Event And Process 1.2.09.02.00 (Large-scale dissolution). The potential impact of water table decline with regard to flow path length in the alluvium is mentioned in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). DOE believes that no additional work is needed in this regard. References: CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230.	
2	1.3.07.02.00	SZ	Water Table Rise	Arnold (S&A)	The conclusion that water table rise has been adequately incorporated into the Saturated Zone flow and transport analyses is labeled as "Preliminary" in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). In addition, the assumption that groundwater flow paths from the repository would not be significantly changed under wetter climatic conditions has been identified and as "To Be Verified" (TBV) in the Analysis/Model Report. Additional modeling with the Saturated Zone site-scale flow and transport model is planned to verify this assumption and to close the TBV. No groundwater discharge at springs along the Saturated Zone flow path from the repository (within 20 km) is anticipated for glacial climatic conditions, as indicated by the lack of paleospring deposits in this area and by regional-scale groundwater flow modeling results (D'Agnese et al. 1999). Paleospring deposits at the southern end of Crater Flats indicate that groundwater discharge has occurred in this area under past glacial conditions and would alter the groundwater flow to some extent. However, these potential discharge points are over 10 km to the west of the present groundwater flow path and are not expected to be a source of potential radionuclide releases to the accessible environment. References: CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. D'Agnese, F.A.; O'Brien, G.M.; Faunt, C.C.; and San Juan, C.A. 1999. *Simulated Effects of Climate Change on the Death Valley Regional Ground-Water Flow System, Nevada and California.* Water-Resources Investigations Report 98-4041. Denver, Colorado: U.S. Geological Survey. TIC: 243555.	
3	2.2.10.03.00	SZ	Natural Geothermal Effects	Arnold (S&A)	**Response same as 2.2.10.13.00** - Density-driven groundwater flow from natural thermal effects due to hydrothermal activity could result in greater dilution of radionuclide concentrations due to convection, as discussed in the section on Feature, Event and Process 1.2.06.00.00 in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). In addition, potential impacts due to increased groundwater flow rates in the Saturated Zone are captured within the range of uncertainty in specific discharge analyzed in the Saturated Zone site-scale flow and transport model for Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq). Specific discharge in the Saturated Zone is scaled upward by a factor of 10 for a significant number of realizations of the Saturated Zone flow and transport system (CRWMS M&O. 2000ar). References CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.	
4	1.2.06.00.00	SZ	Hydrothermal activity	Arnold (S&A)	The approach taken to assigning uncertainty distributions for Kd in the Saturated Zone transport model is to use the most conservative (i.e., lowest Kd values) from among the different volcanic rock types reported in CRWMS M&O (2000as). By taking the most conservative distribution of Kd for all volcanic rock types (including some that have experienced volcanic hydrothermal alteration, such as zeolitization), the Saturated Zone transport analysis implicitly incorporates the consideration of potential future hydrothermal alteration in a conservative manner. It is recognized that the analysis of Kd distributions in CRWMS M&O (2000as) does not directly discuss the issue of hydrothermal alteration, but does include analysis of Kd distributions for zeolitic volcanic units. The reference to low probability at the end of the Supplemental Discussion section is extraneous to the argument of low consequence and will be removed in the next revision of the Saturated Zone Features, Events, and Processes Analysis/Model Report. This comment is addressed in Radionuclide Transport agreement KRT0210. The agreement states in part, "Consistent with the less structured approach for informal expert judgement acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment..." The information obtained from agreement KRT0210 will respond to this comment in full and no additional work is needed. The Saturated Zone Features, Events, and Processes Analysis/Model Report will be revised, to support any potential License Application, to include the new information obtained from agreement KRT0210. References: CRWMS M&O 2000as. *Unsaturated Zone and Saturated Zone Transport Properties (U0100).* ANL-NBS-HS-000019 REV00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL20000829.0006.	KRT0210
5	2.1.09.21.00	SZ	Suspension of Particles Larger than Colloids	Arnold (S&A)	It should be noted that particles larger than colloids are not included in the Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq) analysis and have been explicitly excluded by the waste form and near field environment components of the Total System Performance Assessment. This feature, event and process is identified as potentially included in the Saturated Zone to the extent that it cannot be shown to have sufficiently low consequence to the Saturated Zone component of the analysis. The point is that radionuclides associated with particulate matter (colloids or larger) are treated as colloids in the Saturated Zone analysis, if they are deposited in the Saturated Zone from other components of the Total System Performance Assessment. However, suspension of particles larger than colloids has been excluded from the analysis at the source. If particles larger than colloids are included in the Near Field Environment, Waste Form, and Unsaturated Zone models they will also be included in the Saturated Zone transport model and will be modeled conservatively using the colloid transport model. Likewise if they are excluded in the Near Field Environment, Waste Form, or Unsaturated Zone they will not be included in the Saturated Zone transport model. As indicated in the response to feature, event and process 1.4.06.01.00 (Altered soil or surface water chemistry) above, the treatment of any feature, event and process will be consistent throughout the Total System Performance Assessment components.	
6	NA	SZ	NA		Initiation, tracking, resolution and closure of To Be Verified's in technical products are procedurally controlled per procedure AP-3.15Q. To Be Verified conditions are identified, initiated and resolved by the authors of technical products. Tracking numbers are assigned by a Project-wide coordinator. Progress of TBV condition resolution is monitored and tracked by the coordinator. If technical product inputs are changed during the resolution of To Be Verified conditions, notification of potential downstream impacts is controlled per procedure AP-3.17Q. To Be Verified's are established to facilitate the resolution of information that may be preliminary, requires evaluation, or need confirmation, and as a placeholder for information that may not yet be developed. As the knowledge base of the project grows, these tracking items	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					will either be resolved by the acquisition/confirmation of the required information or eliminated by a change in direction (e.g., re-design). Once the To Be Verified's have been resolved, the Features, Events and Processes Analysis/Model Reports will be revisited to ensure that the screening arguments remain valid or require updates. The schedule for ongoing activities are integrated into the overall project schedule and prioritized based on project milestones and budget. As such, the resolution of those To Be Verified's required to support a potential license application will be considered in the scope of work during the associated planning activities. Recommend To Be Verified's be discussed on a case-by-case basis during the applicable Features, Events and Processes Analysis/Model Report discussions.	
7	1.4.06.01.00	SZ	Altered soil or surface water chemistry	Arnold (S&A) Houseworth (S&A)	The basis for excluding this Feature, Event and Process (FEP) is provided in the Unsaturated Zone (FEPs) Analysis/Model Report (BSC 2001d). This FEP is not considered in the Saturated Zone flow and transport since it has been excluded in the Unsaturated Zone flow and transport, i.e., any effect in the Saturated Zone would be less than that in the Unsaturated Zone. Reference: BSC 2001d. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	
8	1.2.04.07.00	SZ	Ashfall	Arnold (S&A)	The uniform distribution of ashfall along the flow path from the repository to the receptor is a stylized, conservative representation of volcanic ash distribution on the land surface that allows a relatively simple analysis of potential impacts. It is conservative to assume that all of the volcanic ash would be concentrated on a relatively narrow band of the land surface within the capture zone of the well(s) providing groundwater to the hypothetical farming community. The range of waste packages as a result of a volcanic eruption is 3 to 39. The number of waste packages that are assumed to fail in the ashfall analysis is the median number of packages from the Total System Performance Assessment-Site Recommendation modeling (CRWMS M&O 2000aq). The expected behavior with respect to the number of waste package failures is used in the ashfall analysis.; There is no regulatory requirement that conservative parameter values be used in every aspect of the screening analysis. DOE believes no additional work is needed in this regard. References: CRWMS M&O 2000aq. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001005.0282.	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
9	2.2.10.06.00	SZ	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/ dissolution)	Arnold (S&A)	The rationale for excluding this Feature, Event and Process from the Saturated Zone does rest on the conclusions of the unsaturated zone features, events and processes screening analysis that it can be excluded on the basis of low consequence. This rationale is reasonable and appropriate. If the higher temperature conditions in the unsaturated zone near the repository are insufficient to have a significant consequence on radionuclide transport, then the smaller temperature rise in the saturated zone would also have no significant consequences. However, it is recognize that this conclusion is based on a To Be Verified assumption in the unsaturated zone and if the screening decision is changed for the unsaturated zone, the screening decision and justification for the saturated zone would need to be revisited. This comment is addressed in Radionuclide Transport agreement KRT0210. The agreement states in part, "Consistent with the less structured approach for informal expert judgement acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment...." The information obtained from agreement KRT0210 will respond to this comment in full and no additional work is needed. The Saturated Zone Features, Events and Processes Analysis/Model Report will be revised, to support any potential License Application, to include the new information obtained from the Radionuclide Transport agreement KRT0210. References: BSC 2001d. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321. CRWMS M&O 2000as. *Unsaturated Zone and Saturated Zone Transport Properties (U0100).* ANL-NBS-HS-000019 REV00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL20000829.0006.	KRT0210
9	2.2.10.08.00	SZ	Thermo-chemical alteration of the saturated zone	Arnold (S&A)	**See response to 2.2.10.06.00**	
10	2.3.11.04.00	SZ	Groundwater discharge to surface	Arnold (S&A)	No groundwater discharge at springs along the saturated zone flow path from the repository (within 20 km) is anticipated for glacial climatic conditions, as indicated by the lack of paleospring deposits in this area and by regional-scale groundwater flow modeling results (D'Agnese et al. 1999). Paleospring deposits at the southern end of Crater Flats indicate that groundwater discharge has occurred in this area under past glacial conditions and would alter the groundwater flow to some extent. However, these potential discharge points are over 10 km to the west of the present groundwater flow path and are not expected to be a source of potential radionuclide releases to the accessible environment. References: D'Agnese, F.A.; O'Brien, G.M.; Faunt, C.C.; and San Juan, C.A. 1999. *Simulated Effects of Climate Change on the Death Valley Regional Ground-Water Flow System, Nevada and California.* Water-Resources Investigations Report 98-4041. Denver, Colorado: U.S. Geological Survey. TIC: 243555.	
11	1.3.07.01.00	SZ	Drought/water table decline	Arnold (S&A)	The possibility of shorter flow path lengths in the alluvium (due to hydrogeologic uncertainty or potential decline in the water table) is captured in Saturated Zone site-scale model simulations for Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000ar). The general pattern of groundwater flow is not expected to change with water table decline in the Saturated Zone. The regional-scale groundwater flow is controlled by the topographic distribution of recharge and discharge areas, as well as the large-scale distribution of hydrogeologic units and structural features. It is reasonable to expect that there would be relatively minor changes in the shallow groundwater flow paths with water table decline, but major features of the Saturated Zone flow system (e.g., the upward gradient from the carbonate aquifer) are expected to remain stable in the case of either water table decline or water table	KRT0208 KUZD504

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					rise. This comment is addressed in Radionuclide Transport and Unsaturated and Saturated Flow Under Isothermal Conditions agreement KRT0208 and KUZ0504 respectively. The agreements state in part, "DOE will provide additional information to include Nye county data as available, to further justify the uncertainty distribution of flow path lengths in alluvium ..." The information obtained from agreement KRT0208 will respond to this comment in full and no additional work is needed. The Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f) will be revised, to support any potential License Application, to include the new information obtained from agreement KRT0208. References: CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.	
12	2.2.10.13.00	SZ	Density-driven groundwater flow (thermal)	Arnold (S&A)	Density-driven groundwater flow from natural thermal effects due to hydrothermal activity could result in greater dilution of radionuclide concentrations due to convection, as discussed in the section on Feature, Event and Process 1.2.06.00.00 in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). In addition, potential impacts due to increased groundwater flow rates in the saturated zone are captured within the range of uncertainty in specific discharge analyzed in the saturated zone site-scale flow and transport model for Total System Performance Assessment-Site Recommendation. Specific discharge in the saturated zone is scaled upward by a factor of 10 for a significant number of realizations of the saturated zone flow and transport system (CRWMS M&O. 2000ar). References: CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.	
13	2.2.10.02.00	SZ	Thermal convection cell develops in Saturated Zone	Arnold (S&A)	The screening argument, for excluding this Feature, Event and Process, is that thermally driven groundwater flow in the Saturated Zone will not significantly alter the range of uncertainty in specific discharge that is already included in the Saturated Zone site-scale flow and transport model for Total System Performance Assessment-Site Recommendation and therefore will not significantly alter the expected dose. To account for uncertainties, specific discharge in the Saturated Zone is scaled upward by a factor of 10 for a significant number of realizations of the Saturated Zone flow and transport system (CRWMS M&O. 2000ar). In addition, for nominal-case behavior in Total System Performance Assessment-Site Recommendation there is negligible transport of radionuclides through the Unsaturated Zone during the period of significant thermal perturbation. References: CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.	
14	1.2.09.02.00	SZ	Large-scale dissolution	Arnold (S&A)	This Feature, Event and Process is identified as applying to large-scale dissolution processes, such as those that could lead to significant changes to groundwater flow in the aquifer, and does not apply to predominantly clastic hydrogeologic units, like the alluvium. Hence, no additional work is needed in this regard. Multiple episodes of wetter climatic conditions have existed in the geologic past, without apparent loss of calcite in the alluvium due to dissolution. Therefore, it is not expected that future glacial climatic conditions would result in significant loss of sorptive capacity in the alluvium. To address the concern regarding sorption of Np in the alluvium, it should be noted that the	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					uncertainty distribution for the Np Kd in alluvium has a lower bound of zero (CRWMS M&O 2000har), with significant statistical density at lower values of Kd. This uncertainty distribution implicitly incorporates consideration of limited Np sorption in the alluvium. In addition, uncertainty in the flow path length through the alluvium in the Saturated Zone transport simulations significantly limits the sorptive effects of the alluvium in some realizations of the system. References: CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.	
16	2.3.13.01.10	Bio	Natural Ecological Development	Tappen (S&A)	Secondary Features, Events and Processes (FEP), as identified in Sec.3.2 of Freeze et al. 2001, are FEPs that are redundant to another FEP, specific to another Program, or better captured or subsumed in more broadly-defined primary FEP. Based on those criteria it would be appropriate to identify a secondary FEP based on an originator's description, statement, or exclusion of a FEP using verbatim text of the FEP description from originator documentation. The originator is noted in parentheses where possible. No attempt was made to edit this field and it was not used for any screening evaluations. For screening, a Yucca Mountain Project Primary FEP Description was developed for each Primary FEP which contains a Description of each FEP and its potential relevance to YMP, typically edited from the Originator FEP Description. Where secondary FEPs are associated with a primary FEP, the description also includes all of the features, events, and processes described by the secondary FEPs. Using this approach, only the Primary FEPs require screening evaluations and only the Yucca Mountain Project Primary FEP Descriptions require editing for consistency and relevance to Yucca Mountain Project. The Originator FEP Descriptions, whether they are for Primary or Secondary FEPs, are used only for traceability to the source, and are not used for screening.	
17	NA	Bio	NA	Gunter (DOE)	DOE will assess the differences between the Interim Guidance (Dyer 1999) and Part 63 once the final rule is issued. DOE will make modifications to project documents, as necessary.	
18	1.4.07.01.00	Bio	Waste management activities	Tappen (S&A)	This Feature, Event and Process (FEP) can be excluded on the basis of the proposed regulation as this FEP deals with the use of man-made structures and not specifically with the use of groundwater. Since these features do not currently exist in the vicinity of the location of the critical group, not considering them is consistent with the current conditions. The use of groundwater, via well(s), and the changes associated with climate evolution are specifically related to FEP 1.4.07.02.00 "Wells" and is not considered to be part of this FEP. Effect of climate change, FEP 1.3.01.00.00, on water use is considered and addressed in Nominal Case Biosphere Dose Conversion Factor Analysis/Model Report.	
19	Various	Bio	BDCF calculations	Tappen (S&A)	Feature, Event and Process (FEP) 1.3.07.02.00 Water Table Rise and FEP 2.3.11.04.00 Groundwater Discharge to Surface. The processes addressed in FEPs 1.3.07.02.00 & 2.3.11.04.00 are not directly related to the biosphere and are not evaluated by the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e). Effects of any surface discharge or water table rise in the compliance area, if any, would be addressed within FEP 3.3.05.11.00 "Radiation Doses". The effects of climate change within the compliance area, if any, on the processes addressed in these FEP will be evaluated in support of any potential license application. FEP 3.2.10.00.00 Atmospheric Transport of Contaminants - Those FEP, which deal with the mechanics of atmospheric transport of contaminants as a result of a volcanic event, are discussed, considered and evaluated within the scope of the Disruptive Event FEP Analysis/Model Report (CRWMS M&O 2000i). The effects of other atmospheric transport processes, such as wind erosion and resuspension, are currently considered in calculation of	

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					Biosphere Dose Conversion Factors. Specifically, wind erosion is considered under FEP #s 1.2.07.01.00, 1.2.07.02.00, and 2.3.02.02.00. FEP 1.2.04.01.00 Igneous Activity - As described in Freeze et al. 2001, the YMP Primary FEP Description, the Originator FEP Description, and the secondary FEP descriptions, this FEP is focused on the consequences of igneous activity in the geosphere. This FEP is not directly relevant to the biosphere and, as a result, does not need to be evaluated in the Biosphere FEP Analysis/Model Report. FEP 2.2.08.02.00 Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone - As cited Freeze et al. 2001, this FEP corresponds to a FEP titled "Radionuclide transport occurs in a carrier plume in the geosphere". The Yucca Mountain Project Primary FEP Descriptor, Originator Descriptor and associated secondary FEP descriptors all relate to transport in the geosphere. This FEP is not directly relevant to the biosphere and, as a result, it does not need to be evaluated in the Biosphere FEP Analysis/Model Report. DOE agrees that chemical species can effect the dose coefficient selection. In the analyses of radiation doses, FEP 3.3.05.01.00 ,which is considered in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e), this effect is bounded by selecting the highest dose coefficient factor. FEP 2.2.08.11.00 Distribution and Release of Radionuclides from the Geosphere - As stated in the both the Yucca Mountain Project Primary FEP Description and the Originator Description, this FEP is focused exclusively on the transport of radionuclides in the groundwater. The release of radionuclides in groundwater, as cited in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e), is considered via a well, FEP 1.4.07.02.00. This FEP is not directly relevant to the biosphere and, as a result, does not need to be evaluated in the Biosphere FEP Analysis/Model Report. 3.1.01.01.00 FEP Radioactive Decay and Ingrowth - DOE is reconsidering citing this as an applicable FEP. Although this FEP is not cited as an applicable FEP in the Biosphere, the analyses of radiation dose, FEP 3.3.05.01.00, was addressed in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e) and did include the consideration of radioactive decay and progeny ingrowth along the various pathways to man. 1.2.04.07.00 Ashfall - DOE is reconsidering citing this as an applicable FEP. Although this FEP is not cited as an applicable FEP in the Biosphere, the analysis of radiation dose, FEP 3.3.05.01.00, was addressed in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e) and did include ashfall for the disruption event scenario.	
20	2.2.08.07.00	Bio	Radionuclide solubility limits in the geosphere	Tappen (S&A)	The Feature, Event and Process (FEP) as described in the FEP database is specific to "Geosphere." The Biosphere as described in the Biosphere Process Model Report excludes processes in the geosphere, therefore this FEP is not considered in the Biosphere. The concern for limiting the quantity of radioactive material that can leach from soil or tephra deposits does have relevance to the biosphere. The process of leaching in which solubility limits apply is addressed in FEP 2.3.02.02.00, "Radionuclide Accumulation in soil." For the nominal scenario (groundwater contamination), the process depends on the radionuclide build-up in soil, which includes leaching, and partition coefficient (ratio of concentrations in liquid and solid matter). The process would be applicable to the leaching of the contamination from volcanic ash. However for volcanic release, the Biosphere model does not consider contamination removal by leaching and is thus bounding and conservative. In this scenario the dominant pathway is inhalation from resuspended particulate matter. The inclusion of leaching (with solubility limits) as a transport mechanism from the surfacial layer of	

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					contaminated ash (where all resuspension originates) into the deeper layers (where the contamination cannot be resuspended and is thus not available for inhalation) can only reduce the dose contribution from the primary pathway.	
21	2.3.13.01.00	Bio	Biosphere characteristics	Tappen (S&A)	As described in Section 7.1 of the Yucca Mountain Site Description (CRWMS M&O 2000aw), the region around Yucca Mountain lacks permanent surface water bodies (see Feature, Event and Process 2.3.04.01.00 Surface Water Transport and Mixing). Intermittent sources of water on the Nevada Test Site were not considered since access to the Nevada Test Site is controlled and such sources would not be available to members of the critical group. At the present time, the presence of an intermittent seep or spring at the proposed location of the critical group has not been identified and is considered unlikely given the depth to groundwater (>90 meters) at that location. DOE considers that this issue is conservatively addressed in the current analysis of the nominal scenario.	
22	2.3.13.01.00	Bio	Biosphere characteristics	Tappen (S&A)	As cited in Freeze et al. 2001, the objective of the Features, Events and Processes (FEPs) Database is to document a manageable number of primary FEPs (a few hundred) that encompass, through comprehensively worded Yucca Mountain Project primary FEP descriptions, the relevant issues. To ensure comprehensiveness, a Yucca Mountain Project primary FEP description must include all issues identified in the underlying secondary FEPs. However, there is no requirement that an issue identified in a Yucca Mountain Project primary FEP description necessarily has a corresponding secondary FEP. The ultimate evaluation of comprehensiveness will consider just the primary FEPs (i.e., issues identified in the corresponding Yucca Mountain Project primary FEP descriptions, whether they derive directly from a secondary FEP or from some other source). As new issues are identified, the DOE may add them to the database as new FEPs (primary or secondary) or by simply expanding the Yucca Mountain Project primary FEP description of an existing primary FEP. For all of these options, the documentation of the issue ends up in a Yucca Mountain Project primary FEP description. In the case of FEP 2.3.13.01.00, the issue (biosphere characteristics - animals) is already captured in the YMP primary FEP description, and DOE does not deem it necessary to create a new secondary FEP for animals. In cases where the new issue is a significant deviation from an existing FEP, DOE would consider creating a new FEP. "Animals" as a source of radioactive materials contributing to human exposure is specifically considered in Primary FEP 2.4.09.02.00 Animal Farms and Fisheries.	
23	2.3.11.04.00	Bio	Groundwater discharge to surface	Tappen (S&A)	Groundwater discharge from springs along the flowpath from the repository could potentially occur at distances greater than 20 km under wetter climatic conditions. However, in the Total System Performance Assessment-Site Recommendation models discharge to the biosphere occurs through hypothetical pumping wells at the compliance point, assuming complete capture of radionuclides in the water supply of the critical group. This conservative approach is consistent with proposed rule 10 CFR Part 63 and effectively precludes radionuclide transport to more distant discharge points from the analysis. Thus, spring discharge beyond the compliance location will not have an effect on the simulated expected annual dose and can be excluded based on low consequence. Based on the methodology used for Total System Performance Assessment-Site Recommendation radionuclide discharge modeling, DOE does not consider this feature, event and process relevant to the biosphere and therefore it should be excluded from potential consideration	

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24	2.3.13.02.00	Bio	Biosphere transport	Tappen (S&A)	The objective of the Features, Events and Processes (FEPs) Database, as cited in Freeze et al. 2001, is to document a manageable number of primary FEPs that encompass, through comprehensively worded Yucca Mountain Project primary FEP descriptions, all of the relevant issues. To ensure completeness, a Yucca Mountain Project primary FEP description must include those issues identified in the Originator FEP. For this particular FEP, the statement "Once in the biosphere, radionuclides may be transported through and between the different compartments of the biosphere" inherently captures the intent of the Originator FEP Description phrase "Within the biosphere…" The treatment of the this FEP in the biosphere is both transport processes and alterations during transport.	
25	2.4.07.00.00	Bio	Dwellings	Tappen (S&A)	Household (evaporative) cooling is not expected to result in a significant increase in the relative contribution of the inhalation and external pathways to the expected annual dose. For the nominal case (ANL-MGR-MD-000009, Rev 01), which considers indoor exposure as a fraction of the outdoor exposure, the external pathway and the inhalation pathway generally contribute only a small fraction of the Biosphere Dose Conversion Factor. Given the fact that household cooling is used approximately 50% of the time and that people spend less than 50% of their time indoors, any increase in the relative contribution of the external and inhalation pathways to the expected annual as a result of household cooling is expected to be negligible. For the Disruptive Event (CRWMS M&O 2000p), groundwater is uncontaminated. Therefore, use of evaporative cooling would not present any additional source of indoor exposure in significant effect on the expected annual dose. DOE considers effects of this secondary Feature Event and Process to be adequately covered in the current analyses of Biosphere Dose Conversion Factors for the two scenarios.	
26	3.3.08.00.00	Bio	Radon and daughter exposure	Tappen (S&A)	Inventory Abstraction Analysis/Model Report (CRWMS M&O 2000aj) does not identify either Th-230 or Ra-226 as a significant radionuclide, i.e. one of the radionuclides required to account for 95% of the dose, for the inhalation or ingestion pathway within 10,000 years after repository closure. The inventory abstraction analysis has been revised and may be considered in subsequent biosphere analyses.	
80	2.3.02.02.00	Bio	Radionuclide Accumulation in Soil	Tappen (S&A)	DOE has agreed to revisit the issue of surface-redistribution of contaminated ash and soil as part of the resolution of agreement item for Igneous Activity Agreement KIA0206. Specifically, DOE has agreed to develop a linkage between soil removal rate and surface remobilization processes characteristics of the Yucca Mountain region and to document its approach to include uncertainty related to surface-redistribution processes in Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq). Section 14.3.6.7 of Supplemental Science and Performance Analyses (DOE 2001, n progress, see note last page), will provide an overview of the work that may be conducted to address this issue. (Response applicable to each listed feature, event and process) No additional work is required beyond the existing agreement.	KIA0206

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27	2.1.09.09.00	WP	Electrochemical effects (electrophoresis, galvanic coupling)	Pasu (S&A) Bennett (ENG)	See also response to FEP 2.1.06.07.00. Any electrochemical coupling of Alloy 22 with 316NG will result in increased corrosion degradation of 316NG and enhanced performance of Alloy 22. The similarity of the corrosion potentials of Alloy 22 and Titanium Grade 7 indicates that even if electrical contact were established, it would be of little consequence to the degradation characteristics of the waste package or the drip shield. Analyses (CRWMS M&O 2000a) indicate that crevice corrosion of the waste package outer barrier or the drip shield will not occur under repository-relevant exposure conditions. Galvanic coupling of the drip shield to steel components is discussed in FEP 2.1.03.04.00, Hydride Cracking of Waste Containers and Drip Shields and is determined to have no consequence to the performance of the drip shield. Reference: CRWMS M&O 2000a. *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier.* ANL-EBS-PA-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0327CRWMS M&O 2001h. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.	
28	2.1.03.04.00	WP	Hydride cracking of waste containers	Pasu (S&A) Bennett (ENG)	The waste package temperature never exceeds 186°C (CRWMS M&O 2000b, Section 6.3.1) therefore significant ordering and grain-boundary segregation does not occur and the degree of hydrogen embrittlement is negligible. CRWMS M&O 2000an, Section 4.3 details the effect of fluorides on the degradation behavior of Titanium alloys. Fluoride-enhanced passive dissolution coupled to hydrogen absorption will not occur under the alkaline exposure conditions expected for the drip shield, particularly for Palladium-containing alloys such as Titanium Grade 7. Also, the presence of other anions such as sulfate, bicarbonate, and silicates, also present in the concentrated Yucca Mountain waters, will decrease the aggressiveness of any fluoride ions present. The technical basis for the minimum concentration of hydrogen absorbed in order to observe hydrogen embrittlement or hydrogen induced cracking has been extensively documented in CRWMS M&O 2000an, Section 3.4. Reference: CRWMS M&O 2000b. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001206.0143. CRWMS M&O 2000an. *Review of the Expected Behavior of Alpha Titanium Alloys Under Yucca Mountain Conditions.* TDR-EBS-MD-000015 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010108.0011. CRWMS M&O 2001h. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.	
29	2.1.06.07.00	WP	Effects at Material Interfaces	Pasu (S&A) Bennett (ENG) Mast (S&A)	Any electrochemical coupling of Alloy 22 with 316NG will result in increased corrosion degradation of 316NG and enhanced performance of Alloy 22. The similarity of the corrosion potentials of Alloy 22 and Titanium Grade 7 indicates that even if electrical contact were established, it would be of little consequence to the degradation characteristics of the waste package or the drip shield. Analyses (CRWMS M&O 2000a) indicate that crevice corrosion of the waste package outer barrier or the drip shield will not occur under repository-relevant exposure conditions. Galvanic coupling of the drip shield to steel components is discussed in	

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					Feature, Event and Process 2.1.03.04.00, Hydride Cracking of Waste Containers and Drip Shields and is determined to have no consequence to the performance of the drip shield. Interfaces between the waste package and the pallets are not included because the same material is used for the construction. Reference: CRWMS M&O 2000a. *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier.* ANL-EBS-PA-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0327. CRWMS M&O 2001h. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.	
30	2.1.03.05.00	WP	Microbially mediated corrosion of waste container	Pasu (S&A) Bennett (ENG)	Microbial induced corrosion of Titanium Grade 7 has not been reported in the literature. Hence, the microbial induced corrosion of the drip shield was screened out. Accelerated corrosion of drip shield under the seismic event will be addressed and documented under Container Life and Source Term agreement KCL0208.	KCL0208
31	1.2.03.02.00	WP	Seismic vibration causes container failure	Pasu (S&A) Bennett (Design)	DOE has agreed to (Container Life and Source Term agreement KCL0208) performing prior to License Application, calculations that address the effects of static loads from fallen rock on the drip shield during a seismic event. The calculations will consider both intact and degraded conditions of the drip shield. The results of the calculations will be documented in a future revision of the Analysis/Model Report *Design Analysis for the Ex-Container Components* (CRWMS M&O 2000l). DOE believes the existing agreements identified above for the Container Life and Source Term Key Technical Issue are sufficient to address the technical issue identified in the NRC comment without any new agreement items. Reference: CRWMS M&O 2000l. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0374.	KCL0208
33	NA	WP	NA	Pasu (S&A) Bennett (ENG)	The project has reviewed the results reported in Barkatt and Gorman (2000) and has concluded that the testing conditions used were not relevant to Yucca Mountain Project. However existing Container Life and Source Term agreements (KCL0101, KCL0110, and KCL0601) are intended to evaluate the effects of introduced materials on water chemistry and deleterious trace element concentrations on the corrosion behavior of titanium, similar to the electrochemically based studies on Alloy 22. Consideration will be given to adding a new feature, event and process or augmenting an existing feature, event and process to account for the effects of trace elements on Alloy-22 and Titanium corrosion and stress corrosion. DOE believes the existing Container Life and Source Term agreements identified above are sufficient to address the technical issue identified in the NRC comment without any new agreement items.	KCL0101 KCL0110 KCL0601
34	2.1.03.02.00	WP	Stress corrosion cracking of Waste Containers	Pasu (S&A) Bennett (ENG)	It is agreed that simplified calculations by DOE indicate cracks will take considerable time to fill with corrosion products ([CRWMS M&O 2000ap), however, quantitative bounding analyses have been underway to determine whether calcite and other minerals can precipitate at a sufficiently high rate to plug cracks resulted from stress corrosion cracking. The calculation depends mainly on two parameters: the evaporation at the surface of the waste package or drip shield in particular in the vicinity of cracks and the precipitation rate of minerals (BSC 2001c). The analyses consider calcite and amorphous silica as minerals that potentially precipitate within the stress corrosion cracks. The analyses consider two end-member scenarios for	KCL0208

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					potential water flow characteristics in the cracks: film flow and water bridging across the crack opening (BSC 2001c, Section 5.3.3). The water bridging scenario employs highly conservative assumptions such as no corrosion of the crack wall, no mixing of the bridging water with the outside environment, no water transport along the crack wall, and no consideration of mineral precipitate in the presence of fine particulates of corrosion products along the crack wall. The analysis results show that for the film flow scenario, cracks are plugged by mineral precipitates within a decade (BSC 2001c, Tables 6-3 and 6-5). For the conservative scenario (i.e., water bridging scenario), plugging of stress corrosion cracks takes 600 to 1,000 years if the stress corrosion crack opening occurs prior to 20,000 years (BSC 2001c, Tables 6-4 and 6-6). Considering the conservatism employed in the water bridging scenario, the time to plugging the cracks would be sooner than the bounding estimates. In general the analysis results support the assumption for the stress corrosion crack plugging by precipitates in Total System Performance Assessment-Site Recommendation REV 00 (CRWMS M&O 2000aq). The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of the ability of these loading combinations to initiate and/or propagate preexisting cracks will be documented in a future revision of the Design Analysis for Uncanistered Fuel Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). Reference: CRWMS M&O 2000ap. *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material.* ANL-EBS-MD-000005 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0340.	
35	2.1.03.08.00	WP	Juvenile and early failure of waste containers	Pasu (S&A) Bennett (ENG)	The potential early failure mechanisms discussed in CRWMS M&O 2000d indicates that improper heat treatment of waste packages should be included in the waste package degradation and Total System Performance Assessment analysis. Manufacturing defects in the waste package outer barrier closure welds are also considered as in past analyses. Exclusion of the drip shield failures due to manufacturing flaws is not based on slap down analysis but o the fact that they will be annealed to eliminated fabrication stresses. The slap down analyses pertain to waste package failures and the early failure Analysis/Model Report addresses the probabilities and effects of handling damages. Reference: CRWMS M&O 2000d. *Analysis of Mechanisms for Early Waste Package Failure.* ANL-EBS-MD-000023 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001011.0196.	
36	2.1.09.03.00	WP	Volume increase of corrosion products	Pasu (S&A) Bennett (ENG)	Analyses cited in Degradation of Stainless Steel Structural Material (CRWMS M&O 2000j, Section 6.1), indicate that even under very conservative assumptions, the growth of this corrosion product will not exceed 93 μm after 10,000 years. This oxide layer is not thick enough to produce enough pressure to cause mechanical damage to the Alloy 22 container. Reference: CRWMS M&O 2000j. *Degradation of Stainless Steel Structural Material.* ANL-EBS-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000329.1188.	

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37	2.1.07.05.00	WP	Creeping of metallic materials in the EBS	Pasu (S&A) Bennett (ENG)	Treatment of creep of the drip shield is appropriate for the static loads and temperatures expected. Prior calculations assuming the presence of backfill and rockfall on top of the backfill showed the static loads on the drip shield to be low (<25% of yield strength). However, this calculation will be revised to eliminate the backfill effects. In addition, the potential for creep of Titanium drip shield under the static load will be explicitly addressed in the future revision of the Design Analysis for the Ex-Container Components, (CRWMS M&O 2000l) as part of the Container Life and Source Term agreement KCL0208. Additional loading combinations are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of these loading combinations will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components, (CRWMS M&O 2000l)	KCL0208
38	2.1.11.05.00	WP EBS	Differing thermal expansion of repository components	Mast (S&A) Pasu (S&A) Bennett (ENG)	Tensile stresses due to differential thermal expansion between waste package barriers are eliminated by the introduction of a gap between the barriers. This is done to eliminate tensile stresses due to differential thermal expansion from contributing to stress corrosion cracking of the waste package barriers. With this source of stress eliminated, it does not contribute to calculated dose rates due to waste package failure. Thermal expansion calculations already performed and in the process of documentation have indicated a need to increase the gap between the outer barrier lid and the inner barrier lid from the current 3-mm to 6-mm in the next revision to the waste package design concepts. These modifications are underway and will be included in next revisions to the Design Analysis for the UCF Waste Packages (CRWMS M&O 2000n), Design Analysis for the Defense High Level Waste Disposal Containers (CRWMS M&O 2000k), and Design Analysis for the Naval SNF Waste Package (CRWMS M&O 2000m). A more comprehensive listing of interfaces where differing thermal expansion may be of relevance in the Engineered Barrier System will be developed. For each such location, the amount of differential expansion will be estimated relative to the potential impact of such expansion on Engineered Barrier System component performance. This will provide a quantified basis for the Exclude – Low Consequence screening.	
38	2.1.11.05.00	WP EBS WFMisc	Differing Thermal Expansion of Repository Components	Pasu (S&A) Bennett (ENG) Mast (S&A)	See above response	
39	2.1.06.06.00	WP	Effects and degradation of drip shield	Pasu (S&A) Bennett (ENG)	In the current revision of the FEPs Screening of Process and Issues in Drip Shield and Waste Package Degradation (CRWMS M&O 2001h), oxygen embrittlement of titanium results from diffusion of interstitial oxygen into the metal at higher temperatures (>340°C) (ASM International 1987, p. 681). The time to failure depends on the alloy composition, material thickness, and stress state. For the thermal hydrologic time history files used in the Total System Performance Assessment analyses, the waste package surface temperatures never exceed 186°C (CRWMS M&O 2000b, Section 6.3.1), which is less than the threshold temperature of 340°C. Therefore, oxygen embrittlement of the titanium drip shields is excluded on the basis of low consequence to the expected annual dose. Reference ASM International 1987. *Corrosion.* Volume 13 of *Metals Handbook.* 9th Edition. Metals Park, Ohio: ASM International. TIC: 209807. CRWMS M&O 2000b. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001206.0143.	

DOE Discussion Topics for May 15-17, 2001 Features, Events and Processes Technical Exchange

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39	2.1.06.06.00	WP DE	Effects and degradation of drip shield	Pasu (S&A) Bennett (ENG) McGregor (PA)	The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in response to Container Life and Source Term agreements KCL0208 and KCL0209. Evaluations of the ability of these loading combinations to initiate and/or propagate preexisting cracks will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l).	KCL0208 KCL0209
78	1.2.03.02.00	WP DE	Seismic vibration causes container failure	Pasu (S&A) Bennett (Design) McGregor (PA)	The screening argument is based on 1) The design criteria to address preclosure seismic events (it is assumed that these criteria will be met) and 2) The net effect of damage to the waste package (i.e. stated in terms of equivalent drop height) that would occur from median 10^{-8} accelerations of 3.2 g, is met by the preclosure drop height requirement for the initial conditions of the waste package. As NRC has noted, multiple combinations and degradation of material properties have not yet been considered. Pending the results of additional analysis to address agreements from the Container Life and Source Term, Repository Design and Thermal Mechanical Effects and Structural Deformation and Seismicity Key Technical Issue technical exchanges, the screening decision is subject to review. DOE will document its approach to post-closure seismic issues in response to Structural Deformation and Seismicity agreements KSD0102 and KSD0203. With regard to specific issues raised: Additional loading combinations are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of these loading combinations will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of the ability of these loading combinations to initiate and/or propagate preexisting cracks will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). DOE believes that only tensile stresses contribute to the initiation and propagation of the stress corrosion cracks. A purely elastic response of the drip shield, pallet, and/or waste package under the aforementioned loading conditions is not a design requirement. Therefore, there has been no attempt to demonstrate that these components respond in an elastic manner. Plastic deformation is reported when the evaluations indicate such. The potential for stress corrosion cracking will be addressed. The drip shield, in new condition, has been shown to withstand the impact of a 6-metric ton rock block without rupture. Additional loading conditions are being evaluated in response to Container Life and Source Term agreements including point load rockfall (KCL0202), potential embrittlement of the drip shield (KCL0208), wall thinning due to corrosion (KCL0208), and multiple rock blocks (KCL0208). These evaluations will be documented in a future revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l).	KSD0102 KSD0203 KCL0208 KCL0202

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32	2.1.13.01.00	WFMisc WP	Radiolysis	Schenker (S&A) Pasu (S&A)	Container Life and Source Term agreement KCL0302 states in part, "...(DOE) will address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rate of components." And Container Life and Source Term agreement KCL0303 states in part, "(DOE to) provide a more detailed calculation on the in package chemistry effects of radiolysis...." DOE believes that the Analysis/Model Report, In-Package Chemistry for Waste Forms (BSC 2001b) provided information on the effect on in-package chemistry of nitric acid produced by radiolysis, consistent with the Container Life and Source Term agreements KCL0302 and KCL0303. The Miscellaneous Waste Form Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001i) will be revised, to support any potential License Application, to reflect this new information.	KCL0302 KCL0303
41	2.1.02.20.00	WFClad	Pressurization from Helium production causes cladding failure	Siegmann (S&A) Stockman (S&A)	At 100,000 years, the pressure, stresses, and stress intensities are a factor of 2.38 higher than at 100 years (values reported in the Clad Degradation – Summary and Abstraction Analysis/Model Report, CRWMS M&O 2001a). These values are still less than the threshold stress intensity values for stress corrosion cracking from Chlorine, Iodine, and Bromine at room temperature. Hence, the conclusions in the original Analysis/Model Report remain unchanged; stress corrosion cracking is not expected even with alpha decay, the main source of Helium production and pressure buildup, for 100,000 years. The role of helium buildup in cladding degradation will be included in the next revision of the Clad Degradation Summary and Abstraction Analysis/Model Report (CRWMS M&O 2001a).	
44	2.1.02.16.00	WFClad	Localized Corrosion (pitting) of cladding	Siegmann (S&A) Stockman (S&A)	The localized corrosion model will be modified to include pitting by chlorides. This model will be used in future cladding abstractions for Total System Performance Assessment-License Application. Probability distributions for pH will also be included in the analysis. This comment is addressed in agreements KCL0306 and KCL0307. Container Life and Source Term agreement KCL0306 states in part, "(DOE) to provide additional technical basis for the (cladding) failure rate and how the rate is affected by localized corrosion." And Container Life and Source Term agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 (CRWMS M&O 2001a) and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 (CRWMS M&O 2000h) will also be revised, incorporating the results from agreement KCL0307 to support any potential License Application, to reflect this new information.	KCL0306 KCL0307
46	2.1.02.24.00	WFClad	Mechanical failure of cladding	Siegmann (S&A) Stockman (S&A)	The technical bases of the seismic analysis is presented in CAL-EDS-MD-000001 REV 00 (CRWMS M&O 2000ao). Since that work was performed, a sensitivity study was performed and will be presented in the upcoming Supplemental Science and Performance Analysis, Volumes 1 and 2 (DOE 2001, in progress, see note last page). In this new work, a more detailed seismic hazard distribution is used and shown to reduce the dose by 15%. This sensitivity study shows that seismic hazard is not a significant contributor to risk and hence, a more detailed analysis is not needed. In addition to the seismic sensitivity study, cladding failure from a rock overburden was added to the Supplemental Science and Performance Analysis, Volumes 1 and 2. This model addresses the failure of cladding as the Waste Package deteriorates and no longer protects the fuel from the fallen rocks. The robustness or the cladding to extreme accelerations has also been addressed in many transportation studies. E. L. Wilmot (1981, Table VII) recommends the use of 71g accelerations for the failure threshold for fuel rods experiencing side impacts. An experimental threshold of 122 g for spent fuel is referenced. Also noted is that in drop tests, rods were bent with end impacts of 38 g but did not fail. Wilmot references experimental thresholds for end impacts of 234 g. Fischer et al. (1987, Figure 8-3) suggested that 10% of the rods might fail with a 40 g end impact and 100% might fail with a 100 g end impact. Witte et al. (1989, Table 3) report that	

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					the acceleration needed to fail rods from side impact varies from 63 g to 211 g, depending on the fuel design. Sanders et al. (1992, Attachment III) presents detailed structural analysis of various assemblies under impacts and gives (Table III-10) the probability of rod failure from 9 meter drops of transportation casks. All these references show the robustness of spent fuel rods to failure from impacts. Because these references support current analysis, no further analysis is planned. These references and new analysis presented in Supplemental Science and Performance Analysis (see note last page) will be included in the next revision of the Clad Degradation Features, Events and Processes Analysis/Model Report (CRWMS M&O 2000h). References for Response: Fischer, L.E.; Chou, C.K.; Gerhard, M.A.; Kimura, C.Y.; Martin, R.W.; Mensing, R.W.; Mount, M.E.; and Witte, M.C. 1987. *Shipping Container Response to Severe Highway and Railway Accident Conditions.* NUREG/CR-4829. Volume 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: NNA.19900827.0230. Sanders, T.L.; Seager, K.D.; Rashid, Y.R.; Barrett, P.R.; Malinauskas, A.P.; Einziger, R.E.; Jordan, H.; Duffey, T.A.; Sutherland, S.H.; and Reardon, P.C. 1992. *A Method for Determining the Spent-Fuel Contribution to Transport Cask Containment Requirements.* SAND90-2406. Albuquerque, New Mexico: Sandia National Laboratories. TIC: 232162.Wilmot, E.L. 1981. *Transportation Accident Scenarios for Commercial Spent Fuel.* SAND80-2124. Albuquerque, New Mexico: Sandia National Laboratories. ACC: HQO.19871023.0215. Witte, M.C.; Chun, R.C.; and Schwartz, M.W. 1989. "Dynamic Impact Effects on Spent Fuel Assemblies." *9th International Symposium on the Packaging and Transportation of Radioactive Materials, Washington, D.C., June 11-16, 1989. 1,* 186-194. Oak Ridge, Tennessee: Oak Ridge National Laboratory. TIC: 240741.	
47	2.1.02.17.00	WFClad	Localized corrosion (crevice corrosion) of cladding	Siegmann (S&A) Stockman (S&A)	DOE will continue to review new crevice corrosion literature as part of the execution of Container Life and Source Term agreement KCL0307. Agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 will be revised, incorporating information from agreement KCL0307, including a summary of any significant new crevice corrosion literature, in time to support any potential License Application	KCL0307
48	2.1.01.04.00	WFMisc WP	Spatial heterogeneity of emplaced waste	Pasu (S&A)	Spatial heterogeneity of the waste is addresses below. Spatial variability that may affect degradation of the waste package will be addressed as part of the resolution of the Container Life and Source Term agreement KCL0101. The scope of the agreement includes the evaluation of the range of chemical environments on the waste package.	KCL0101
48	2.1.01.04.00	WFMisc	Spatial heterogeneity of emplaced waste	Schenker (S&A) Stockman (S&A)	The Near Field agreement KEN0303 states in part, "The DOE will provide analysis justifying the use of bulk chemistry as opposed to local chemistry for solubility and waste form degradation models..." and Container Life and Source Term agreement KCL0307 states in part, "...the technical basis for the models used for localized corrosion and stress corrosion cracking (of cladding) will be expanded in future revisions..." The information obtained from these agreements will respond to this comment in full. The Miscellaneous Waste Form Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001i) and In-Package Chemistry for Waste Forms Analysis/Model Report (BSC 2001b) will be revised incorporating the appropriate new information.	KCL0307

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49	2.1.02.15.00	WFClad	Acid corrosion of cladding from radiolysis	Siegmann (S&A) Stockman (S&A)	Radiolysis by itself is not expected to damage the cladding. Radiolysis as a possible cause of pH reduction and coupled with $FeCl_3$ pitting is a possible mechanism for cladding failure. A new cladding localized corrosion model addressing radiolysis and low pH (pH < 2) will be developed in time to support any potential License Application. This comment is addressed in Container Life and Source Term agreement KCL0307. Agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 (CRWMS M&O 2001a) and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 (CRWMS M&O 2000h) will be revised, incorporating information from agreement KCL0307, in time to support any potential License Application.	KCL0307
50	2.1.02.13.00	WFClad	General Corrosion of Cladding	Siegmann (S&A) Stockman (S&A)	The distributions of fuel characteristics developed in the Analysis/Model Report: Initial Cladding Condition (CRWMS M&O 2000ah) addresses fuel burnup to 75 MWd/kgU and oxide thickness to 120 μm, 20 μm above the NRC allowable limit of 100 μm. The distribution developed has 10.1% of the rods exceeding the NRC limit and 2.55% at 120 μm. These projections adequately address the general corrosion of the higher burnup fuels. In all calculations involving stress, the oxide thickness is subtracted off of the wall thickness (no structural credit for oxides). The Clad Degradation Features, Events and Processes Analysis/Model Report (CRWMS M&O 2000h) will be revised to reflect this information.	
51	2.1.02.14.00	WFClad	Microbially induced corrosion of cladding	Siegmann (S&A) Stockman (S&A)	The impact of microbial induced corrosion on the cladding environment and corrosion will be re-evaluated and documented during the execution of the Container Life and Source Term agreement KCL0307. Agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 (CRWMS M&O 2001a) and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 (CRWMS M&O 2000h) will be revised, incorporating information from agreement KCL0307, in time to support any potential License Application.	KCL0307
52	1.2.04.04.00	WFMisc	Magma Interacts w/ Waste	Schenker (S&A) Stockman (S&A)	FEP 1.2.04.04.00 (Magma Interacts with Waste) includes in the WFMisc screening argument a citation of a 1996 document to indicate the igneous activity is not a significant contributor to risk. Igneous activity has been screened in for Total System Performance Assessment. The mean annual igneous hazard described in the Probabilistic Volcanic Hazard Analysis was nominally 1.5×10^{-8}. The revised probability for the repository and the contingency blocks was about 1.6×10^{-8}. DOE acknowledges that igneous activity is a contributor to postclosure risk, however, the risk in terms of dose (mrem/yr) is almost 3 orders of magnitude below the proposed standard. The Probabilistic Volcanic Hazard Analysis did not include the estimation of the consequences of igneous activity. Calculations by DOE indicate that the maximum annual dose during the 10,000 year performance period of about 0.03 mrem. The average annual peak dose during the first 100,000 years following closure is 0.2 mrem, which occurs at about 30,000 years after closure. Even if the NRC's preferred probability value of 10^{-7}/year is chosen as the basis for a dose calculation, the maximum annual dose during the 10,000 year performance period increases to about 0.16 mrem, and the average annual peak dose increases to about 3 mrem at about 22,000 years. Increasing the mean annual probability from about 1.6×10^{-8} to 10^{-7} results in an increase in dose during the performance period from about 0.03 mrem to about 0.16 mrem or about half an order of magnitude. Similarly, the average annual peak dose increases from about 0.2 mrem to about 3 mrem--an increase of about one and a half order of magnitude. Hence, there is no basis for the statement that the consequences of volcanism have increased by many orders of magnitude in the last 5 years. DOE has not tried to screen igneous activity probability or consequences; both subissues are	

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					included in the Total System Performance Assessment analyses. Hence, no screening argument was made. Furthermore, the Probabilistic Volcanic Hazard Analysis is not out-of-date. The document remains the basis for the probability analyses documented in the Analysis/Model Report, Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (CRWMS M&O 2000ay) and the Disruptive Events PMR (CRWMS M&O 2000s). The Miscellaneous Waste Form Features, Events and Processes Analysis/Model Report (ANL-WIS-MD-000009) (CRWMS M&O 2001l) will be revised, to support any potential License Application, incorporating the appropriate new information developed relative to assessing igneous activity as a significant contributor to risk.	
53	2.1.02.22.00	WFClad	Hydride embrittlement of cladding	Siegmann (S&A) Stockman (S&A)	This response is applicable to Features, Events and Processes 2.1.02.22.00 through 2.1.02.22.07. The next revision to the Clad Degradation Features, Events and Processes Analysis/Model Report (ANL-WIS-MD-000008 will update the discussion of each component of hydride embrittlement in the 8 Features, Events and Processes (2.1.02.22.00 through 2.1.02.22.07) with emphasis on providing better organized, more quantitative discussion and the combined effects of both stress and temperature. .2.1.02.22.07 will be changed from exclude to include based on recent experimental evidence.	
53	2.1.02.22.01	WFClad	Hydride embrittlement from zirconium corrosion (of cladding)	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	
53	2.1.02.22.02	WFClad	Hydride embrittlement from WP corrosion and hydrogen absorption (of cladding)	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	
53	2.1.02.22.03	WFClad	Hydride embrittlement from galvanic corrosion of WP contacting cladding	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	
53	2.1.02.22.04	WFClad	Delayed hydride cracking (of cladding)	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	
53	2.1.02.22.05	WFClad	Hydride reorientation (of cladding)	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	
53	2.1.02.22.06	WFClad	Hydride axial migration (of cladding)	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	
53	2.1.02.22.07	WFClad	Hydride embrittlement from fuel reaction (causes failure	Siegmann (S&A) Stockman (S&A)	See response to Features, Events and Processes 2.1.02.22.00	

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			if cladding)			
54	2.1.09.02.00	EBS	Interaction w/ Corrosion products	Mast (S&A)	An estimate of potential heterogeneity in seepage water chemistry due to localized interactions with Engineered Barrier System components and their corrosion products in addition to the potential for such seepage interacting with Engineered Barrier System components and accelerating Engineered Barrier System degradation processes will be addressed as part of agreement KEN0206. An evaluation of the impact of the range of local chemistry (e.g., dripping of equilibrated evaporated cement leachate and corrosion products) conditions at the drip shield and waste package considering the chemical divide phenomena that may propagate small uncertainties into large effects. The DOE will evaluate the range of local chemical conditions at the drip shield and waste package (e.g. local variations in water composition associated with cement leaching or the presence of corrosion products), considering potential evaporative concentration and the chemical divide effect whereby small differences in initial composition could cause large differences in brine characteristics.	KEN0206
55	2.1.09.07.00	EBS	Reaction Kinetics in Waste and EBS	Mast (S&A)	In the Near Field agreement KEN0211, the DOE will provide additional technical basis for the treatment of precipitation-dissolution kinetics by the in-drift geochemical models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model Analysis/Model Report (CRWMS M&O 2000w). The technical basis will include reaction progress simulation for laboratory evaporative concentration tests, and will include appropriate treatment of time as related to the residence times associated with the abstractions used to represent in-drift processes in Total System Performance Assessment. In addition, agreement KEN0208 indicates that DOE will provide additional technical basis for the suppression of individual minerals predicted by equilibrium models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model Analysis/Model Report (CRWMS M&O 2000w)	KEN0211 KEN0208
55	2.1.09.07.00	EBS WFMisc	Reaction Kinetics in Waste and EBS	Mast (S&A)	See above response.	
56	2.1.07.06.00	EBS	Floor buckling	Mast (S&A) Duan (ENG)	The information on the buckling or heave of the floor of an emplacement drift can be inferred from computer output files generated for ground control analyses, such as Ground Control for Emplacement Drifts for Site Recommendation (CRWMS M&O 2000ae). The topic was not addressed in ground control analyses in an explicit manner because it has no direct implications on ground control. An ICN is currently being issued to Ground Control for Emplacement Drifts for Site Recommendation, and the preliminary results using latest thermal properties indicate that the maximum differential movement of the invert area is well within 10 mm. The Repository Design and Thermal Mechanical Effects agreement on floor heave, KRD0309: "DOE will provide appropriate analysis that shows rock movements in the floor of the emplacement drift are within the range acceptable for preclosure operations. The analysis results will be provided in a revision to the Ground Control for Emplacement Drifts for Site Recommendation (CRWMS M&O 2000ae) (or other document) supporting any potential license application," will be addressed in detail in additional ground control analyses necessary for Key Technical Issue resolution.	KRD0309
57	1.1.02.03.00	EBS	Undesirable materials left	Mast (S&A)	An inherent assumption in the licensing and construction process, as stated in the features, events and processes (FEPs) Analysis/Model Report, is that the repository will be built as designed, and that the quality control requirements will be adhered to, monitored, and enforced per the NRC's regulations. A review of the current repository design will be conducted to provide estimates of the quantities of "undesirable materials" (organics, cementitious materials, etc.) to be used in the current design pre-closure phase relative to the limits discussed in the referenced document. This review will also consider the assessment of trace material impact on Engineered Barrier System groundwater chemistry (both within the drift as well as the plume leaving the drift) being conducted as part of the Engineered Barrier System Thermo-hydrologic	

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					chemical modeling. Operational process controls, such as, (1) providing procedural assurance that future operational actions will be done according to a plan, and (2) including in FEPs analysis a reasonable estimate of the uncertainty associated with our ability to implement the plan exactly, is sufficient to account for the potential of undesirable conditions.	
58	Various	EBS	NA		The use of the term "Preliminary" is intended to denote that the screening argument was ongoing analyses. Once these analyses are completed, the screening arguments will be strengthened and the Features, Events, and Processes Analysis/Model Report revised to remove "preliminary." The schedule for ongoing activities are integrated into the overall project schedule and prioritized based on project milestones and budget. A final list of Features, Events, and Processes will be completed by License Application. The resolution of preliminary screening arguments required to support a potential license application will be considered in the scope of work during the associated planning activities. Recommend preliminary screening arguments be discussed on a case-by-case basis during the applicable the Features, Events, and Processes Analysis/Model Report discussions.	
59	2.1.08.04.00	EBS	Cold traps	Mast (S&A)	Thermal Effects on Flow agreement KTE0205 states that technical support for the inclusion or exclusion of the cold trap effect in the various scale models will be documented in the Multi-scale Thermal Hydrological Model. The analysis will consider repository edge effects and in-drift geochemical environment abstraction. The magnitude of such enhancement relative to the seepage flux will be considered relative to its impact on drip shield and waste package failure and on waste form dissolution and radionuclide transport. This will provide a quantified basis for the Exclude – Low Consequence screening.	KTB0205
60	2.1.12.01.00	EBS	Gas generation	Mast (S&A)	Engineered Barrier System will estimate the potential heterogeneity in local gas composition within the drift, due to gas generation from corrosion, microbial action, and concrete degradation. Based on such bounding estimates of compositional heterogeneity, the impact on local chemistry and key reaction rates will also be estimated.	
61	2.2.10.12.00	NFE UZ	Geosphere dry-out due to waste heat	Itamura (S&A) Houseworth (S&A)	DOE will cite the suggested reference for this question and include this feature, event and process in the next revision of the Features, Events, and Processes in Unsaturated Zone Flow and Transport Analysis/Model Report (ANL-NBS-MD-000001, BSC 2001d)	
62	2.2.01.02.00	NFE	Thermal and other waste and EBS-related changes in the adjacent host rock	Itamura (S&A)	See response to Feature, Event and Process 2.2.01.01.00	
62	2.2.01.02.00	NFE	Thermal and other waste and EBS-related changes in the adjacent host rock	Itamura (S&A) Kicker (ENG) Duan (ENG)	The current Total System Performance Assessment increases the quantity of seepage that enters an intact drift by 50% to account for the degradation of the drift. This value was based on a sensitivity study performed in the seepage model. Although the drift is not expected to degrade everywhere, this 50% increase in seepage flow is used at all locations. In addition, the subject matter introduced by this question is the basis for two Repository Design and Thermal Mechanical Effects agreements between DOE and NRC (KRD0311 and KRD0319). In the Repository Design and Thermal Mechanical Effects agreement KRD0311, the DOE will	KRD0311 KRD0319

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					justify the preclosure ground support system design (including the effects of long term degradation of rock mass and joint strength properties) in a revision to the Ground Control for Emplacement Drifts for Site-Recommendation (CRWMS M&O 2000ae) (or other document) supporting any potential license application. In the Repository Design and Thermal Mechanical Effects agreement KRD0319, the DOE states its belief that the Drift Degradation Analysis is consistent with current understanding of the Yucca Mountain site and the level of detail of the design to date. As understanding of the site and the design evolve, DOE will: (1) provide revised Discrete Region Key-Block Analysis (DRKBA) analyses using appropriate range of strength properties for rock joints from a design parameters analysis report (or other document), accounting for their long-term degradation; (2) provide an analysis of block sizes based on the full distribution of joint trace length data from the Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon(CRWMS M&O 2000ad), supplemented by available small joint trace length data; (3) verify the results of the revised DRKBA analyses using: (a) appropriate boundary conditions for thermal and seismic loading; (b) critical fracture patterns from the DRKBA Monte Carlo simulations (at least two patterns for each rock unit); (c) thermal and mechanical properties for rock blocks and joints from a design parameters analysis report (or other document); (d) long-term degradation of joint strength parameters; and (e) site-specific ground motion time histories appropriate for post-closure period. This will be documented in a revision to the Drift Degradation Analysis (CRWMS M&O 2000t). Based on the results of the analyses above and subsequent drip shield calculation revisions, DOE will reconsider the screening decision for inclusion or exclusion of rockfall in performance assessment analysis. Any changes to screening decisions will be documented in analyses prior to any potential License Application.	
63	2.1.09.12.00	NFE	Rind (altered zone) formation in waste, EBS and adjacent rock	Itamura (S&A)	This technical issue introduced by this comment is the subject of an existing near field agreement KEN0103. KEN0103 commits to gathering information on the quantity of unreacted solute mass that is trapped in dry-out zone in TOUGHREACT simulations, as well as how this would affect precipitation and the resulting change in hydrologic properties. The DOE provided to NRC documentation of model validation, consistent with the DOE quality assurance requirements, in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Analysis/Model Report (CRWMS M&O 2001c) in March 2001. In accordance with agreement KEN0103, DOE will provide information on the quantity of unreacted solute mass that is trapped in the dryout zone in TOUGHREACT simulations in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Models Analysis/Model Report Rev 02. This information will be used to provide the basis for inclusion or exclusion of the subject scenario.	KEN0103
64	2.2.10.06.00	NFE	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/dissolution	Itamura (S&A)	This Feature, Event and Process is conservatively ignored with respect to solubility reduction in the far-field, since Total System Performance Assessment assumes that all radionuclides remain soluble and do not precipitate. The effects of colloid formation are accounted for in the colloid source term and are included in the Performance Assessment model. Colloids are expected to be formed from the degradation of the High Level Waste and Spent Nuclear Fuel waste forms, Engineered Barrier System materials and rock. Radionuclides associated with colloids are assumed to be either irreversibly or reversibly attached to colloids (Refer to Particle Tracking Model and Abstraction of Transport Processes [CRWMS M&O 2000al], Section 6, and Unsaturated Zone Colloid Transport Model (CRWMS M&O 2000at), Section 6). The near-field thermal-chemical analysis indicates only small changes in hydrologic properties and mineralogy as a result of these coupled processes (Drift-Scale Coupled Processes [Drift-Scale Test and Thermal-hydrological-chemical Seepage] Models, [CRWMS M&O 2000u],Section 6). Therefore, far-field changes are likewise expected to be small (Assumption 11), including mineral precipitation/dissolution and alteration of minerals such as zeolites and clays. Therefore, this Feature, Event and Process is excluded from Total System Performance Assessment on the basis of low consequence. Additionally, this technical issue introduced by this comment is the	KEN0103

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					subject of an existing Near Field agreement (KEN0103). KEN0103 commits to gathering information on the quantity of unreacted solute mass that is trapped in dry-out zone in TOUGHREACT simulations, as well as how this would affect precipitation and the resulting change in hydrologic properties. The DOE provided to NRC documentation of model validation, consistent with the DOE Quality Assurance requirements, in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Analysis/Model Report (CRWMS M&O 2001c) in March 2001. In accordance with agreement KEN0103, DOE will provide information on the quantity of unreacted solute mass that is trapped in the dryout zone in TOUGHREACT simulations in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Analysis/Model Report Rev 02. This information will be used to provide the basis for inclusion or exclusion of the subject scenario.	
65	2.1.11.02.00	NFE	Nonuniform heat distribution/edge effects in repository	Itamura (S&A)	Repository wide non-uniform heating effects are the subject of Thermal Effects on Flow agreement KTE0205 this work will represent the cold-trap effect in the appropriate models or provide the technical basis for exclusion of it in the various scale models.	KTE0205
66	2.2.06.01.00	NFE	Changes in stress due to thermal, seismic or tectonic effects	Itamura (S&A)	See response to Feature, Event and Process 2.2.01.01.00	
66	2.2.06.01.00	NFE DE	Changes in stress due to thermal, seismic or tectonic effects	McGregor (PA) Blair (S&A) Houseworth (S&A)	Thermal-mechanical effects may result in changes in fracture apertures in support pillars between drifts. If the horizontal fractures open up more than the vertical fractures, it may be possible that flow could divert towards the drifts. DOE is presently performing process-model simulations using both continuum and discrete fracture models to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts. Furthermore, DOE is performing thermal-hydrological/ thermal-hydrological-chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. Based on the results, DOE will revisit the Feature, Event and Process screening arguments. Interim results are reported in the Supplemental Science and Performance Analysis (see note last page).	
67	2.2.10.05.00	NFE	Thermo-mechanical alteration of rocks above and below the repository	Itamura (S&A)	See response to Feature, Event and Process 2.2.01.01.00	
68	1.2.02.01.00	NFE	Fractures	Itamura (S&A) Blair (S&A) Houseworth (S&A)	Thermal-mechanical effects may result in changes in fracture apertures in support pillars between drifts. If the horizontal fractures open up more than the vertical fractures, it may be possible that flow could divert towards the drifts. DOE is presently performing process-model simulations using both continuum and discrete fracture models to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts. Furthermore, DOE is performing thermal-hydrological/ thermal-hydrological -chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. Based on the results, DOE will revisit the Feature, Event and Process screening arguments. Interim results are reported in the Supplemental Science and Performance Analysis (see note last page).	

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69	2.2.01.01.00	NFE	Excavation and construction-related changes in the adjacent host rock	Itamura (S&A) Blair (S&A) Houseworth (S&A)	Thermal-mechanical effects may result in changes in fracture apertures in support pillars between drifts. If the horizontal fractures open up more than the vertical fractures, it may be possible that flow could divert towards the drifts. DOE is presently performing process-model simulations using both continuum and discrete fracture models to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts. Furthermore, DOE is performing thermal-hydrological/ thermal-hydrological-chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. Based on the results, DOE will revisit the Feature, Event and Process screening arguments. Interim results are reported in the Supplemental Science and Performance Analysis (see note last page).	
70	2.2.10.04.00	NFE	Thermo-mechanical alteration of fractures near repository	Itamura (S&A)	See response to Feature, Event and Process 2.2.01.01.00	
70	2.2.10.04.00	NFE	Thermo-Mechanical alteration of fractures near repository	Itamura (S&A)	See response to Feature, Event and Process 2.2.01.01.00	
71	1.1.07.00.00	SYS	Repository design	McGregor (PA)	The design will include access tunnels and shafts appropriate to the repository design basis. This will include as appropriate the effects of the tunnels and shafts, the range of the properties of materials that are likely to be encountered. These will have been the subject of extensive study and quantification of uncertainty. In this sense, access and tunnel and shafts, have been included as an element of the primary features, events and processes. The secondary features, events and processes (FEPs) were compiled from various sources including Waste Isolation Pilot Project, SKI/SKB, and NAGRA. The particular secondary FEP listed is from NAGRA as noted by designator in the description. The description includes the qualifier "higher-permeability rock zones in the crystalline basement". The FEP was excluded on regulatory grounds due to the "crystalline basement" descriptor. Because the access tunnels and shafts and the factors affecting the flow conditions are part of the design and have been included in the Total System Performance Assessment, the need to include this particular secondary FEP is unclear.	
72	1.1.08.00.00	SYS	Quality control	McGregor (PA)	An inherent assumption in the licensing and construction process, as stated in the features, events and processes (FEPs) Analysis/Model Report, is that the repository will be built as designed, and that the quality control requirements will be adhered to, monitored, and enforced per the NRC's regulations. Additionally, uncertainty and sensitivity analyses are being performed to identify critical systems and quantify the effect of uncertainty in the behavior of components through time. Operational process controls, such as, (1) providing procedural assurance that future operational actions will be done according to a plan, and (2) including in FEPs analysis a reasonable estimate of the uncertainty associated with our ability to implement the plan exactly, is sufficient to account for potential defects and failures.	
73	2.3.13.03.00	SYS Bio	Effects of repository heat on biosphere	McGregor (PA)	The issues to be addressed are 1) Does the repository heat cause a change in vegetation leading to changes in infiltration 2) What is the magnitude/nature of the change in vegetation, and 3) Do existing infiltration models cover this change. For Item 1) Yes, a change in temperature due to repository heat has the potential to change the vegetative state from brush to grasses, with a subsequent change in infiltration rates. Item 2) The amount of change is unquantified. However, evapotranspiration from brush may account for as little as 2 to as much as 50 percent of the evapotranspiration losses, and 1 degree	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					change in soil temps may cause a shift (decrease) for as much as a one percent change in brush concentrations. So assuming elimination of brush entirely would suggest a maximum possible increase in infiltration of 50 percent over the present conditions (if all factors are considered, it is likely much less of an increase). As stated in the Features, Events and Processes Analysis/Model Report, the average infiltration at present is estimated to be between 4.5 and 6.5 mm/yr, a 50 percent increase would suggest an average ranging from about 6 to 9 mm/yr. Item 3). The existing models already examine the effects of infiltration rates occurring at several times the resulting infiltration rates. With regard to the first point, regardless of the effect of vegetative effects in future climates, the net infiltration for future climate states is still significantly increased compared to either the current state, or the current state plus repository-induced (e.g. based on the glacial transition uncertainty model, the mean is about 22.5 mm/yr with a standard deviation of 19.5). Hence, the effects due strictly to repository-induced heat would be similar to some type of minimal increase (the low case of the uncertainty analysis) of the glacial transition climate, and fall within the bounds of that analysis - they are therefore insignificant to the expected annual dose. The net infiltration increase is BOUNDED by the existing analysis - not INCLUDED as suggested by the reviewer. On the second point, the uncertainty analysis was made purely for the purposes for evaluating the uncertainty for a given climatic scenario - glacial transitional and the distribution and weighting of possible ranges. There is no requirement that the analysis incorporate the repository heat effect on the net infiltration rate. The potential effect or repository heat is only potentially significant with regard to the present climate and the resultant change in net infiltration. The net infiltration due to a change climate state, and its potential effect, is significantly greater (order of magnitude) than that caused by repository-induced heat. The effects of repository-induced changes would be negated by the climatic change - again suggesting that repository-induced vegetative change are of low consequence to expected annual dose and are bounded by the present analysis using climate changes.	
74	Various	SYS	Critically in waste and EBS	Rechard (S&A) Thomas (ENG)	DOE's process for evaluating criticality is stated in the *Disposal Criticality Analysis Methodology Topical Report*, (YMP 2000). The process includes calculating the probability and consequences of potential criticality events, based on mechanisms at the site, and evaluating them using the Total System Performance Assessment processes, including Features, Events and Processes (FEPs) screenings. DOE will finish the criticality calculations following an igneous event or develop an argument as to why the consequences to the source from such an igneous event can be ignored. Furthermore, DOE will re-evaluate the criticality FEPs, should the reevaluation (as agreed to in the Container Life and Source Term agreement K0106) of the waste package FEPs, related to seismicity and rock fall, show that waste packages will fail prior to 10,000 years. Specifically, agreement KCR0106 indicates that DOE will perform a "what if" (non-risk-informed) evaluation that determines the consequences of criticality for a non-mechanistic, waste package failure during the 10,000 year regulatory period. The results of this evaluation are not part of the normal Total System Performance Assessment process, and thus will not be included as part of the FEPs process. The results will be used as a sensitivity evaluation. The probability of 2.7 x 10^{-11} is per waste package. The probability of a waste package failure in the first 10,000 years with ~11,000 packages is 3.2 x 10^{-7}. The probability results for stress corrosion cracking based failure shown in Probability of Criticality before 10,000 Years (CRWMS 2000am, Section 6.1.1, page 19) are based on the information from Analysis of Mechanisms for Early Waste Package Failure (CRWMS 2000d, page 43) with inputs from Abstraction of Models of Stress Corrosion Cracking of Drip Shield and Waste Package Outer Barrier and Hydrogen Induced Corrosion of Drip Shield (CRWMS 2000aaa, page 28).	KCR0106 KCL0201 KCL0202 KCL0208 KCL0301 KRD0317 KRD0319

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					DOE will examine the apparent discrepancy of waste package failure at 10,000 years in the Total System Performance Assessment at the 95th percentile with the calculational mean probability of 3.2 x 10^{-7} and if necessary, supercede this waste package failure probability The criticality FEPs screening is based on the current inputs for waste package failure. When the inputs are revised to address additional concerns (e.g., dead loads, indirect effects of rock block impacts, tilting of breached waste packages) then the criticality FEPs screening will be reassessed. The NRC concerns will be addressed when the seismic vibration Feature, Event and Process is modified (Container Life and Source Term agreement KCL0114). In addition, DOE will evaluate the rockfall effect and dead weight effects on the waste package. Other pertinent rockfall agreements are KCL0201, KCL0202, KCL0208, KCL0301, KRD0317, and KRD03019. The criticality FEPs screening is based on the current inputs for waste form degradation. When the inputs are revised to address additional concerns, then the criticality FEPs screening will be reassessed. With respect to cladding degradation, DOE notes that within zone 2 all of the cladding is perforated and all the drip shields are removed, thus cladding damage is already accounted for. In addition, DOE may argue that the combination of criticality and igneous intrusion on the source-term can be neglected based on low consequence in a future revision of this Feature, Event and Process. The effect of temperature with respect to damage to Zone 2 waste packages was addressed in the Analysis/Model Report Dike Propagation Near Drifts; (CRWMS &O 2000o). Reference to this Analysis/Model Report will be made in the future. As explained in § 3.10.2.3.2 of the Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq), the failure size of the lid weld varies between 1 cm^2 and 1 x 10^4 cm^2 (cross section of a lid) with a mean of 10 cm^2. This failure is applied to all containers in zone 2. DOE notes that in zone 2 the shields have been removed and so a direct path to the waste package is possible. Furthermore, in Total System Performance Assessment-Viability Assessment (DOE 1998), the effect of dikes on fluid flow in the saturated zone was evaluated. The influence was negligible. DOE will cite this work in a future revision as indirect evidence that the secondary effects of igneous intrusion have only a secondary effect on dose. In addition, DOE may argue that the combination of criticality and igneous intrusion can be neglected based on low consequence in a future revision of this Feature, Event and Process. DOE has examine the inconsistency and determined the value listed in Table 5-1 for water content in magma is a typo (water fraction was listed instead of water wt%). The 5-wt% value listed in the rest of the document is correct. It is based on a conservative number from Characterize Eruptive Processes at Yucca Mountain, Nevada ANL-MGR-GS-000002 REV 00 (CRWMS 2000e, Section 6.2.2, pg. 28). DOE has reviewed its computer files and the value used was 5 wt%. DOE needs to look at the computer files supplied to the NRC to be able to identify the source of the 1.6-wt% number	
82	1.5.01.01.00	SYS	Meteorite impact	NA	DOE agrees. No further discussion on this FEP is necessary	
83	1.5.01.02.00	SYS	Extraterrestrial events	NA	DOE agrees. No further discussion on this FEP is necessary	
75	Various	DE	Excavation/ Construction	McGregor (PA) Quittmeyer (S&A)	The following Features, Events and Processes (FEPs) will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
			Incomplete/ Closure Canister Failure(long term) Mechanical Degradation or Collapse of Drift Topography & Morphology		FEP 1.1.02.00.00 (Excavation/Construction) – It is not clear which specific rock changes due to excavation and construction with which the NRC is concerned. Changes in stress due to excavation and their possible effects on dike interactions with the drift are addressed in the Dike Propagation Near Drifts Analysis/Model Report (CRWMS M&O 2000o, Section 6.3.1). This effect is considered in the evaluation of FEP 1.2.04.03.00, Igneous Intrusion into the Repository, and thus consideration under FEP 1.1.02.00.00 is not needed. Magma flow through drifts to a ventilation shaft and then to the surface is not considered in the current DOE analysis. FEP 1.1.04.01.00 (Incomplete Closure) – The DOE analysis documented in the Dike Propagation Near Drifts Analysis/Model Report (CRWMS M&O 2000o) does not assume or rely upon drift seals to contain magma. Rather, the high energy nature of the system causes the drifts to become plugged or clogged with debris and materials from pyroclastic flows, cooling magma, and repository components. Therefore, consideration of FEP 1.1.04.01.00 with respect to igneous intrusion is not needed. FEP 2.1.03.12.00 (Canister Failure (Long-Term) –The effect of magma on waste packages is considered under FEP 1.2.04.04.00, "Magma Interacts with Waste." Therefore, consideration of FEP 1.1.04.01.00 with respect to igneous intrusion is not needed. The end-cap breach is used because it is the locus for the largest stress and deformation resulting from increased heat and pressure. The end cap weld damage is used as a "surrogate" as a means to estimate the extent of damage. As stated in the igneous consequence modeling Analysis/Model Report in Section 6.2 "Although the mean value can be thought of conceptually as corresponding to a 1-mm-wide crack that propagates for 1 m along a weld, or a 2-mm-wide crack that extends 50 cm, it was not chosen to represent any specific dimensions of a weld failure. Rather, it was chosen as an approximation of the size of opening necessary to permit rapid gas flow and pressure equilibration. Sampling the area of the breach from a distribution that includes much larger hole sizes is intended to account for both uncertainty regarding the nature of the magmatic fluids and the package response and spatial variability in the extent of damage within the drifts." DOE has evaluated this issue under the FEPs "Igneous Intrusion Into the Repository" or "Magma Interacts with Waste. Consideration under FEP 2.1.03.12.00 is not needed. FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) - To address this comment, DOE needs to know by what process the NRC believes collapse of the drift will increase dose determined for igneous disruption of a repository. Any effects of drift collapse can be covered in the screening evaluation for FEP 1.2.04.03.00, "Igneous Intrusion into the Repository." FEP 2.3.01.00.00 (Topography and Morphology) - To address this comment, the DOE needs to know in what manner the NRC believes topography will affect dike propagation. Any effects can be covered in the screening evaluation for the FEP 1.0.04.06.00, "Basaltic Cinder Cone Erupts Through the Repository."	
76	Generic	DE	Hydrothermal activity	McGregor (PA) Quittmeyer (S&A)	The following Features, Events and Processes (FEPs) will be discussed at the May, 18, 2001, Igneous Activity Appendix 7 Meeting, The issues identified in the NRC's comment do not require definition of new features, events and processes. The processes listed are already included in existing features, events and processes. For example, Secondary features, events and processes that have been evaluated in conjunction with the Primary feature, event and process "Magma Interacts with Waste" (1.2.04.04.00) include:	

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
					Magma volatiles attack waste (1.2.04.04.01) Dissolution of spent fuel in magma (1.2.04.04.02) Dissolution of other waste in magma (1.2.04.04.03) Heating of waste container by magma (without contact) (1.2.04.04.04) Failure of waste container by direct contact with magma (1.2.04.04.05) Fragmentation (1.2.04.04.06). Screening evaluation of these features, events and processes is based on simplified analyses. The DOE's approach has been to combine its simplified analyses with reasonable assumptions to appropriately abstract the consequences of dike/drift interactions for inclusion in the Total System Performance Assessment. This approach is documented in the following Analysis/Model Reports, which have been provided to the NRC: *Dike Propagation Near Drifts* (CRWMS M&O 2000o), *Igneous Consequence Modeling for TSPA-SR* (CRWMS M&O 2000aq), *Number of Waste Packages Hit by Igneous Intrusion* (CRWMS M&O 2000ak). The DOE does not attempt to model in detail the complicated interactions between an ascending dike and a waste emplacement drift containing waste packages and other engineered barrier system components. Rather, the DOE assumes that waste packages within and near an intersecting dike are damaged such that they provide no further protection. Beyond the immediate vicinity of the intersecting dike, magma processes, such as those identified by the NRC, are assumed to damage all waste packages in an intersected drift, although not to the extent that they provide no further protection. Damage to end-cap welds is used as a surrogate for all types of waste package damage. Damage is characterized by a distribution of induced crack apertures ranging up to the size of an end-cap (CRWMS M&O 2000aq, Section 6.2). In this way DOE has reasonably taken into account dike/drift interactions.	
77	2.1.07.02.00	DE	Mechanical degradation or collapse of drift	McGregor (PA) Mast (S&A) Blair (S&A)	The screening decisions were based solely on the results of the Drift Degradation Analysis and will be revisited once the analysis to resolve the Repository Design Thermal Mechanical Effects agreement KRD0319 has been completed. NRC should consider providing an advanced copy of the cited paper (Hsuing and Shi 2001) since it is not currently available. The referenced expert panel report on drift stability also clearly states on page 2-3 that "Fracture propagation during cooling and tectonic events appears to have been arrested by the lithophysae so that continuous joints, which could form large rock blocks and overbreak, are largely absent. Overbreak or rock loosening in the form of slabs or block was almost nonexistent in the lithophysal zones in both the 7.6-meter diameter North Ramp and the 5-meter diameter Cross Drift." This would suggest that NRC's concerns about fracture length and the possible formation of extensive slabs of rock expressed during multiple Key Technical Issues is at conflict with the findings of this panel as well. DOE requests that the NRC provide a specific citation (section/conclusionary statement) from the expert panel report that they feel is in conflict with the Drift Degradation Analysis.	KRD0319

DOE Discussion Topics for May 15-17, 2001 Features, Events and Processes Technical Exchange

Item No.	FEP#	FEP AMR	FEP Name	Response Authors	DOE Discussion	Agreement No.
79	2.1.07.01.00	DE WP	Rockfall (Large Block)	Pasu (S&A) Bennett (ENG) McGregor (PA)	The screening decision is dependent on the results of the Drift Degradation Analysis for Maximum Key Block Size and on the Design Criteria for the Drip Shield. The screening decision will be reviewed pending completion of the Repository Design and Thermal Mechanical Effects agreements (KRD0317 and KRD0319) to perform additional analyses. With regard to specific issues raised: i. The temperature effects on mechanical material behavior are being included in the evaluations being currently performed and will be included in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). ii. Seismic motion of the supporting invert is being included in the evaluations being currently performed and will be included in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). iii. Point load impact is being addressed in the current evaluations as agreed upon in the Container Life and Source Term agreement KCL0202. These evaluations will be included in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). iv. The material failure criteria used were questioned, and the DOE agreed in Container Life and Source Term agreement KCL0203 to justify whatever failure criteria are used in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). v. Drip shield wall thinning due to corrosion is being addressed in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l) per the Container Life and Source Term agreement KCL0208. vi. Multiple rock block impacts is being addressed in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l) per the Container Life and Source Term agreement KCL0208. vii. This was discussed at the time of the Container Life and Source Term Technical Exchange and was not listed as an agreement item because these boundary conditions are already included in DOE's evaluations. The DOE has performed and continues to perform evaluations to demonstrate that the drip shield has been designed to withstand 6-metric ton rock block impacts. Evaluations of impacts of blocks larger than 6-metric ton are performed to determine the consequences to the drip shield and waste package. The carbon steel members of the invert are surrounded by a ballast material, which will provide some support to the waste packages for the entire regulatory period. While the carbon steel invert may not keep the waste packages in a horizontal position for the entire regulatory period, it is designed to keep the waste packages in a horizontal position for the preclosure period. One of the repository closure activities is the installation of drip shields, which would prevent direct impact of rock blocks on the waste packages.	KRD0317 KRD0319 KCL0202 KCL0203 KCL0208
79	2.1.07.01.00	DE WFClad	Rockfall (large block)	Siegmann (S&A) Stockman (S&A)	The revised Clad Degradation: Summary and Abstraction Analysis/Model Report (ANL-WIS-MD-000007 REV 00, ICN 01, CRWMS M&O 2001a) was forwarded to the NRC as part of the Container Life and Source Term Agreement KCL0306. The revised Analysis/Model Report expanded the mechanical failure model to include cladding failure from rock overburden as the waste package deteriorates. The issue of rockfall is addressed in Container Life and Source Term agreement KCL0310. The Analysis/Model Report will be further revised as necessary to incorporate new information on rockfall, in time to support any potential License Application.	KCL0306 KCL0310
79	2.1.07.01.00	DE	Rockfall (Large Block)	McGregor (S&A) Kicker (ENG)	The screening decision is dependent on the waste package calculations and the Drift Degradation Analysis, which is used to determine the maximum key block size. When additional analyses identified in Repository Design and Thermal Mechanical Effects agreements (KRD0317 and KRD0319) are completed, the screening decision will be reviewed.	KRD0317 KRD0319

Note:

The Supplementary Science and Performance Analysis (SSPA) Report will be issued by DOE in the next few months to provide additional information for use in consideration of a possible recommendation of the Yucca Mountain site. The information will include the results of ongoing sensitivity studies and uncertainty analyses, expanded studies of potential thermal operating ranges and is expected to be adequate to support a preliminary evaluation of the Yucca Mountain site. It is not intended to affect or modify the design basis information provided in the Analysis and Model Reports, Process Model Reports, Total System Performance Analysis for Site Recommendation, or Science and Engineering Report.

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Please Note: The enclosed letter to DOE documents a Technical Exchange and Management Meeting on the Key Technical Issue, "Total System Performance Assessment and Integration," conducted on May 15-17, 2001. The meeting summary is included as an enclosure to the letter. Attachment 1 to the meeting summary lists the agreements made by the NRC/DOE at the meeting, Attachment 2 provides a table containing all the features, events, and processes discussed during the meeting and their associated NRC/DOE agreed upon path forward, Attachment 3 is the agenda, and Attachment 4 is the attendance list. Due to the size of Attachment 5 (presenter's slides), they are not included in this mailing. If you are interested in viewing or printing this attachment, it can be obtained from the NRC website (www.nrc.gov) under the ADAMS icon (or you can go directly to the ADAMS homepage at www.nrc.gov/NRC/ADAMS. If you do not have access to the website and/or are interested in getting a hard copy of Attachment 5, please contact Ms. Darlene Higgs at 301-415-6711 or e-mail at gdh1@nrc.gov.