NUREG-1762, Vol. 2
Rev. 1

Integrated Issue Resolution Status Report

Appendices A through D

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555-0001

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Division of High-Level Waste Repository Safety
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

ABSTRACT

This Integrated Issue Resolution Status Report provides background information about the status of prelicensing interactions between the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC) concerning a potential high-level waste geologic repository at Yucca Mountain, Nevada. The NRC staff has, for many years, engaged in prelicensing interactions with DOE and various stakeholders. In recent years, DOE and NRC have reached a number of agreements related to key technical issues important to repository performance after permanent closure and items important to safety during the period before permanent closure. During the prelicensing period, the NRC staff also have undertaken a risk insights initiative to enhance the use of available risk information and develop, as a common basis for understanding, the significance of features, events, and processes that may affect the performance of potential engineered and natural barriers at Yucca Mountain.

This report provides an overview of available information and status (as of March 2004, with exceptions as noted) of the Key Technical Issue agreements reached between DOE and NRC. The report also documents the risk insights (Appendix D) and information considered by the NRC staff in formulating their views, including the results of in-depth reviews of available DOE and contractor documents; the independent confirmatory work of NRC and its contractor, the Center for Nuclear Waste Regulatory Analyses; published literature; and other publicly available information.

This report may be of value to stakeholders in understanding the technical rationale used by the NRC staff to identify certain information as being necessary for a quality license application. The staff has not made any determination about compliance with regulations applicable to a potential repository at Yucca Mountain. If DOE submits a license application for a potential repository at Yucca Mountain, the staff will review the information provided by DOE and make determinations based on information provided at that time.

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APPENDIX A

The following table provides the status of the Key Technical Issue–Agreement–Integrated Subissue Crosswalk as of August 2004. For those Agreements that relate to more than one Integrated Subissue (ISI), the additional ISIs are listed on separate lines.

KTI Agreement - ISI

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.1.01	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 8. [establish credible range of brine water chemistry; evaluate effect of introduced materials on water chemistry; determine likely concentrations and chemical form of minor constituents in YM waters; characterize YM waters with respect to the parameters which define the type of brine which would evolve; evaluate periodic water drip evaporation] DOE will provide the documentation in a revision to AMR "Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier" by LA.	Complete
CLST.1.02	ENG1	Provide the documentation for the path forward items listed on slide 12. [surface elemental analysis of alloy test specimens is necessary for determination of selective dissolution; surface analysis of welded specimens for evidence of dealloying; continue testing including simulated saturated repository environment to confirm enhancement factor] DOE will provide the documentation in a revision to AMR "General and Localized Corrosion of Waste Package Outer Barrier" by LA.	Received
CLST.1.03	ENG1	Provide documentation that confirms the linear polarization resistance measurements with corrosion rate measurements using other techniques. DOE will provide the documentation in a revision to AMR "General and Localized Corrosion of Waste Package Outer Barrier" by LA.	Received
CLST.1.04	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 14. [continue testing in the LTCTF; add new bounding water test environments to LTCTF (SSW & BSW); install thinner coupons in LTCTF with larger surface area/volume rations; install high sensitivity probes of Alloy 22 in some of the LTCTF vessels; materials testing continues during performance confirmation] DOE will provide the documentation in a revision to AMR "ANL-EBS-MD-000003 and ANL-EBS-MD-000004" by LA.	Received
CLST.1.05	ENG1	Provide additional details on sensitivities, resolution of measurements, limitations, and deposition of silica for the high sensitivity probes. DOE will document the results of the sensitivity probes including limitation and resolution of measurements as affected by silica deposition in the Alloy 22 AMR and Ti Corrosion AMR (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Complete
CLST.1.06	ENG1	Provide the documentation on testing showing corrosion rates in the absence of silica deposition. DOE will document the results of testing in the absence of silica deposits in the revision of Alloy 22 AMR (ANL-EBS-MD-000003) prior to LA.	Received
CLST.1.07	ENG1	Provide the documentation for the alternative methods to measure the corrosion rate of the waste package material (e.g., ASTM G-102 testing) or provide justification for the current approach. DOE will document the alternative methods of corrosion measurement in the revision of Alloy 22 AMR (ANL-EBS-MD-000003), prior to LA.	Complete
CLST.1.08	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 16 and 17. [calculate potential-pH diagrams for multi-component Alloy 22; grow oxide films at higher temperatures in autoclaves, in air and/or electrochemically to accelerate film growth for compositional and structural studies below; resolve kinetics of film growth: parabolic or higher order, whether film growth becomes linear, and if, as film grows it becomes mechanically brittle and spalls off; determine chemical, structural, and mechanical properties of films, including thicken films; correlate changes in Ecorr measured in LTCTF with compositional changes in passive film over time; perform analyses on cold-worked materials to determine changes in film structural properties; perform examination of films formed on naturally occurring Josephinite; compare films formed on Alloy 22 with other similar passive film Alloys with longer industrial experience] DOE will provide the documentation in the revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.1.09	ENG1	Provide the data that characterizes the passive film stability, including the welded and thermally aged specimens. DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Received
CLST.1.10	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 21 and 22. [measure corrosion potentials in the LTCTF to determine any shift of potential with time toward the critical potentials for LC; determine critical potentials on welded and welded and aged coupons of Alloy 22 vs those for base metal - particularly important if precipitation or severe segregation of alloying elements occurs in the welds; separate effects of ionic mix of specimens in YM waters on critical potentials - damaging species from potentially beneficial species; determine critical potentials in environments containing heavy metal concentrations] DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Received
CLST.1.11	ENG1	Provide the technical basis for the selection of the critical potentials as bounding parameters for localized corrosion, taking into account MIC. DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000003 and ANL-EBS-MD-000004) prior to LA.	Received
CLST.1.12	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slides 34 and 35. [qualify and optimize mitigation processes; generate SCC data for mitigated material over full range of metallurgical conditions; new vessels for LTCTF will house many of the SCC specimens; continue SSRT in same types of environments as above, specimens in the same range of metallurgical conditions; determine repassivation constants needed for film rupture SCC model to obtain value for the model parameter 'n'; continue reversing direct current potential drop crack propagation rate determinations in same types of environments and same metallurgical conditions as for SSRT and LTCTF tests; evaluate SCC resistance of welded and laser peened material vs non-welded unpeened material; evaluate SCC resistance in induction annealed material; evaluate SCC resistance of full thickness material obtained from the demonstration prototype cylinder of Alloy 22] DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000005 and ANL-EBS-MD-000006) prior to LA.	Received
CLST.1.13	ENG1	Provide the data that characterizes the distribution of stresses due to laser peening and induction annealing of Alloy 22. DOE will provide the documentation in a revision to AMR (ANL-EBS-MD-000005) prior to LA.	Received
CLST.1.13	PRE	Provide the data that characterizes the distribution of stresses due to laser peening and induction annealing of Alloy 22. DOE will provide the documentation in a revision to AMR (ANL-EBS-MD-000005) prior to LA.	Received
CLST.1.13	ENG2	Provide the data that characterizes the distribution of stresses due to laser peening and induction annealing of Alloy 22. DOE will provide the documentation in a revision to AMR (ANL-EBS-MD-000005) prior to LA.	Received
CLST.1.14	PRE	Provide the justification for not including the rockfall effect and deadload from drift collapse on SCC of the waste package and drip shield. DOE will provide the documentation for the rockfall and dead-weight effects in the next revision of the SCC AMR (ANL-EBS-MD-000005) prior to LA.	Received
CLST.1.14	ENG2	Provide the justification for not including the rockfall effect and deadload from drift collapse on SCC of the waste package and drip shield. DOE will provide the documentation for the rockfall and dead-weight effects in the next revision of the SCC AMR (ANL-EBS-MD-000005) prior to LA.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.1.15	ENG1	Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 39. [install specimens cut from welds of SR design mock-up in LTCTF and in other SCC test environments - determine which specimen geometry is most feasible to complement SCC evaluation; evaluate scaling and weld process factors between thin coupons and dimensions in actual welded waste package containers - including thermal/metallurgical structural effects of multi-pass weld processes; provide representative weld test specimens for MIC work, thermal aging and localized corrosion evaluations] DOE will provide documentation for Alloy 22 and Ti path forward items on slide 39 in a revision to the SCC and general and localized corrosion AMRs (ANL-EBS-MD-000003, ANL-EBS-MD-000004, ANL-EBS-MD-000005) by LA.	Received
CLST.1.16	ENG2	Provide the documentation on the measured thermal profile of the waste package material due to induction annealing. DOE stated that the thermal profiles will be measured during induction annealing, and the results will be reported in the next SCC AMR (ANL-EBS-MD-000005) prior to LA.	Complete
CLST.1.16	ENG1	Provide the documentation on the measured thermal profile of the waste package material due to induction annealing. DOE stated that the thermal profiles will be measured during induction annealing, and the results will be reported in the next SCC AMR (ANL-EBS-MD-000005) prior to LA.	Complete
CLST.1.16	PRE	Provide the documentation on the measured thermal profile of the waste package material due to induction annealing. DOE stated that the thermal profiles will be measured during induction annealing, and the results will be reported in the next SCC AMR (ANL-EBS-MD-000005) prior to LA.	Complete
CLST.1.17	ENG2	Provide additional detail on quality assurance acceptance testing. DOE stated that it would provide guidance and criteria in the next revision of the Technical Guidance Document (TGD) for LA. The development of the LA sections and associated programs and process controls for the procurement and fabrication of waste package materials and components will be included. This will include consideration of the controls for compositional variations in Alloy 22. The TGD revision will be issued by June 2001, contingent upon NRC publication of the final 10 CFR 63 and the Yucca Mountain Review Plan.	Complete
CLST.1.17	ENG1	Provide additional detail on quality assurance acceptance testing. DOE stated that it would provide guidance and criteria in the next revision of the Technical Guidance Document (TGD) for LA. The development of the LA sections and associated programs and process controls for the procurement and fabrication of waste package materials and components will be included. This will include consideration of the controls for compositional variations in Alloy 22. The TGD revision will be issued by June 2001, contingent upon NRC publication of the final 10 CFR 63 and the Yucca Mountain Review Plan.	Complete
CLST.1.17	PRE	Provide additional detail on quality assurance acceptance testing. DOE stated that it would provide guidance and criteria in the next revision of the Technical Guidance Document (TGD) for LA. The development of the LA sections and associated programs and process controls for the procurement and fabrication of waste package materials and components will be included. This will include consideration of the controls for compositional variations in Alloy 22. The TGD revision will be issued by June 2001, contingent upon NRC publication of the final 10 CFR 63 and the Yucca Mountain Review Plan.	Complete
CLST.2.01	PRE	Either provide documentation using solid element formulation, or provide justification for not using it, for the drip shield - rockfall analysis. DOE stated that shell elements include normal stresses and transverse stresses in the calculations and provide more accurate results for thin plates and use far fewer elements. Therefore, shell elements will be used instead of solid elements. This justification will be documented in the next revision of AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, prior to LA.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.2.01	ENG2	Either provide documentation using solid element formulation, or provide justification for not using it, for the drip shield - rockfall analysis. DOE stated that shell elements include normal stresses and transverse stresses in the calculations and provide more accurate results for thin plates and use far fewer elements. Therefore, shell elements will be used instead of solid elements. This justification will be documented in the next revision of AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, prior to LA.	Received
CLST.2.02	PRE	Provide the documentation for the point loading rockfall analysis. DOE stated that point loading rock fall calculations will be documented in the next revisions of AMRs ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, and ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, both to be completed prior to LA.	Received
CLST.2.02	ENG2	Provide the documentation for the point loading rockfall analysis. DOE stated that point loading rock fall calculations will be documented in the next revisions of AMRs ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, and ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, both to be completed prior to LA.	Received
CLST.2.03	PRE	Demonstrate how the Tresca failure criterion bounds a fracture mechanics approach to calculating the mechanical failure of the drip shield. DOE stated that it believes its current approach of using ASME Code is appropriate for this application. Additional justification for this conclusion will be included in the next revision of AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Received
CLST.2.03	ENG2	Demonstrate how the Tresca failure criterion bounds a fracture mechanics approach to calculating the mechanical failure of the drip shield. DOE stated that it believes its current approach of using ASME Code is appropriate for this application. Additional justification for this conclusion will be included in the next revision of AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Received
CLST.2.04	ENG1	Provide information on the effect of the entire fabrication sequence on phase instability of Alloy 22, including the effect of welding thick sections using multiple weld passes and the proposed induction annealing process. DOE stated that the aging studies will be expanded to include solution annealed and induction annealed Alloy 22 weld and base metal samples from the mock-ups as well as laser peened thick, multi-pass welds. This information will be included in revisions of the AMR "Aging and Phase Stability of the Waste Package Outer Barrier," ANL-EBS-MD-000002, before LA.	Received
CLST.2.04	PRE	Provide information on the effect of the entire fabrication sequence on phase instability of Alloy 22, including the effect of welding thick sections using multiple weld passes and the proposed induction annealing process. DOE stated that the aging studies will be expanded to include solution annealed and induction annealed Alloy 22 weld and base metal samples from the mock-ups as well as laser peened thick, multi-pass welds. This information will be included in revisions of the AMR "Aging and Phase Stability of the Waste Package Outer Barrier," ANL-EBS-MD-000002, before LA.	Received
CLST.2.04	ENG2	Provide information on the effect of the entire fabrication sequence on phase instability of Alloy 22, including the effect of welding thick sections using multiple weld passes and the proposed induction annealing process. DOE stated that the aging studies will be expanded to include solution annealed and induction annealed Alloy 22 weld and base metal samples from the mock-ups as well as laser peened thick, multi-pass welds. This information will be included in revisions of the AMR "Aging and Phase Stability of the Waste Package Outer Barrier," ANL-EBS-MD-000002, before LA.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.2.05	ENG2	Provide the "Aging and Phase Stability of Waste Package Outer Barrier," AMR, including the documentation of the path forward items listed in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slides 5 & 6. [data input to current models is being further evaluated and quantified to reduce uncertainty; aging of Alloy 22 samples for microstructural characterization, tensile property test, and Charpy impact test is ongoing; theoretical modeling will be employed to enhance confidence in extrapolating aging kinetic data to repository thermal conditions and time scale - modeling will utilize thermodynamic principles of the processes; Alloy 22 samples for SCC compact tension test are being added to aging studies; test program will be expanded to include welded and cold worked materials; effects of stress mitigation techniques such as laser peening and induction annealing on phase instability will be investigated; aging test facility will be expanded to include aging at lower temperatures] DOE stated that the "Aging and Phase Stability of the Waste Package Outer Barrier" AMR, ANL-EBS-MD-000002, Rev. 00 was issued 3/20/00. This AMR will be revised to include the results of the path forward items before LA.	Received
CLST.2.05	PRE	Provide the "Aging and Phase Stability of Waste Package Outer Barrier," AMR, including the documentation of the path forward items listed in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slides 5 & 6. [data input to current models is being further evaluated and quantified to reduce uncertainty; aging of Alloy 22 samples for microstructural characterization, tensile property test, and Charpy impact test is ongoing; theoretical modeling will be employed to enhance confidence in extrapolating aging kinetic data to repository thermal conditions and time scale - modeling will utilize thermodynamic principles of the processes; Alloy 22 samples for SCC compact tension test are being added to aging studies; test program will be expanded to include welded and cold worked materials; effects of stress mitigation techniques such as laser peening and induction annealing on phase instability will be investigated; aging test facility will be expanded to include aging at lower temperatures] DOE stated that the "Aging and Phase Stability of the Waste Package Outer Barrier" AMR, ANL-EBS-MD-000002, Rev. 00 was issued 3/20/00. This AMR will be revised to include the results of the path forward items before LA.	Received
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CLST.2.06	ENG2	Provide the technical basis for the mechanical integrity of the inner overpack closure weld. DOE will provide the documentation in AMR, ANL-UDC-MD-000001, Rev. 00, Design Analysis for UFC Waste Packages in the next revision, prior to LA.	Complete
CLST.2.06	PRE	Provide the technical basis for the mechanical integrity of the inner overpack closure weld. DOE will provide the documentation in AMR, ANL-UDC-MD-000001, Rev. 00, Design Analysis for UFC Waste Packages in the next revision, prior to LA.	Complete
CLST.2.06	ENG1	Provide the technical basis for the mechanical integrity of the inner overpack closure weld. DOE will provide the documentation in AMR, ANL-UDC-MD-000001, Rev. 00, Design Analysis for UFC Waste Packages in the next revision, prior to LA.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.2.07	ENG1	Provide documentation for the fabrication process, controls, and implementation of the phases which affect the TSPA model assumptions for the waste package (e.g., filler metal, composition range). DOE stated that updates of the documentation on the fabrication processes and controls (TDR-EBS-ND-000003, Waste Package Operations Fabrication Process Report and TDP-EBS-ND-000005, Waste Package Operations FY-00 Closure Weld Technical Guidelines Document) will be available to the NRC in January 2001.	Complete
CLST.2.07	ENG2	Provide documentation for the fabrication process, controls, and implementation of the phases which affect the TSPA model assumptions for the waste package (e.g., filler metal, composition range). DOE stated that updates of the documentation on the fabrication processes and controls (TDR-EBS-ND-000003, Waste Package Operations Fabrication Process Report and TDP-EBS-ND-000005, Waste Package Operations FY-00 Closure Weld Technical Guidelines Document) will be available to the NRC in January 2001.	Complete
CLST.2.07	PRE	Provide documentation for the fabrication process, controls, and implementation of the phases which affect the TSPA model assumptions for the waste package (e.g., filler metal, composition range). DOE stated that updates of the documentation on the fabrication processes and controls (TDR-EBS-ND-000003, Waste Package Operations Fabrication Process Report and TDP-EBS-ND-000005, Waste Package Operations FY-00 Closure Weld Technical Guidelines Document) will be available to the NRC in January 2001.	Complete
CLST.2.08	PRE	Provide documentation of the path forward items in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slide 16. [future rockfall evaluations will address (1) effects of potential embrittlement of WP closure material after stress annealing due to aging, (2) effects of drip shield wall thinning due to corrosion; (3) effects of hydrogen embrittlement on titanium drip shield; and (4) effects of multiple rock blocks falling on WP and drip shield; future seismic evaluations will address the effects of static loads from fallen rock on drip shield during seismic events] DOE stated that the rockfall calculations addressing potential embrittlement of the waste package closure weld and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, to be completed prior to LA. Rock fall calculations addressing drip shield wall thinning due to corrosion, hydrogen embrittlement of titanium, and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA. Seismic calculations addressing the load of fallen rock on the drip shield will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Received
CLST.2.08	ENG1	Provide documentation of the path forward items in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slide 16. [future rockfall evaluations will address (1) effects of potential embrittlement of WP closure material after stress annealing due to aging, (2) effects of drip shield wall thinning due to corrosion; (3) effects of hydrogen embrittlement on titanium drip shield; and (4) effects of multiple rock blocks falling on WP and drip shield; future seismic evaluations will address the effects of static loads from fallen rock on drip shield during seismic events] DOE stated that the rockfall calculations addressing potential embrittlement of the waste package closure weld and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, to be completed prior to LA. Rock fall calculations addressing drip shield wall thinning due to corrosion, hydrogen embrittlement of titanium, and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA. Seismic calculations addressing the load of fallen rock on the drip shield will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
CLST.2.08	ENG2	Provide documentation of the path forward items in the "Subissue 2: Effects of Phase Instability of Materials and Initial Defects on the Mechanical Failure and Lifetime of the Containers" presentation, slide 16. [future rockfall evaluations will address (1) effects of potential embrittlement of WP closure material after stress annealing due to aging, (2) effects of drip shield wall thinning due to corrosion; (3) effects of hydrogen embrittlement on titanium drip shield; and (4) effects of multiple rock blocks falling on WP and drip shield; future seismic evaluations will address the effects of static loads from fallen rock on drip shield during seismic events] DOE stated that the rockfall calculations addressing potential embrittlement of the waste package closure weld and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-UDC-MD-000001, Design Analysis for UCF Waste Packages, to be completed prior to LA. Rock fall calculations addressing drip shield wall thinning due to corrosion, hydrogen embrittlement of titanium, and rock falls of multiple rock blocks will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA. Seismic calculations addressing the load of fallen rock on the drip shield will be included in the next revision of the AMR ANL-XCS-ME-000001, Design Analysis for the Ex-Container Components, to be completed prior to LA.	Received
CLST.2.09	PRE	Demonstrate the drip shield and waste package mechanical analysis addressing seismic excitation is consistent with the design basis earthquake covered in the SDS KTI. DOE stated that the same seismic evaluations of waste packages and drip shield (revision of AMRs ANL-UDC-MD-000001 and ANL-XCS-ME-000001) will support both the SDS KTI and the CLST KTI, therefore consistency is ensured. These revisions will be completed prior to LA.	Received
CLST.2.09	ENG2	Demonstrate the drip shield and waste package mechanical analysis addressing seismic excitation is consistent with the design basis earthquake covered in the SDS KTI. DOE stated that the same seismic evaluations of waste packages and drip shield (revision of AMRs ANL-UDC-MD-000001 and ANL-XCS-ME-000001) will support both the SDS KTI and the CLST KTI, therefore consistency is ensured. These revisions will be completed prior to LA.	Received
CLST.3.01	ENG4	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.	Complete
CLST.3.01	TSPAI	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.	Complete
CLST.3.02	ENG3	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.3.02	ENG4	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.	Received
CLST.3.03	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a more detailed calculation on the in-package chemistry effects of radiolysis. DOE stated that the calculations recently performed as discussed at the 9/12/00 Technical Exchange and preceeding teleconferences are being documented. These calculations will be referenced and justified in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and will be available in January 2001.	Received
CLST.3.04	TSPAI	The agreement addresses CLST Subissues 3 & 4. Need consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of engineered materials on the chemistry of water used for input to in-package abstractions. DOE stated that the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 will discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR. The revision will be available in January 2001.	Received
CLST.3.04	ENG3	The agreement addresses CLST Subissues 3 & 4. Need consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of engineered materials on the chemistry of water used for input to in-package abstractions. DOE stated that the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 will discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR. The revision will be available in January 2001.	Received
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CLST.3.05	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the plan for experiments demonstrating in-package chemistry, and take into account subsequent NRC comments, if any. DOE stated that the current planning provides for the analysis of additional in-package chemistry model support. This analysis will determine which parts of the model are amenable to additional support by testing, and which parts are more amenable to sensitivity analysis, or use of analogues. Based on these results, longer range testing will be considered. If testing is determined to be appropriate, test plans will be written in FY01 and made available to the NRC.	Received
CLST.3.06	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide additional technical basis for the failure rate and how the rate is affected by localized corrosion. DOE stated that the technical basis for local corrosion conditions will be added to by additional discussion of local chemistry in the Summary of In-package Chemistry for Waste Forms revision ANL-EBS-MD-000050 which will be available in January 2001. Current Clad Degradation Summary Abstraction AMR Section 6.3, ANL-WIS-MD-000007 and Clad Degradation - Local Corrosion of Zirconium and its Alloys Under Repository Conditions AMR, ANL-EBS-MD-000012 contain the overall technical basis.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.3.07	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide data to address chloride induced localized corrosion and SCC under the environment predicted by in-package chemistry modeling. DOE stated that the technical basis for the models used for localized corrosion and SCC will be expanded in future revisions of the Clad Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, available by LA.	Received
CLST.3.08	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the documentation on the distribution for cladding temperature and stress used for hydride embrittlement. DOE stated that the stresses are documented in the Initial Cladding Conditions AMR, ANL-EBS-MD-000048. CAL-UDC-ME-000001 contains the waste package internal temperatures. Waste package surface temperatures were provided within the TSPA model (ANL-EBS-HS-000003, Rev 00, ICN 01 and ANL-EBS-MD-000049). The updated versions of these documents will be available in January 2001.	Received
CLST.3.09	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a technical basis for critical stress that is relevant for the environment in which external SCC takes place. DOE stated that critical stress from SCC experiments under more aggressive conditions will be cited in the Revision of the Cladding Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, which will be available in January 2001.	Received
CLST.3.10	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide analysis of the rockfall and vibratory loading effects on the mechanical failure of cladding, as appropriate. DOE stated that the vibratory effects are documented in Sanders et. al. 1992 SAND90-2406, A Method For Determining The Spent-Fuel Contribution To Transport Cask Containment Requirements. This will be discussed in the SDS KTI meeting. The analysis of the rockfall effects on the mechanical failure of cladding will be addressed if the agreed to updated rockfall analysis in Subissue #2, Item 8 and Subissue #1, Item 14 demonstrate that the rock will penetrate the drip shield and damage the waste package.	Received
CLST.4.01	ENG4	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.	Complete
CLST.4.01	TSPAI	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.	Complete
CLST.4.02	ENG3	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.	Complete

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CLST.4.02	ENG4	The agreement addresses CLST Subissues 3 & 4. In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.	Complete
CLST.4.03	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a more detailed calculation on the in-package chemistry effects of radiolysis. DOE stated that the calculations recently performed as discussed at the 9/12/00 Technical Exchange and preceeding teleconferences are being documented. These calculations will be referenced and justified in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and will be available in January 2001.	Complete
CLST.4.04	ENG4	The agreement addresses CLST Subissues 3 & 4. Need consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of engineered materials on the chemistry of water used for input to in-package abstractions. DOE stated that the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 will discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR. The revision will be available in January 2001.	Complete
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CLST.4.05	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the plan for experiments demonstrating in-package chemistry, and take into account subsequent NRC comments, if any. DOE stated that the current planning provides for the analysis of additional in-package chemistry model support. This analysis will determine which parts of the model are amenable to additional support by testing, and which parts are more amenable to sensitivity analysis, or use of analogues. Based on these results, longer range testing will be considered. If testing is determined to be appropriate, test plans will be written in FY01 and made available to the NRC.	Complete
CLST.4.06	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide additional technical basis for the failure rate and how the rate is affected by localized corrosion. DOE stated that the technical basis for local corrosion conditions will be added to by additional discussion of local chemistry in the Summary of In-package Chemistry for Waste Forms revision ANL-EBS-MD-000050 which will be available in January 2001. Current Clad Degradation Summary Abstraction AMR Section 6.3, ANL-WIS-MD-000007 and Clad Degradation - Local Corrosion of Zirconium and its Alloys Under Repository Conditions AMR, ANL-EBS-MD-000012 contain the overall technical basis.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.4.07	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide data to address chloride induced localized corrosion and SCC under the environment predicted by in-package chemistry modeling. DOE stated that the technical basis for the models used for localized corrosion and SCC will be expanded in future revisions of the Clad Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, available by LA.	Complete
CLST.4.08	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide the documentation on the distribution for cladding temperature and stress used for hydride embrittlement. DOE stated that the stresses are documented in the Initial Cladding Conditions AMR, ANL-EBS-MD-000048. CAL-UDC-ME-000001 contains the waste package internal temperatures. Waste package surface temperatures were provided within the TSPA model (ANL-EBS-HS-000003, Rev 00, ICN 01 and ANL-EBS-MD-000049). The updated versions of these documents will be available in January 2001.	Complete
CLST.4.09	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide a technical basis for critical stress that is relevant for the environment in which external SCC takes place. DOE stated that critical stress from SCC experiments under more aggressive conditions will be cited in the Revision of the Cladding Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, which will be available in January 2001.	Complete
CLST.4.10	ENG4	The agreement addresses CLST Subissues 3 & 4. Provide analysis of the rockfall and vibratory loading effects on the mechanical failure of cladding, as appropriate. DOE stated that the vibratory effects are documented in Sanders et. al. 1992 SAND90-2406, A Method For Determining The Spent-Fuel Contribution To Transport Cask Containment Requirements. This will be discussed in the SDS KTI meeting. The analysis of the rockfall effects on the mechanical failure of cladding will be addressed if the agreed to updated rockfall analysis in Subissue #2, Item 8 and Subissue #1, Item 14 demonstrate that the rock will penetrate the drip shield and damage the waste package.	Complete
CLST.4.11	ENG4	See also CLST Subissue 3 agreements. In addition, in the revision to the "Defense High Level Waste Glass Degradation," AMR, address specific NRC questions regarding (a) the inconsistency of the rates in acid leg for glasses, (b) the technical basis for use of boron versus silica in the radionuclide release from glass, and (c) clarification of the definition of long term rates of glass dissolution. DOE stated that these questions will be addressed in the Defense High Level Waste AMR revision and will be available in January 2001.	Complete
CLST.5.01	ENG3	Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
CLST.5.01	ENG1	Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
CLST.5.01	ENG2	Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
CLST.5.01	TSPAI	Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
CLST.5.01	ENG4	Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
CLST.5.02	TSPAI	Provide the Disruptive Events FEPs AMR, the FEPs database, and the Analyses to Support Screening of System-Level Features, Events, and Processes for the Yucca Mountain Total System Performance Assessment-Site Recommendation. DOE stated that it will provide the FEPs AMRs, the Analyses to Support Screening of System-Level Features, Events, and Processes for the Yucca Mountain Total System Performance Assessment-Site Recommendation AMR, and the FEPs database to NRC during January 2001.	Complete
CLST.5.03	TSPAI	DOE will provide an updated technical basis for screening criticality from the post-closure performance assessment. The technical basis will include (1) a determination of whether the formation of condensed water could allow liquid water to enter the waste package without the failure of the drip shield, and (2) an assessment of improper heat treatment, if it is shown to result in early failure of waste packages, considering potential failure modes. The documentation of the technical basis is comprised of (1) Analysis of Mechanisms for Early Waste Package Failure AMR, (2) Probability of Criticality Before 10,000 years calculation, and (3) Features, Event, and Process System Level and Criticality AMR. The first document will be provided to NRC in FY02, the second and third documents will be provided in FY03.	Received
CLST.5.03	ENG2	DOE will provide an updated technical basis for screening criticality from the post-closure performance assessment. The technical basis will include (1) a determination of whether the formation of condensed water could allow liquid water to enter the waste package without the failure of the drip shield, and (2) an assessment of improper heat treatment, if it is shown to result in early failure of waste packages, considering potential failure modes. The documentation of the technical basis is comprised of (1) Analysis of Mechanisms for Early Waste Package Failure AMR, (2) Probability of Criticality Before 10,000 years calculation, and (3) Features, Event, and Process System Level and Criticality AMR. The first document will be provided to NRC in FY02, the second and third documents will be provided in FY03.	Received
CLST.5.03	ENG1	DOE will provide an updated technical basis for screening criticality from the post-closure performance assessment. The technical basis will include (1) a determination of whether the formation of condensed water could allow liquid water to enter the waste package without the failure of the drip shield, and (2) an assessment of improper heat treatment, if it is shown to result in early failure of waste packages, considering potential failure modes. The documentation of the technical basis is comprised of (1) Analysis of Mechanisms for Early Waste Package Failure AMR, (2) Probability of Criticality Before 10,000 years calculation, and (3) Features, Event, and Process System Level and Criticality AMR. The first document will be provided to NRC in FY02, the second and third documents will be provided in FY03.	Received
CLST.5.04	SZ2	Provide the list of validation reports and their schedules. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received
CLST.5.04	ENG4	Provide the list of validation reports and their schedules. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.5.04	ENG1	Provide the list of validation reports and their schedules. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received
CLST.5.05	ENG1	Provide information on how the increase in the radiation fields due to the criticality event affects the consequence evaluation because of increased radiolysis inside the waste package and at the surfaces of nearby waste packages or demonstrate that the current corrosion and dissolution models encompass the range of chemical conditions and corrosion potentials that would result from this increase in radiolysis. DOE stated that the preliminary assessment (calculation) of radiolysis effects from a criticality event will be available to NRC during February 2001. The final assessment of these conditions will be available to NRC prior to LA.	Received
CLST.5.05	ENG4	Provide information on how the increase in the radiation fields due to the criticality event affects the consequence evaluation because of increased radiolysis inside the waste package and at the surfaces of nearby waste packages or demonstrate that the current corrosion and dissolution models encompass the range of chemical conditions and corrosion potentials that would result from this increase in radiolysis. DOE stated that the preliminary assessment (calculation) of radiolysis effects from a criticality event will be available to NRC during February 2001. The final assessment of these conditions will be available to NRC prior to LA.	Received
CLST.5.05	ENG3	Provide information on how the increase in the radiation fields due to the criticality event affects the consequence evaluation because of increased radiolysis inside the waste package and at the surfaces of nearby waste packages or demonstrate that the current corrosion and dissolution models encompass the range of chemical conditions and corrosion potentials that would result from this increase in radiolysis. DOE stated that the preliminary assessment (calculation) of radiolysis effects from a criticality event will be available to NRC during February 2001. The final assessment of these conditions will be available to NRC prior to LA.	Received
CLST.5.06	ENG2	Provide a "what-if" analysis to evaluate the impact of an early criticality assuming a waste package failure. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete
CLST.5.06	ENG1	Provide a "what-if" analysis to evaluate the impact of an early criticality assuming a waste package failure. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete
CLST.5.06	TSPAI	Provide a "what-if" analysis to evaluate the impact of an early criticality assuming a waste package failure. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete
CLST.5.07	TSPAI	Provide sensitivity analyses that will include the most significant probability/consequence criticality scenarios. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete
CLST.5.07	ENG4	Provide sensitivity analyses that will include the most significant probability/consequence criticality scenarios. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete
CLST.5.07	ENG1	Provide sensitivity analyses that will include the most significant probability/consequence criticality scenarios. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete
CLST.5.07	ENG2	Provide sensitivity analyses that will include the most significant probability/consequence criticality scenarios. DOE stated that it would provide the requested analyses prior to LA. Actual schedule to be provided pending DOE planning process.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
CLST.6.01	ENG1	Provide documentation for the path forward items in the "Subissue 6: Alternate EBS Design Features - Effect on Container Lifetime" presentation, slides 7 & 8. [perform more sensitivity measurements of general corrosion rates - same approach as taken for Alloy 22; confirm no deleterious effects of fluoride ion and trace heavy metal ions in water on corrosion behavior of titanium - similar approach to that taken in electrochemically based studies on Alloy 22; establish damaging hydrogen levels in titanium alloys - Grade 2 vs Grades 7 and 16 vs Grade 5 and 24 - evaluate hydrogen charged notched tensile speciems and hydrogen pickup of galvanically coupled LTCTF specimens; conduct SCC testing of titanium, similar to approach taken for Alloy 22; confirm intergranular or internal oxidation of titanium is not applicable under YM thermal and environmental conditions] DOE stated that the documentation of the path forward items will be completed and as results become available, they will documented in the revisions of AMRs (ANL-EBS-MD-000005, Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Structural Material, and ANL-EBS-MD-000004, General Corrosion and Localized Corrosion of the Drip Shield), to be completed by LA.	Received
CLST.6.02	ENG1	Provide additional justification for the use of a 400 ppm hydrogen criterion or perform a sensitivity analysis using a lower value. DOE stated that additional justification will be found in the report "Review of Expected Behaviour of Alpha Titanium Alloys under Yucca Mountain Condition" TDR-EBS-MD-000015, which is in preparation and will be available in January 2001.	Received
CLST.6.03	ENG1	Provide the technical basis for the assumed fraction of hydrogen absorbed into titanium as a result of corrosion. DOE stated that additional justification will be found in the report "Review of Expected Behaviour of Alpha Titanium Alloys under Yucca Mountain Condition" TDR-EBS-MD-000015, which is in preparation and will be available in January 2001.	Received
CLST.6.04	ENG1	Provide temperature distribution (CCDF) of the drip shield as a function of time under the current EBS design. DOE stated that the temperature distribution will be provided in the next revision of the AMR, ANL-EBS-MD-000049, Rev 00, ICN 01, which will be available in January 2001.	Complete
CLST.6.04	PRE	Provide temperature distribution (CCDF) of the drip shield as a function of time under the current EBS design. DOE stated that the temperature distribution will be provided in the next revision of the AMR, ANL-EBS-MD-000049, Rev 00, ICN 01, which will be available in January 2001.	Complete
ENFE.1.01	ENG3	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 17 FEPs associated with Subissue 1 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Complete
ENFE.1.01	TSPAI	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 17 FEPs associated with Subissue 1 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Complete

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ENFE.1.02	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Complete
ENFE.1.03	UZ2	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02, including (1) 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 and (2) documentation of model validation consistent with the DOE QA requirements. The DOE will provide documentation of model validation, consistent with the DOE QA requirements, in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01, expected to be available to the NRC in March 2001. The 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 (DST and THC Seepage) Models AMR Rev 02, expected to be available to the NRC in FY 02.	Received
ENFE.1.03	ENG3	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02, including (1) 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 and (2) documentation of model validation consistent with the DOE QA requirements. The DOE will provide documentation of model validation, consistent with the DOE QA requirements, in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01, expected to be available to the NRC in March 2001. The 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 (DST and THC Seepage) Models AMR Rev 02, expected to be available to the NRC in FY 02.	Received
ENFE.1.04	UZ2	Provide additional technical bases for the DOE's treatment of the effects of cementitious materials on hydrologic properties. The DOE will provide additional information on the effects of cementitious materials in an update to the Unsaturated Zone Flow and Transport PMR (TDR-NBS-HS-000002), available in FY 02. Information provided will include results of evaluation of the magnitude of potential effects on hydrologic properties and radionuclide transport characteristics of the unsaturated zone.	Received
ENFE.1.04	ENG3	Provide additional technical bases for the DOE's treatment of the effects of cementitious materials on hydrologic properties. The DOE will provide additional information on the effects of cementitious materials in an update to the Unsaturated Zone Flow and Transport PMR (TDR-NBS-HS-000002), available in FY 02. Information provided will include results of evaluation of the magnitude of potential effects on hydrologic properties and radionuclide transport characteristics of the unsaturated zone.	Received
ENFE.1.05	UZ2	Address the various sources of uncertainty (e.g., model implementation, conceptual model, and data uncertainty (hydrologic, thermal, and geochemical)) in the THC model. The DOE will evaluate the various sources of uncertainty in the THC process model, including details as to how the propagation of various sources of uncertainty are calculated in a systematic uncertainty analysis. The DOE will document that uncertainty evaluation in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 02 (or in another future document), expected to be available in FY 02.	Received
ENFE.1.05	ENG3	Address the various sources of uncertainty (e.g., model implementation, conceptual model, and data uncertainty (hydrologic, thermal, and geochemical)) in the THC model. The DOE will evaluate the various sources of uncertainty in the THC process model, including details as to how the propagation of various sources of uncertainty are calculated in a systematic uncertainty analysis. The DOE will document that uncertainty evaluation in the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 02 (or in another future document), expected to be available in FY 02.	Received

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ENFE.1.06	TSPAI	Provide the technical basis for excluding entrained colloids in the analysis of FEP 2.2.10.06.00 (Thermo-Chemical Alteration) or an alternative FEP. The DOE will provide the technical basis for screening entrained colloids in the analysis of FEP 2.2.10.06.00 in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02.	Received
ENFE.1.06	ENG3	Provide the technical basis for excluding entrained colloids in the analysis of FEP 2.2.10.06.00 (Thermo-Chemical Alteration) or an alternative FEP. The DOE will provide the technical basis for screening entrained colloids in the analysis of FEP 2.2.10.06.00 in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02.	Received
ENFE.1.07	ENG3	Provide physical evidence that supports the model of matrix fracture interaction precipitation effects (e.g., coring). The DOE will provide the following evidence that supports the model of matrix/fracture interaction precipitation effects: (1) Existing data from the Single Heater Test (SHT) of post-test overcoring Mineralogy-Petrology (Min-Pet) analysis (SHT final report [MOL.20000103.0634] and DTN LASL831151.AQ98.001) is expected to be provided to the NRC in March 2001. (2) Results of ongoing side-wall sampling Min-Pet analyses of DST samples are expected to be provided to the NRC in FY 02. (3) The DOE expects to provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01 to the NRC as evidence of matrix-fracture interaction in March 2001.	Received
ENFE.2.01	ENG3	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 24 FEPs associated with Subissue 2 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Complete
ENFE.2.01	TSPAI	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 24 FEPs associated with Subissue 2 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Complete
ENFE.2.02	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Complete
ENFE.2.03	ENG3	Provide the technical basis for FEP 1.2.06.00 (Hydrothermal Activity), addressing points (a) through (e) of NRC Subissue 2 slide handed out at the January 2001 ENFE technical exchange. The DOE will provide additional technical bases for the screening of FEP 1.2.06.00 (Hydrothermal Activity), in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02. Within these technical bases, the DOE will address NRC comments [points (a) through (e)] presented on the NRC Subissue 2 slide handed out at the January 2001 ENFE technical exchange or provide justification that it is not needed.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
ENFE.2.03	TSPAI	Provide the technical basis for FEP 1.2.06.00 (Hydrothermal Activity), addressing points (a) through (e) of NRC Subissue 2 slide handed out at the January 2001 ENFE technical exchange. The DOE will provide additional technical bases for the screening of FEP 1.2.06.00 (Hydrothermal Activity), in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02. Within these technical bases, the DOE will address NRC comments [points (a) through (e)] presented on the NRC Subissue 2 slide handed out at the January 2001 ENFE technical exchange or provide justification that it is not needed.	Received
ENFE.2.04	ENG1	Provide the technical basis for bounding the trace elements and fluoride for the geochemical environment affecting the drip shield and waste package, including the impact of engineered materials. The DOE will document the concentrations of trace elements and fluoride in waters that could contact the drip shield and waste package in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), which will be available in FY02. In addition, trace elements and fluoride concentrations in introduced materials in the EBS (including cement grout, structural steels, and other materials as appropriate) will be addressed in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY 02.	Complete
ENFE.2.04	ENG3	Provide the technical basis for bounding the trace elements and fluoride for the geochemical environment affecting the drip shield and waste package, including the impact of engineered materials. The DOE will document the concentrations of trace elements and fluoride in waters that could contact the drip shield and waste package in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), which will be available in FY02. In addition, trace elements and fluoride concentrations in introduced materials in the EBS (including cement grout, structural steels, and other materials as appropriate) will be addressed in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY 02.	Complete
ENFE.2.05	ENG3	Evaluate data and model uncertainties for specific in-drift geochemical environment submodels used in TSPA calculations and propagate those uncertainties following the approach described in Agreement #5, Subissue 1. The DOE will evaluate data and model uncertainties for specific in-drift geochemical environment submodels used in TSPA calculations and propagate those uncertainties following the approach described in Subissue 1, Agreement #5. The DOE will document the evaluation in an update to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033) (or in another future document), expected to be available in FY 02.	Received
ENFE.2.06	ENG3	Evaluate 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. This evaluation will be documented in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY 02.	Received
ENFE.2.07	ENG3	Identify specific coupling relationships that are included and excluded from TSPA, including Onsager couples, and give technical bases for their inclusion or exclusion. The DOE will identify specific coupling relationships that are included and excluded from TSPA, including Onsager couples, and give the technical basis for inclusion and exclusion. This information will be documented in a revision to the Engineered Barrier System Degradation, Flow, and Transport PMR (TDR-EBS-MD-000006), expected to be available by September 2001.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
ENFE.2.08	ENG3	Provide stronger technical basis for the suppression of individual minerals predicted by equilibrium models. The DOE will provide additional technical basis for suppression of individual minerals predicted by equilibrium models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY02.	Complete
ENFE.2.09	ENG3	Provide the In-Drift Precipitates/Salts Analysis AMR, Rev. 00, ICN 02, including (1) the major anionic (e.g., fluoride or chloride) and cationic species, and (2) additional technical basis for the low relative humidity model. The DOE will provide the In-Drift Precipitates/Salts Analysis AMR (ANL-EBS-MD-000045), Rev. 00, ICN 02, including the major anionic (e.g., fluoride or chloride) and cationic species, in January 2001. The DOE will provide to the NRC an update to the In-Drift Precipitates/Salts Analysis AMR (ANL-EBS-MD-000045) that will provide additional technical bases for the low relative humidity model, expected to be available in FY 02.	Complete
ENFE.2.10	ENG3	Provide additional information about the range of composition of waters that could contact the drip shield or waste package, including whether such waters are of the bicarbonate or chloride-sulfate type. The DOE will describe the range of bulk composition for waters that could affect corrosion of the drip shield or waste package outer barrier, in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), expected to be	Received
ENFE.2.11	ENG3	Provide the technical basis for the current treatment of the kinetics of chemical processes in the in-drift geochemical models. This basis should address data in the figure on page 16 of the G.Gdowski Subissue 2 presentation with appropriate treatment of time as related to abstractions used in TSPA. 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 AMR (ANL-EBS-MD-000033), expected to be available in FY02. 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 TSPA.	Complete
ENFE.2.12	ENG3	Provide the documentation and analysis of the column crush tuff experiments. The DOE will provide documentation of the results obtained from the crushed tuff hydrothermal column experiment, and of post-test analysis, in new reports specific to the column test, expected to be available by September 2001.	Complete
ENFE.2.13	ENG3	Provide documentation regarding the deposition of dust and its impact on the salt analysis. The DOE will provide documentation of dust sampling in the Exploratory Studies Facility, and analysis of the dust and evaluation of its impact on the chemical environment on the surface of the drip shield and waste package, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033), expected to be available in FY02.	Received
ENFE.2.14	ENG1	Provide the analysis of laboratory solutions that have interacted with introduced materials. The DOE will provide additional information about laboratory solutions that have interacted with introduced materials, in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), expected to be available in FY02.	Complete
ENFE.2.14	ENG3	Provide the analysis of laboratory solutions that have interacted with introduced materials. The DOE will provide additional information about laboratory solutions that have interacted with introduced materials, in a revision to the Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR (ANL-EBS-MD-000001), expected to be available in FY02.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
ENFE.2.15	ENG3	Provide the additional data to constrain the interpolative low relative humidity salts model. The data should provide the technical basis as to why the assumption of the presence of sodium nitrate is conservative, when modeling and experimental results indicate the presence of other mineral phases for which the deliquesence point is unknown. The DOE will provide additional information to constrain the low-relative humidity salts model. The information will include the deliquescence behavior of mineral assemblages derived from alternative starting water compositions (including bulk water compositions, and local variations associated with cement leaching or the presence of corrosion products) representing the range of potential water compositions in the emplacement drifts. This information will be documented in a revision to the In-Drift Precipitates/Salts Analysis AMR (ANL-EBS-MD-000045), expected to be available in FY02.	Complete
ENFE.2.16	ENG3	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models, Rev. 01, including information supporting both the limited suite mineral model and the more complete extended model. The DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01, including information supporting both the limited suite mineral model and the more complete extended model, in March 2001.	Complete
ENFE.2.17	ENG3	Provide documentation of data used to calibrate models and data to support model predictions, and an assessment of data uncertainty (e.g., sampling and analytical), that includes critical analyses of variables that affect the data measurements and their interpretations (e.g., drift-scale thermal test and evaporation tests). The DOE will provide documentation of data used to calibrate models and data to support model predictions, and an assessment of data uncertainty (e.g., sampling and analytical) in the area of water and gas chemistry from the drift-scale thermal tests and evaporation tests. This documentation will be provided in revisions to the following AMRs: Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier (ANL-EBS-MD-000001), Engineered Barrier System: Physical and Chemical Environment Model (ANL-EBS-MD-000033), and Drift-Scale Coupled Processes (DST and THC Seepage) Models (MDL-NBS-HS-000001), or other documents as appropriate. All documents or revisions are expected to be available in FY 02.	Received
ENFE.2.18	ENG3	The NRC and DOE agreed the following documents would be provided with the schedule indicated: Engineered Barrier System: Physical and Chemical Environment Model (ANL-EBS-MD-000033) Rev. 01: FY 02; Multiscale Thermohydrologic Model (ANL-EBS-MD-000049) Rev. 00, ICN 01: January 2001;Abstraction of Drift-Scale Coupled Processes (ANL-NBS-HS-000029) Rev 01: September 2001; Environment on the Surfaces of the Drip Shield and the Waste Package Outer Barrier (ANL-EBS-MD-000001) Rev. 00, ICN 01: January 2001; Waste Package Degradation PMR (TDR-WIS-MD-000002) Rev. 00, ICN 01: January 2001; Engineered Barrier System Degradation, Flow, and Transport PMR (TDR-EBS-MD-000006) Rev. 01: September 2001; Near Field Environment PMR (TDR-NBS-MD-000001) Rev. 00, ICN 02: January 2001 and Rev. 01: September 2001; Hydrogen Induced Cracking of Drip Shield (ANL-EBS-MD-000006) Rev. 00, ICN 01: January 2001; Drift Degradation Analysis (ANL-EBS-MD-000027) Rev. 01: January 2001; Design Analysis for the Ex-Container Components, ANL-XCS-ME-000001 Rev. 00: January 2001; Longevity of Emplacement Drift Ground Support Materials (ANL-EBS-GE-000003) Rev. 01: January 2001; Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) Rev. 00, ICN 01: January 2001; In-Drift Microbial Communities (ANL-EBS-MD-000038) Rev. 00, ICN 01: January 2001; Physical and Chemical Environmental Abstraction Model (ANL-EBS-MD-000046) Rev. 00, ICN 01: January 2001; Unsaturated Zone Flow and Transport Model PMR (TDR-NBS-HS-000002) Rev. 01: September 2001; General Corrosion and Localized Corrosion of the Drip Shield (ANL-EBS-MD-000004) Rev. 00: January 2001; Water Distribution and Removal Model (ANL-EBS-MD-000032) Rev. 01: January 2001.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
ENFE.3.01	ENG1	The NRC and DOE agreed the following documents would be provided in February 2001: WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001) Rev 00 ICN 01; Near Field Environment PMR (TDR-NBS-MD-000001) Rev 00 ICN 03; Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050) Rev 01; Calculation of General Corrosion Rate of Drip Shield and Waste Package Outer Barrier to Support WAPDEG Analysis (CAL-EBS-PA-000002) Rev 01; Abstraction of Models for Stainless Steel Structural Material Degradation (ANL-EBS-PA-000005) Rev 00; In-Package Chemistry Abstraction AMR (ANL-EBS-MD-000037) Rev 01; Total System Performance Assessment for the Site Recommendation (TDR-WIS-PA-000001) Rev 00; Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary AMR (ANL-WIS-MD-000012) Rev 00 ICN 01	Complete
ENFE.3.01	ENG3	The NRC and DOE agreed the following documents would be provided in February 2001: WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001) Rev 00 ICN 01; Near Field Environment PMR (TDR-NBS-MD-000001) Rev 00 ICN 03; Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050) Rev 01; Calculation of General Corrosion Rate of Drip Shield and Waste Package Outer Barrier to Support WAPDEG Analysis (CAL-EBS-PA-000002) Rev 01; Abstraction of Models for Stainless Steel Structural Material Degradation (ANL-EBS-PA-000005) Rev 00; In-Package Chemistry Abstraction AMR (ANL-EBS-MD-000037) Rev 01; Total System Performance Assessment for the Site Recommendation (TDR-WIS-PA-000001) Rev 00; Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary AMR (ANL-WIS-MD-000012) Rev 00 ICN 01	Complete
ENFE.3.02	ENG3	Provide the thermodynamic database and the report associated with the database. The DOE will provide the thermodynamic data base [Input Transmittal for Thermodynamic Data Input Files for Geochemical Calculations (MO0009THRMODYN.001)] and Data Qualification Report for the Thermodynamic Data File, DATA0.ympR0 for Geochemical Code EQ 3/6 (TDR-EBS-MD-000012) to the NRC in February 2001.	Complete
ENFE.3.03	ENG3	Provide analyses to verify that bulk-scale chemical processes dominate the in-package chemical environment. The DOE will provide analyses justifying the use of bulk chemistry as opposed to local chemistry for solubility and waste form degradation models. These analyses will be documented in an update to the Miscellaneous Waste-Form FEPs AMR (ANL-WIS-MD-000009) or in an update to the Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050), expected to be available in FY 02.	Received
ENFE.3.03	ENG4	Provide analyses to verify that bulk-scale chemical processes dominate the in-package chemical environment. The DOE will provide analyses justifying the use of bulk chemistry as opposed to local chemistry for solubility and waste form degradation models. These analyses will be documented in an update to the Miscellaneous Waste-Form FEPs AMR (ANL-WIS-MD-000009) or in an update to the Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050), expected to be available in FY 02.	Received
ENFE.3.04	ENG4	Complete validation of in-package chemistry models. Agreement #5 for CLST subissue 3 addresses testing plans. Model validation based on this testing and further analysis will be documented in an update to the Summary of In-Package Chemistry for Waste Forms AMR (ANL-EBS-MD-000050), expected to be available in FY 02.	Received
ENFE.3.05	UZ3	Provide the technical basis for selection of radionuclides that are released via reversible and irreversible attachment to colloids for different waste forms in the TSPA. The technical bases for the selection of radionuclides released via reversible and irreversible attachments to colloids for different waste forms is provided in section 3.5.6.1 of the Total System Performance Assessment (TSPA) Model for Site Recommendation (MDL-WIS-PA-000002) Rev 00. This document will be provided to the NRC in January 2001.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
ENFE.3.05	ENG3	Provide the technical basis for selection of radionuclides that are released via reversible and irreversible attachment to colloids for different waste forms in the TSPA. The technical bases for the selection of radionuclides released via reversible and irreversible attachments to colloids for different waste forms is provided in section 3.5.6.1 of the Total System Performance Assessment (TSPA) Model for Site Recommendation (MDL-WIS-PA-000002) Rev 00. This document will be provided to the NRC in January 2001.	Received
ENFE.3.05	ENG4	Provide the technical basis for selection of radionuclides that are released via reversible and irreversible attachment to colloids for different waste forms in the TSPA. The technical bases for the selection of radionuclides released via reversible and irreversible attachments to colloids for different waste forms is provided in section 3.5.6.1 of the Total System Performance Assessment (TSPA) Model for Site Recommendation (MDL-WIS-PA-000002) Rev 00. This document will be provided to the NRC in January 2001.	Received
ENFE.4.01	ENG3	Provide the executable version of the most recently qualified version of TOUGHREACT. The DOE will provide the executable TOUGHREACT Rev 2.2 to the NRC by February 2001, subject to the NRC obtaining any applicable agreement for usage of the software.	Complete
ENFE.4.02	ENG3	Provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR, Rev. 01 and 02. The DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR (MDL-NBS-HS-000001) Rev 01 to the NRC in March 2001. The DOE will provide the Drift-Scale Coupled Processes (DST and THC Seepage) Models AMR Rev 02 to the NRC in FY 02.	Received
ENFE.4.03	ENG3	Provide the technical bases for screening out coupled THC effects on radionuclide transport properties and colloids. The DOE will provide the technical bases for screening out coupled THC effects on radionuclide transport properties and colloids in a new AMR or in a revision to an existing AMR, expected to be available in FY 02.	Received
ENFE.4.03	TSPAI	Provide the technical bases for screening out coupled THC effects on radionuclide transport properties and colloids. The DOE will provide the technical bases for screening out coupled THC effects on radionuclide transport properties and colloids in a new AMR or in a revision to an existing AMR, expected to be available in FY 02.	Received
ENFE.4.04	ENG3	Provide the technical basis for excluding entrained colloids in the analysis of FEP 2.2.10.06.00 (Thermo-Chemical Alteration) or an alternative FEP. The DOE will provide the technical basis for screening entrained colloids in the analysis of FEP 2.2.10.06.00 in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02.	Received
ENFE.4.04	TSPAI	Provide the technical basis for excluding entrained colloids in the analysis of FEP 2.2.10.06.00 (Thermo-Chemical Alteration) or an alternative FEP. The DOE will provide the technical basis for screening entrained colloids in the analysis of FEP 2.2.10.06.00 in a future revision of the Features, Events, and Processes in UZ Flow and Transport AMR (ANL-NBS-MD-000001), expected to be available in FY 02.	Received
ENFE.4.05	TSPAI	Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR Inventory Abstraction (ANL-WIS-MD-000006) Rev 00, ICN 01. The DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR Colloid-Associated Concentration Limits: Abstraction and Summary (ANL-WIS-MD-000012) Rev 0, in the Total System Performance Assessment for the Site Recommendation (TDR-WIS-PA-000001) Rev 00 ICN 01, and in the Total System Performance Assessment (TSPA) Model for Site Recommendation (MDL-WIS-PA-000002) Rev 00. These documents will be available to the NRC in January 2001.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
ENFE.4.06	TSPAI	Provide documentation to demonstrate suitability of the bounding values used for colloid transport through the perturbed near-field environment. For example, consider sensitivity analyses to investigate the effects of varying colloid sorption parameters (Kc) on repository performance. The DOE will evaluate the suitability of the colloid transport model under perturbed conditions as discussed in agreement #3 for this subissue. As part of this work, the DOE will consider sensitivity analyses to investigate the effects of varying colloid sorption parameters (Kc) on repository performance. The DOE will also provide the TSPA-SR (TDR-WIS-PA-000001) Rev 00 ICN 01 in January 2001. The TSPA-SR includes sensitivity studies in the form of barrier degradation and parameter sensitivity analyses that investigate the effect of sorption and colloid parameters on repository performance.	Received
ENFE.4.06	ENG4	Provide documentation to demonstrate suitability of the bounding values used for colloid transport through the perturbed near-field environment. For example, consider sensitivity analyses to investigate the effects of varying colloid sorption parameters (Kc) on repository performance. The DOE will evaluate the suitability of the colloid transport model under perturbed conditions as discussed in agreement #3 for this subissue. As part of this work, the DOE will consider sensitivity analyses to investigate the effects of varying colloid sorption parameters (Kc) on repository performance. The DOE will also provide the TSPA-SR (TDR-WIS-PA-000001) Rev 00 ICN 01 in January 2001. The TSPA-SR includes sensitivity studies in the form of barrier degradation and parameter sensitivity analyses that investigate the effect of sorption and colloid parameters on repository performance.	Received
ENFE.4.07	TSPAI	Provide updated FEPs AMRs with additional technical bases for those FEPs previously identified by the NRC in Rev. 03 of the ENFE IRSR as inadequately screened. In Rev 03 of the ENFE IRSR, the NRC identified 17 FEPs associated with Subissue 1 for which no screening arguments were identified in the FEPs data base, screening arguments were inconsistent with other project documents, or inadequate exclusion arguments were provided. The lack of screening arguments has been addressed in Rev 00 of the FEPs data base and Rev 00 of the supporting AMRs. Current revisions (or ICNs) of the FEPs AMRs, scheduled for completion in January 2001, will partially address the remaining NRC comments. Consideration of the remaining NRC comments will be provided in subsequent FEPs AMR revisions, expected to be available as periodic revisions, the entirety of which will be available prior to license application.	Complete
ENFE.4.08	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Complete
ENFE.5.01	TSPAI	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
ENFE.5.01	ENG3	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
ENFE.5.02	TSPAI	Provide the updated FEPs database. DOE stated that it would provide the FEPs AMRs and the FEPs database to NRC during January 2001.	Complete
ENFE.5.03	ENG1	Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
GEN.1.01	ENG4	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	UZ2	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	SZ1	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	UZ3	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	ENG3	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	ENG2	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	ENG1	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
GEN.1.01	SZ2	For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.	Partly Received
IA.1.01	TSPAI	In addition to DOE's licensing case, include for Site Recommendation and License Application, for information purposes, the results of a single point sensitivity analysis for extrusive and intrusive igneous processes at 10E-7. DOE agreed that the analysis will be included in TSPA-SR Rev. 0 and will be available to the NRC in November 2000.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
IA.1.01	DIRECT1	In addition to DOE's licensing case, include for Site Recommendation and License Application, for information purposes, the results of a single point sensitivity analysis for extrusive and intrusive igneous processes at 10E-7. DOE agreed that the analysis will be included in TSPA-SR Rev. 0 and will be available to the NRC in November 2000.	Complete
IA.1.02	DIRECT1	Examine new aeromagnetic data for potential buried igneous features (see U.S. Geological Survey, Open-File Report 00-188, Online Version 1.0), and evaluate the effect on the probability estimate. If the data survey specifications are not adequate for this use, this action is not required. DOE agreed and will document the results of the evaluation in an update to the AMR, Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (ANL-MGR-GS-000001), expected to be available in FY 2003.	Received
IA.1.02	TSPAI	Examine new aeromagnetic data for potential buried igneous features (see U.S. Geological Survey, Open-File Report 00-188, Online Version 1.0), and evaluate the effect on the probability estimate. If the data survey specifications are not adequate for this use, this action is not required. DOE agreed and will document the results of the evaluation in an update to the AMR, Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (ANL-MGR-GS-000001), expected to be available in FY 2003.	Received
IA.2.01	DIRECT2	Re-examine the ASHPLUME Code to confirm that particle density is appropriately changed when waste particles are incorporated into the ash. (Eruptive AC-4) DOE agreed and will correct the description in the ICN to AMR, Igneous Consequences Modeling for TSPA-SR [ANL-WIS-MD-000017] as needed to address the concern. This will be available to the NRC in January 2001.	Complete
IA.2.02	DIRECT2	Document results of sensitivity studies for particle size, consistent with (1) above. (Eruptive AC-4) DOE agreed and will document the waste particle size sensitivity study in a calculation document. This will be available to the NRC in FY2002.	Complete
IA.2.03	DIRECT2	Document how the tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanos. (Eruptive AC-1) DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in FY2002.	Received
IA.2.04	DIRECT2	Document that the ASHPLUME model, as used in the DOE performance assessment, has been compared with an analog igneous system. (Eruptive AC-2) DOE agreed and will complete calculation CAL-WIS-MD-000011 that will document a comparison of the ASHPLUME code results to observed data from the 1995 Cerro Negro eruption. This will be available to the NRC in January 2001. DOE will consider Cerro Negro as an analog and document that in the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in FY2002.	Complete
IA.2.05	DIRECT1	Document how the current approach to calculating the number of waste packages intersected by conduits addresses potential effects of conduit elongation along a drift. (Eruptive AC-3) DOE agreed and will document the way in which the change in geometry of the repository drifts affects the number of waste packages incorporated into the volcanic conduit. Possible consequences of conduit elongation parallel to drifts will be documented in TSPA-SR Rev. 1, available to the NRC in June 2001.	Complete
IA.2.06	DOSE3	Develop a linkage between soil removal rate used in TSPA and surface remobilization processes characteristics of the Yucca Mountain region (which includes additions and deletions to the system). (Eruptive AC-5) DOE agreed and will document its approach to include uncertainty related to surface-redistribution processes in TSPA-SR, Rev. 0. DOE will revisit the approach in TSPA-SR, Rev. 1. This documentation will be available to the NRC in June 2001.	Complete
IA.2.06	DOSE2	Develop a linkage between soil removal rate used in TSPA and surface remobilization processes characteristics of the Yucca Mountain region (which includes additions and deletions to the system). (Eruptive AC-5) DOE agreed and will document its approach to include uncertainty related to surface-redistribution processes in TSPA-SR, Rev. 0. DOE will revisit the approach in TSPA-SR, Rev. 1. This documentation will be available to the NRC in June 2001.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
IA.2.07	DOSE3	Document the basis for airborne particle concentrations used in TSPA in Rev. 1 to the Input Values for External and Inhalation Radiation Exposure AMR. (Eruptive AC-5) DOE agreed and will provide documentation for the input values in the Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to NRC in January 2001.	Complete
IA.2.07	DOSE2	Document the basis for airborne particle concentrations used in TSPA in Rev. 1 to the Input Values for External and Inhalation Radiation Exposure AMR. (Eruptive AC-5) DOE agreed and will provide documentation for the input values in the Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to NRC in January 2001.	Complete
IA.2.08	DOSE2	Provide additional justification on the reasonableness of the assumption that the inhalation of particles in the 10-100 micron range is treated as additional soil ingestion, or change the BDCFs to reflect ICRP-30. (Eruptive AC-5) DOE agreed and will review how 10-100 micron particles are considered in the model for the eruptive scenario. The results will be documented in Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to the NRC in January 2001.	Complete
IA.2.08	DOSE3	Provide additional justification on the reasonableness of the assumption that the inhalation of particles in the 10-100 micron range is treated as additional soil ingestion, or change the BDCFs to reflect ICRP-30. (Eruptive AC-5) DOE agreed and will review how 10-100 micron particles are considered in the model for the eruptive scenario. The results will be documented in Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to the NRC in January 2001.	Complete
IA.2.09	DIRECT2	Use the appropriate wind speeds for the various heights of eruption columns being modeled. (Eruptive AC-5) DOE agreed and will evaluate the wind speed data appropriate for the height of the eruptive columns being modeled. This will be documented in a calculation document. This will be available to the NRC in FY2002.	Received
IA.2.10	ENG2	Document the ICNs to the Igneous Consequences AMR and the Dike Propagation AMR regarding the calculation of the number of waste packages hit by the intrusion. Include in these or other documents (1) the intermediate results of the releases from Zone 1 and 2, separately, and (2) the evaluation of thermal and mechanical effects, as well as shock, in assessing the degree of waste package damage in Zone 1 and 2. (Intrusive AC 4) DOE agreed and will provide ICN 1 of the following AMRs: Igneous Consequences Modeling for TSPA-SR AMR [ANL-WIS-MD-000017], the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015], the Characterize Framework for Igneous Activity at Yucca Mountain, Nevada AMR [ANL-MGR-GS-000001], and the Calculation Number of Waste Packages Hit by Igneous Intrusion [CAL-WIS-PA-000001]. This will be available to the NRC in January 2001. DOE will provide the results showing the relative contributions of releases from Zones 1 and 2 in a calculation document. This will be available to the NRC in FY2002. DOE will provide the evaluation of thermal mechanical effects on waste package damage in Zones 1 and 2 in ICN 1 of the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015]. This will be available to the NRC in January 2001.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
IA.2.10	DIRECT1	Document the ICNs to the Igneous Consequences AMR and the Dike Propagation AMR regarding the calculation of the number of waste packages hit by the intrusion. Include in these or other documents (1) the intermediate results of the releases from Zone 1 and 2, separately, and (2) the evaluation of thermal and mechanical effects, as well as shock, in assessing the degree of waste package damage in Zone 1 and 2. (Intrusive AC 4) DOE agreed and will provide ICN 1 of the following AMRs: Igneous Consequences Modeling for TSPA-SR AMR [ANL-WIS-MD-000017], the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015], the Characterize Framework for Igneous Activity at Yucca Mountain, Nevada AMR [ANL-MGR-GS-000001], and the Calculation Number of Waste Packages Hit by Igneous Intrusion [CAL-WIS-PA-000001]. This will be available to the NRC in January 2001. DOE will provide the results showing the relative contributions of releases from Zones 1 and 2 in a calculation document. This will be available to the NRC in FY2002. DOE will provide the evaluation of thermal mechanical effects on waste package damage in Zones 1 and 2 in ICN 1 of the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015]. This will be available to the NRC in January 2001.	Complete
IA.2.11	DOSE2	Provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group. DOE will provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Need Additional Information
IA.2.11	DOSE3	Provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group. DOE will provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Need Additional Information
IA.2.12	DOSE2	Provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This should include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions. DOE will provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This will include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.12	DOSE3	Provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This should include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions. DOE will provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This will include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.13	DOSE2	Provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes. DOE will provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
IA.2.13	DOSE3	Provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes. DOE will provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.14	DOSE2	Provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period. DOE will provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.14	DOSE3	Provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period. DOE will provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.15	DOSE2	Clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. Include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters. DOE will clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. DOE will include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.15	DOSE3	Clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. Include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters. DOE will clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. DOE will include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.16	DOSE2	Document that neglecting the effects of climate change on disruptive event BDCFs is conservative. DOE will document that neglecting the effects of climate change on disruptive event BDCFs is conservative in a subsequent revision to the AMRs Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) and Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or equivalent document. This will be available to the NRC in FY02.	Complete
IA.2.16	DOSE3	Document that neglecting the effects of climate change on disruptive event BDCFs is conservative. DOE will document that neglecting the effects of climate change on disruptive event BDCFs is conservative in a subsequent revision to the AMRs Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) and Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or equivalent document. This will be available to the NRC in FY02.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
IA.2.17	DOSE2	DOE will evaluate conclusions that the risk effects (i.e., effective annual dose) of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR, Rev 00, ICN1. DOE will examine rates of eolian and fluvial mobilization off slopes, rates of transport in Fortymile Wash, and rates of deposition or removal at proposed critical group location. DOE will evaluate changes in grain size caused by these processes for effects on airborne particle concentrations. DOE will also evaluate the inherent assumption in the mass loading model that the concentration of radionuclides on soil in the air is equivalent to the concentration of radionuclides on soil on the ground does not underestimate dose (i.e., radionuclides important to dose do not preferentially attach to smaller particles). DOE will provide the justification for the range of transition BDCFs sampled. DOE will document the results of investigations in the AMR, Eruptive Processes and Soil Redistribution ANL-MGR-GS-000002, expected to be available in fiscal year 2003 and in the AMR, Input Parameter Values for External and Inhalation Radiation Exposure Analysis, ANL-MGR-MD-000001, available FY 2003, or another appropriate technical document.	Received
IA.2.17	DOSE3	DOE will evaluate conclusions that the risk effects (i.e., effective annual dose) of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR, Rev 00, ICN1. DOE will examine rates of eolian and fluvial mobilization off slopes, rates of transport in Fortymile Wash, and rates of deposition or removal at proposed critical group location. DOE will evaluate changes in grain size caused by these processes for effects on airborne particle concentrations. DOE will also evaluate the inherent assumption in the mass loading model that the concentration of radionuclides on soil in the air is equivalent to the concentration of radionuclides on soil on the ground does not underestimate dose (i.e., radionuclides important to dose do not preferentially attach to smaller particles). DOE will provide the justification for the range of transition BDCFs sampled. DOE will document the results of investigations in the AMR, Eruptive Processes and Soil Redistribution ANL-MGR-GS-000002, expected to be available in fiscal year 2003 and in the AMR, Input Parameter Values for External and Inhalation Radiation Exposure Analysis, ANL-MGR-MD-000001, available FY 2003, or another appropriate technical document.	Received
IA.2.18	DIRECT1	DOE will evaluate how the presence of repository structures may affect magma ascent, conduit localization, and evolution of the conduit and flow system. The evaluation will include the potential effects of topography and stress, strain response on existing or new geologic structures resulting from thermal loading of HLW, in addition to a range of physical conditions appropriate for the duration of igneous events. DOE will also evaluate how the presence of engineered repository structures in the LA design (e.g., drifts, waste packages, backfill, etc.) could affect magma flow processes for the duration of an igneous event. The evaluation will include the mechanical strength and durability of natural or engineered barriers that could restrict magma flow within intersected drifts. The results of this investigation will be documented in an update to the AMR, Dike Propagation and Interaction with Drifts, ANL-WIS-MD-000015, expected to be available in FY 2003, or another appropriate technical document.	Received
IA.2.18	ENG2	DOE will evaluate how the presence of repository structures may affect magma ascent, conduit localization, and evolution of the conduit and flow system. The evaluation will include the potential effects of topography and stress, strain response on existing or new geologic structures resulting from thermal loading of HLW, in addition to a range of physical conditions appropriate for the duration of igneous events. DOE will also evaluate how the presence of engineered repository structures in the LA design (e.g., drifts, waste packages, backfill, etc.) could affect magma flow processes for the duration of an igneous event. The evaluation will include the mechanical strength and durability of natural or engineered barriers that could restrict magma flow within intersected drifts. The results of this investigation will be documented in an update to the AMR, Dike Propagation and Interaction with Drifts, ANL-WIS-MD-000015, expected to be available in FY 2003, or another appropriate technical document.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
IA.2.19	DIRECT1	DOE will evaluate waste package response to stresses from thermal and mechanical effects associated with exposure to basaltic magma, considering the results of evaluations attendant to IA Agreement 2.18. As currently planned, the evaluation, if implemented, would include (1) appropriate at-condition strength properties and magma flow paths, for duration of an igneous event; and (2) aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event, which will include the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE will also evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gases at conditions appropriate for an igneous event, considering the results of evaluations attendant to IA Agreement 2.18. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. The results of this investigation would be documented in an update to the technical product Waste Package Behavior in Magma CAL-EBS-ME-000002, which would be available by the end of FY 2003, or another appropriate technical document.	Received
IA.2.19	ENG2	DOE will evaluate waste package response to stresses from thermal and mechanical effects associated with exposure to basaltic magma, considering the results of evaluations attendant to IA Agreement 2.18. As currently planned, the evaluation, if implemented, would include (1) appropriate at-condition strength properties and magma flow paths, for duration of an igneous event; and (2) aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event, which will include the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE will also evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gases at conditions appropriate for an igneous event, considering the results of evaluations attendant to IA Agreement 2.18. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. The results of this investigation would be documented in an update to the technical product Waste Package Behavior in Magma CAL-EBS-ME-000002, which would be available by the end of FY 2003, or another appropriate technical document.	Received
IA.2.20	DIRECT1	DOE will evaluate how ascent and flow of basaltic magma through repository structures could result in processes that might incorporate HLW, considering the results of evaluations attendant to IA Agreements 2.18 and 2.19. As currently planned, the evaluation, if implemented, would include the potential for HLW incorporation along reasonable potential flow paths that could develop during an igneous event. The evaluation would also include the physical and chemical response of HLW and cladding after heating and potential disruption of waste package and contents, for waste packages remaining in drifts. The evaluation would examine effects that may result in increased solubility potential relative to undisturbed HLW forms. The results of this investigation would be documented in a new AMR to document the waste form response to magmatic conditions, which is expected to be available by the end of FY 2003. DOE will describe the method of HLW incorporation used in DOE models, including consideration of particle aggregation and the effect on waste transport. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. This will be documented in an update to the igneous consequences AMR, ANL-WIS-MD-000017, which is expected to be available in FY 2003, or another appropriate technical document.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
IA.2.20	ENG2	DOE will evaluate how ascent and flow of basaltic magma through repository structures could result in processes that might incorporate HLW, considering the results of evaluations attendant to IA Agreements 2.18 and 2.19. As currently planned, the evaluation, if implemented, would include the potential for HLW incorporation along reasonable potential flow paths that could develop during an igneous event. The evaluation would also include the physical and chemical response of HLW and cladding after heating and potential disruption of waste package and contents, for waste packages remaining in drifts. The evaluation would examine effects that may result in increased solubility potential relative to undisturbed HLW forms. The results of this investigation would be documented in a new AMR to document the waste form response to magmatic conditions, which is expected to be available by the end of FY 2003. DOE will describe the method of HLW incorporation used in DOE models, including consideration of particle aggregation and the effect on waste transport. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. This will be documented in an update to the igneous consequences AMR, ANL-WIS-MD-000017, which is expected to be available in FY 2003, or another appropriate technical document.	Received
IA.2.20	DIRECT2	DOE will evaluate how ascent and flow of basaltic magma through repository structures could result in processes that might incorporate HLW, considering the results of evaluations attendant to IA Agreements 2.18 and 2.19. As currently planned, the evaluation, if implemented, would include the potential for HLW incorporation along reasonable potential flow paths that could develop during an igneous event. The evaluation would also include the physical and chemical response of HLW and cladding after heating and potential disruption of waste package and contents, for waste packages remaining in drifts. The evaluation would examine effects that may result in increased solubility potential relative to undisturbed HLW forms. The results of this investigation would be documented in a new AMR to document the waste form response to magmatic conditions, which is expected to be available by the end of FY 2003. DOE will describe the method of HLW incorporation used in DOE models, including consideration of particle aggregation and the effect on waste transport. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. This will be documented in an update to the igneous consequences AMR, ANL-WIS-MD-000017, which is expected to be available in FY 2003, or another appropriate technical document.	Received
RDTME.2.01	PRE	Provide Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide Seismic Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, expected to be available to the NRC in January 2002.	Received
RDTME.2.02	PRE	Provide the substantive technical content of Topical Report 3. The DOE will provide the preliminary seismic design input data sets used in Site Recommendation design analyses to the NRC by April 2001. The DOE will provide the draft final seismic design inputs for license application via an Appendix 7 meeting after calculations are complete prior to delivery of Seismic Topical Report 3.	Received
RDTME.3.01	PRE	Provide the technical basis for the range of relative humidities, as well as the potential occurrence of localized liquid phase water, and resulting affects on ground support systems. The DOE will provide the technical basis for the range of relative humidity and temperature, and the potential effects of localized liquid phase water on ground support systems, during the forced ventilation preclosure period, in the Longevity of Emplacement Drift Ground Support Materials, ANL-EBS-GE-000003 Rev 01, and revision 1 of the Ventilation Model, ANL-EBS-MD-000030, analysis and model reports. These are expected to be available to NRC in September and March 2001, respectively.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
RDTME.3.02	PRE	Provide the critical combinations of in-situ, thermal, and seismic stresses, together with their technical bases, and their impacts on ground support performance. The DOE will examine the critical combinations of in-situ, thermal, and seismic stresses, together with their technical bases and their impacts on preclosure ground support performance. These results will be documented in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.03	ENG2	Provide the Seismic Design Inputs AMR and the Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide the Seismic Design Inputs analysis and model report and Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. These documents are expected to be available to NRC in January 2002.	Received
RDTME.3.03	PRE	Provide the Seismic Design Inputs AMR and the Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide the Seismic Design Inputs analysis and model report and Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. These documents are expected to be available to NRC in January 2002.	Received
RDTME.3.04	PRE	Provide in the Design Parameter Analysis Report (or some other document) site-specific properties of the host rock, as a minimum those included in the NRC handout, together with the spatial and temporal variations and uncertainties in such properties, as an update to the information contained in the March 1997 Yucca Mountain Site Geotechnical Report. The DOE will: (1) evaluate the adequacy of the currently available measured and derived data to support the potential repository licensing case and identify areas where available data may warrant additional field measurements or testing to reduce uncertainty. DOE will provide a design parameters analysis report (or other document) that will include the results of these evaluations, expected to be available to NRC in FY 2002; and (2) acquire data and/or perform additional analyses as necessary to respond to the needs identified in 1 above. The DOE will provide these results prior to any potential license application.	Received
RDTME.3.05	PRE	Provide the Rock Mass Classification Analysis (or some other document) including the technical basis for accounting for the effects of lithophysae. The DOE will provide a rock mass classification analysis (or other document), including the technical basis for accounting for the effects of lithophysae, expected to be available to NRC in FY 2002.	Received
RDTME.3.06	PRE	Provide the design sensitivity and uncertainty analyses of the rock support system. The DOE will prepare a scoping analysis to determine the significance of the input parameters for review by NRC staff by August 2002. Once an agreed set of significant parameters has been determined by the DOE and the NRC staff, the DOE will prepare an analysis of the sensitivity and uncertainty of the preclosure rock support system to design parameters in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.07	PRE	The DOE should account for the effect of sustained loading on intact rock strength or provide justification for not accounting for it. The DOE will assess the effects of sustained loading on intact rock strength. The DOE will provide the results of this assessment in a design parameters analysis report (or other document), expected to be available to NRC in FY 2002.	Received
RDTME.3.08	PRE	Provide the design sensitivity and uncertainty analyses of the fracture pattern (with respect to Subissue 3, Component 1). The DOE will provide sensitivity and uncertainty analysis of fracture patterns (based on observed orientation, spacing, trace length, etc) on the preclosure ground control system design in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
RDTME.3.09	PRE	Provide appropriate analysis that shows that rock movements in the invert are either controlled or otherwise remain within the range acceptable to provide for retrieval and other necessary operations within the deposal drifts. 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 SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.10	PRE	Provide technical basis for the assessment that two-dimensional modeling for emplacement drifts is considered to be adequate, considering the fact that neither the in-situ stress field nor the principle fracture orientation are parallel or perpendicular to emplacement drift orientation. The DOE will provide the technical bases for the modeling methods used in ground control analysis in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.11	PRE	Provide continuum and discontinuum analyses of ground support system performance that take into account long-term degradation of rockmass and joint strength properties. The DOE will 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 SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.12	PRE	Provide dynamic analyses (discontinuum approach) of ground support system performance using site specific ground motion time history as input. The DOE will provide appropriate analyses to include dynamic analyses (discontinuum approach) of preclosure ground support systems, using site specific ground motion time histories as input, in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.13	PRE	Provide technical justification for boundary conditions used for continuum and discontinuum modeling used for underground facility design. The DOE will provide the technical justification for boundary conditions used in modeling for preclosure ground control analyses in a revision to the Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 (or other document) supporting any potential license application. This is expected to be available to NRC in FY 2003.	Received
RDTME.3.14	UZ2	Provide the results of the ventilation modeling being conducted at the University of Nevada-Reno (Multi-Flux code) and validation testing at the Atlas Facility (validation of the ventilation model based on the ANSYS code), including: 1) the technical bases for the adequacy of discretization used in these models and 2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. The DOE will provide the results of the ventilation tests in a update to the Ventilation Model, ANL-EBS-MD-000030, analysis and model report including: 1) the technical bases for the adequacy of discretization used in these models and 2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. This is expected to be available to NRC in FY 2002.	Received
RDTME.3.14	PRE	Provide the results of the ventilation modeling being conducted at the University of Nevada-Reno (Multi-Flux code) and validation testing at the Atlas Facility (validation of the ventilation model based on the ANSYS code), including: 1) the technical bases for the adequacy of discretization used in these models and 2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. The DOE will provide the results of the ventilation tests in a update to the Ventilation Model, ANL-EBS-MD-000030, analysis and model report including: 1) the technical bases for the adequacy of discretization used in these models and 2) the technical bases for the applicability of the modeling results to prediction of heat removal from the repository. This is expected to be available to NRC in FY 2002.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
RDTME.3.15	ENG2	Provide field data and analysis of rock bridges between rock joints that are treated as cohesion in DRKBA modeling together with a technical basis for how a reduction in cohesion adequately accounts for thermal effects. The DOE will provide clarification of the approach and technical basis for how reduction in cohesion adequately accounts for thermal effects, including any additional applicable supporting data and analyses. Additionally, the adequacy of the cohesion reduction approach will be verified according to the approach described in Subissue 3, Agreement 19, of the Repository Design and Thermal-Mechanical Effects Technical Exchange. This will be documented in a revision to the Drift Degradation Analysis, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003.	Received
RDTME.3.16	ENG2	Provide a technical basis for the DOE position that the method used to model joint planes as circular discs does not under-represent the smaller trace-length fractures. The DOE will analyze the available small trace-length fracture data from the Exploratory Studies Facility and Enhanced Characterization of the Repository Block, including their effect on block development. This will be documented in a revision to the Drift Degradation Analysis, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003.	Received
RDTME.3.17	ENG2	Provide the technical basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle. The DOE will provide the technical basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle. This will be documented in revisions to the Drift Degradation Analysis, ANL-EBS-MD-000027, and the Rockfall on Drip Shield, CAL-EBS-ME-000001, expected to be available to NRC in FY 2003.	Received
RDTME.3.18	ENG1	Provide a technical basis for a stress measure that can be used as the equivalent uniaxial stress for assessing the susceptibility of the various engineered barrier system materials to stress corrosion cracking (SCC). The proposed stress measure must be consistent and compatible with the methods proposed by the DOE to assess SCC of the containers in WAPDEG and in accordance with the agreements reached at the CLST Technical Exchange. The DOE will include a detailed discussion of the stress measure used to determine nucleation of stress corrosion cracks in the calculations performed to evaluate waste package barriers and the drip shield against stress corrosion cracking criterion. DOE will include these descriptions in future revisions of the following: Design Analysis for UCF Waste Packages, ANL-UDC-MD-000001, Design Analysis for the Defense High-Level Waste Disposal Container, ANL-DDC-ME-000001, Design Analysis for the Naval SNF Waste Package, ANL-UDC-ME-000001, and Design Analysis for the Ex-Container Components, ANL-XCS-ME-000001. The stresses reported in these documents will be used in WAPDEG and will be consistent with the agreements and associated schedule made at the Container Life and Source Term Technical Exchange (Subissue 1, Agreement 14, Subissue 6, Agreement 1).	Received
RDTME.3.18	ENG2	Provide a technical basis for a stress measure that can be used as the equivalent uniaxial stress for assessing the susceptibility of the various engineered barrier system materials to stress corrosion cracking (SCC). The proposed stress measure must be consistent and compatible with the methods proposed by the DOE to assess SCC of the containers in WAPDEG and in accordance with the agreements reached at the CLST Technical Exchange. The DOE will include a detailed discussion of the stress measure used to determine nucleation of stress corrosion cracks in the calculations performed to evaluate waste package barriers and the drip shield against stress corrosion cracking criterion. DOE will include these descriptions in future revisions of the following: Design Analysis for UCF Waste Packages, ANL-UDC-MD-000001, Design Analysis for the Defense High-Level Waste Disposal Container, ANL-DDC-ME-000001, Design Analysis for the Naval SNF Waste Package, ANL-UDC-ME-000001, and Design Analysis for the Ex-Container Components, ANL-XCS-ME-000001. The stresses reported in these documents will be used in WAPDEG and will be consistent with the agreements and associated schedule made at the Container Life and Source Term Technical Exchange (Subissue 1, Agreement 14, Subissue 6, Agreement 1).	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
RDTME.3.19	ENG2	The acceptability of the process models that determine whether rockfall can be screened out from performance assessment abstractions needs to be substantiated by the DOE by doing the following: (1) provide revised DRKBA analyses using appropriate range of strength properties for rock joints from the Design Analysis Parameters Report, 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 Report for the Stratigraphic Units of the Repository Host Horizon, including small joints trace lengths; (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 the Design Analysis Parameters Report; (d) long-term degradation of rock block and joint strength parameters; and (e) site-specific groundmotion time histories appropriate for post-closure period; provide a detailed documentation of the analyses results; and (4) in view of the uncertainties related to the rockfall analyses and the importance of the outcome of the analyses to the performance of the repository, evaluate the impacts of rockfall in performance assessment calculations. DOE believes 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 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, ANL-EBS-GE-000006, 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, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003. 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.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
RDTME.3.19	TSPAI	The acceptability of the process models that determine whether rockfall can be screened out from performance assessment abstractions needs to be substantiated by the DOE by doing the following: (1) provide revised DRKBA analyses using appropriate range of strength properties for rock joints from the Design Analysis Parameters Report, 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 Report for the Stratigraphic Units of the Repository Host Horizon, including small joints trace lengths; (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 the Design Analysis Parameters Report; (d) long-term degradation of rock block and joint strength parameters; and (e) site-specific groundmotion time histories appropriate for post-closure period; provide a detailed documentation of the analyses results; and (4) in view of the uncertainties related to the rockfall analyses and the importance of the outcome of the analyses to the performance of the repository, evaluate the impacts of rockfall in performance assessment calculations. DOE believes 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 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, ANL-EBS-GE-000006, 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, ANL-EBS-MD-000027, expected to be available to NRC in FY 2003. 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.	Received
RDTME.3.20	UZ2	Provide the sensitivity analyses including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation (from Subissue 3, Component 3, Slide 39). The DOE will provide sensitivity analyses of thermal-mechanical effects on fracture permeability, including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation. This will be provided consistent with site data and integrated with appropriate models in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, ANL-NBS-HS-000037, and is expected to be available to NRC in FY 2003.	Received
RDTME.3.20	ENG3	Provide the sensitivity analyses including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation (from Subissue 3, Component 3, Slide 39). The DOE will provide sensitivity analyses of thermal-mechanical effects on fracture permeability, including the effects of boundary conditions, coefficient of thermal expansion, fracture distributions, rock mass and fracture properties, and drift degradation. This will be provided consistent with site data and integrated with appropriate models in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, ANL-NBS-HS-000037, and is expected to be available to NRC in FY 2003.	Received
RDTME.3.21	UZ2	Provide the results of additional validation analysis of field tests (from Subissue 3, Component 3, Slide 39). The DOE will provide the results of additional validation analysis of field tests related to the thermal-mechanical effects on fracture permeability in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, ANL-NBS-HS-000037, and is expected to be available to NRC in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
RDTME.3.21	ENG3	Provide the results of additional validation analysis of field tests (from Subissue 3, Component 3, Slide 39). The DOE will provide the results of additional validation analysis of field tests related to the thermal-mechanical effects on fracture permeability in a future revision to the Coupled Thermal Hydrologic Mechanical Effects on Permeability, ANL-NBS-HS-000037, and is expected to be available to NRC in FY 2003.	Received
RT.1.01	UZ2	Provide the basis for the proportion of fracture flow through the Calico Hills non-welded vitric. DOE will revise the AMR UZ Flow Models and Submodels and the AMR Calibrated Properties Model to provide the technical basis for the proportion of fracture flow through the Calico Hills Nonwelded Vitric. These reports will be available to the NRC in FY 2002. In addition, the field data description will be documented in the AMR In Situ Field Testing of Processes in FY 2002.	Received
RT.1.01	UZ3	Provide the basis for the proportion of fracture flow through the Calico Hills non-welded vitric. DOE will revise the AMR UZ Flow Models and Submodels and the AMR Calibrated Properties Model to provide the technical basis for the proportion of fracture flow through the Calico Hills Nonwelded Vitric. These reports will be available to the NRC in FY 2002. In addition, the field data description will be documented in the AMR In Situ Field Testing of Processes in FY 2002.	Received
RT.1.02	UZ3	Provide analog radionuclide data from the tracer tests for Calico Hills at Busted Butte and from similar analog and radionuclide data (if available) from test blocks from Busted Butte. DOE will provide data from tracers used at Busted Butte and data from (AECL) test blocks from Busted Butte in an update to the AMR In Situ Field Testing of Processes in FY 2002.	Received
RT.1.02	SZ2	Provide analog radionuclide data from the tracer tests for Calico Hills at Busted Butte and from similar analog and radionuclide data (if available) from test blocks from Busted Butte. DOE will provide data from tracers used at Busted Butte and data from (AECL) test blocks from Busted Butte in an update to the AMR In Situ Field Testing of Processes in FY 2002.	Received
RT.1.03	UZ3	Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of the radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR Inventory Abstraction. DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary, in the TSPA-SR Technical Report, and in the TSPA-SR Model Document. These documents will be available to the NRC in January 2001.	Received
RT.1.03	SZ2	Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of the radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR Inventory Abstraction. DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary, in the TSPA-SR Technical Report, and in the TSPA-SR Model Document. These documents will be available to the NRC in January 2001.	Received
RT.1.03	TSPAI	Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of the radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR Inventory Abstraction. DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary, in the TSPA-SR Technical Report, and in the TSPA-SR Model Document. These documents will be available to the NRC in January 2001.	Received
RT.1.04	UZ3	Provide sensitivity studies on Kd for plutonium, uranium, and protactinium to evaluate the adequacy of the data. DOE will analyze column test data to determine whether, under the flow rates pertinent to the Yucca Mountain flow system, plutonium sorption kinetics are important to performance. If they are found to be important, DOE will also perform sensitivity analyses for uranium, protactinium, and plutonium to evaluate the adequacy of KD data. The results of this work will be documented in an update to the AMR Unsaturated Zone and Saturated Zone Transport Properties available to the NRC in FY 2002.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
RT.1.04	SZ2	Provide sensitivity studies on Kd for plutonium, uranium, and protactinium to evaluate the adequacy of the data. DOE will analyze column test data to determine whether, under the flow rates pertinent to the Yucca Mountain flow system, plutonium sorption kinetics are important to performance. If they are found to be important, DOE will also perform sensitivity analyses for uranium, protactinium, and plutonium to evaluate the adequacy of KD data. The results of this work will be documented in an update to the AMR Unsaturated Zone and Saturated Zone Transport Properties available to the NRC in FY 2002.	Complete
RT.1.05	SZ1	Provide additional documentation to explain how transport parameters used for performance assessment were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with DOE procedure AP-3.10Q, DOE will document how it derived the transport parameter distributions for performance assessment, in a report expected to be available in FY 2002.	Received
RT.1.05	SZ2	Provide additional documentation to explain how transport parameters used for performance assessment were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with DOE procedure AP-3.10Q, DOE will document how it derived the transport parameter distributions for performance assessment, in a report expected to be available in FY 2002.	Received
RT.1.05	UZ3	Provide additional documentation to explain how transport parameters used for performance assessment were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with DOE procedure AP-3.10Q, DOE will document how it derived the transport parameter distributions for performance assessment, in a report expected to be available in FY 2002.	Received
RT.2.01	SZ1	Provide further justification for the range of effective porosity in alluvium, considering possible effects of contrasts in hydrologic properties of layers observed in wells along potential flow paths. DOE will use data obtained from the Nye County Drilling Program, available geophysical data, aeromagnetic data, and results from the Alluvium Testing Complex testing to justify the range of effective porosity in alluvium, considering possible effects of contrasts in hydrologic properties of layers observed in wells along potential flowpaths. The justification will be provided in the Alluvial Testing Complex AMR due in FY 2003.	Complete
RT.2.01	SZ2	Provide further justification for the range of effective porosity in alluvium, considering possible effects of contrasts in hydrologic properties of layers observed in wells along potential flow paths. DOE will use data obtained from the Nye County Drilling Program, available geophysical data, aeromagnetic data, and results from the Alluvium Testing Complex testing to justify the range of effective porosity in alluvium, considering possible effects of contrasts in hydrologic properties of layers observed in wells along potential flowpaths. The justification will be provided in the Alluvial Testing Complex AMR due in FY 2003.	Complete
RT.2.02	SZ1	The DOE should demonstrate that TSPA captures the spatial variability of parameters affecting radionuclide transport in alluvium. DOE will demonstrate that TSPA captures the variability of parameters affecting radionuclide transport in alluvium. This information will be provided in the TSPA-LA document due in FY 2003.	Received
RT.2.02	SZ2	The DOE should demonstrate that TSPA captures the spatial variability of parameters affecting radionuclide transport in alluvium. DOE will demonstrate that TSPA captures the variability of parameters affecting radionuclide transport in alluvium. This information will be provided in the TSPA-LA document due in FY 2003.	Received
RT.2.02	TSPAI	The DOE should demonstrate that TSPA captures the spatial variability of parameters affecting radionuclide transport in alluvium. DOE will demonstrate that TSPA captures the variability of parameters affecting radionuclide transport in alluvium. This information will be provided in the TSPA-LA document due in FY 2003.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
RT.2.03	SZ2	Provide a detailed testing plan for alluvial testing (the ATC and Nye County Drilling Program) to reduce uncertainty (for example, the plan should give details about hydraulic and tracer tests at the well 19 complex and it should also identify locations for alluvium complex testing wells and tests and logging to be performed). NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for the October/November 2000 Saturated Zone meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. The plan will be amended to include laboratory testing. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Complete
RT.2.03	SZ1	Provide a detailed testing plan for alluvial testing (the ATC and Nye County Drilling Program) to reduce uncertainty (for example, the plan should give details about hydraulic and tracer tests at the well 19 complex and it should also identify locations for alluvium complex testing wells and tests and logging to be performed). NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for the October/November 2000 Saturated Zone meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. The plan will be amended to include laboratory testing. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Complete
RT.2.04	SZ1	The NRC needs DOE to document the pre-test predictions for the ATC. DOE will document pretest predictions for the Alluvial Testing Complex in the SZ In Situ Testing AMR available in October 2001.	Complete
RT.2.04	SZ2	The NRC needs DOE to document the pre-test predictions for the ATC. DOE will document pretest predictions for the Alluvial Testing Complex in the SZ In Situ Testing AMR available in October 2001.	Complete
RT.2.05	SZ2	Provide the laboratory testing plan for laboratory radionuclide transport studies. NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for the October/November 2000 Saturated Zone meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. The plan will be amended to include laboratory testing. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Complete
RT.2.06	SZ2	If credit is taken for retardation in alluvium, the DOE should conduct Kd testing for radionuclides important to performance using alluvium samples and water compositions that are representative of the full range of lithologies and water chemistries present within the expected flow paths (or consider alternatives such as testing with less disturbed samples, use of samples from more accessible analog sites (e.g., 40-mile Wash), detailed process level modeling, or other means). DOE will conduct Kd experiments on alluvium using samples from the suite of samples obtained from the existing drilling program; or, DOE will consider supplementing the samples available for testing from the alternatives presented by the NRC. This information will be documented in an update to the SZ In Situ Testing AMR, available in FY 2003. Kd parameter distributions for TSPA will consider the uncertainties that arise from the experimental methods and measurements.	Complete
RT.2.07	SZ2	Provide the testing results for the alluvial and laboratory testing. DOE will provide testing results for the alluvial field and laboratory testing in an update to the SZ In Situ Testing AMR available in FY 2003.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
RT.2.08	SZ1	Provide additional information to further justify the uncertainty distribution of flow path lengths in the alluvium. This information currently resides in the Uncertainty Distribution for Stochastic Parameters AMR. DOE will provide additional information, to include Nye County data as available, to further justify the uncertainty distribution of flowpath lengths in alluvium in updates to the Uncertainty Distribution for Stochastic Parameters AMR and to the Saturated Zone Flow and Transport PMR, both expected to be available in FY 2002.	Complete
RT.2.09	SZ1	Provide the hydro-stratigraphic cross-sections that include the Nye County data. DOE will provide the hydrostratigraphic cross sections in an update to the Hydrogeologic Framework Model for The Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available during FY 2002, subject to availability of Nye County data.	Received
RT.2.10	TSPAI	Provide additional documentation to explain how transport parameters used for PA were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment, in a report expected to be available in FY 2002.	Received
RT.2.10	UZ3	Provide additional documentation to explain how transport parameters used for PA were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment, in a report expected to be available in FY 2002.	Received
RT.2.10	SZ2	Provide additional documentation to explain how transport parameters used for PA were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment, in a report expected to be available in FY 2002.	Received
RT.2.11	SZ1	Provide the updated UZ Flow and Transport and the SZ Flow and Transport FEPs AMRs. DOE will provide updates to the AMRs Features, Events, and Processes in UZ Flow and Transport and Features, Events, and Processes in SZ Flow and Transport, both available in January 2001.	Complete
RT.2.11	TSPAI	Provide the updated UZ Flow and Transport and the SZ Flow and Transport FEPs AMRs. DOE will provide updates to the AMRs Features, Events, and Processes in UZ Flow and Transport and Features, Events, and Processes in SZ Flow and Transport, both available in January 2001.	Complete
RT.3.01	UZ3	For transport through fault zones below the repository, provide the technical basis for parameters/distributions (consider obtaining additional information, for example, the sampling of wells WT-1 and WT-2), or show the parameters are not important to performance. DOE will provide a technical basis for the importance to performance of transport through fault zones below the repository. This information will be provided in an update to the AMR Radionuclide Transport Models Under Ambient Conditions available to the NRC in FY 2002. If such transport is found to be important to performance, DOE will provide the technical basis for the parameters/distributions used in FY 2002. DOE will consider obtaining additional information.	Received
RT.3.01	SZ1	For transport through fault zones below the repository, provide the technical basis for parameters/distributions (consider obtaining additional information, for example, the sampling of wells WT-1 and WT-2), or show the parameters are not important to performance. DOE will provide a technical basis for the importance to performance of transport through fault zones below the repository. This information will be provided in an update to the AMR Radionuclide Transport Models Under Ambient Conditions available to the NRC in FY 2002. If such transport is found to be important to performance, DOE will provide the technical basis for the parameters/distributions used in FY 2002. DOE will consider obtaining additional information.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
RT.3.02	UZ2	Provide the analysis of geochemical data used for support of the flow field below the repository. DOE will provide the analysis of geochemical data used for support of the fluid flow patterns in the AMR UZ Flow Models and Submodels, available to the NRC in FY 2002.	Received
RT.3.02	UZ3	Provide the analysis of geochemical data used for support of the flow field below the repository. DOE will provide the analysis of geochemical data used for support of the fluid flow patterns in the AMR UZ Flow Models and Submodels, available to the NRC in FY 2002.	Received
RT.3.03	SZ1	Provide additional information to further justify the uncertainty distribution of flow path lengths in the tuff. This information currently resides in the Uncertainty Distribution for Stochastic Parameters AMR. DOE will provide additional information, to include Nye County data as available, to further justify the uncertainty distribution of flowpath lengths from the tuff at the water table through the alluvium at the compliance boundary in updates to the Uncertainty Distribution for Stochastic Parameters AMR and to the Saturated Zone Flow and Transport Process Model Report, both expected to be available in FY 2002.	Complete
RT.3.04	UZ3	Provide sensitivity studies for the relative importance of the hydrogeological units beneath the repository for transport of radionuclides important to performance. DOE will provide a sensitivity study to fully evaluate the relative importance of the different units below the repository that could be used to prioritize data collection, testing, and analysis. This study will be documented in an update to the AMR Radionuclide Transport Models Under Ambient Conditions available to the NRC in FY 2002.	Received
RT.3.05	UZ3	Provide the documentation for the Alcove 8/Niche 3 testing and predictive modeling for the unsaturated zone. DOE will provide documentation for the Alcove 8 / Niche 3 testing and predictive modeling for the unsaturated zone in updates to the AMRs In Situ Field Testing of Processes and Radionuclide Transport Models Under Ambient Conditions, both available to the NRC in FY 2002.	Received
RT.3.05	UZ2	Provide the documentation for the Alcove 8/Niche 3 testing and predictive modeling for the unsaturated zone. DOE will provide documentation for the Alcove 8 / Niche 3 testing and predictive modeling for the unsaturated zone in updates to the AMRs In Situ Field Testing of Processes and Radionuclide Transport Models Under Ambient Conditions, both available to the NRC in FY 2002.	Received
RT.3.06	UZ2	The NRC needs DOE to document the pre-test predictions for the Alcove 8/Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.	Complete
RT.3.06	UZ3	The NRC needs DOE to document the pre-test predictions for the Alcove 8/Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.	Complete
RT.3.07	SZ2	Provide sensitivity studies to test the importance of colloid transport parameters and models to performance for UZ and SZ. Consider techniques to test colloid transport in the Alcove 8/Niche 3 test (for example, microspheres). DOE will perform sensitivity studies as the basis for consideration of the importance of colloid transport parameters and models to performance for the unsaturated and saturated zones and will document the results in updates to appropriate AMRs, and in the TSPA-LA document, all to be available in FY 2003. DOE will evaluate techniques to test colloidal transport in Alcove 8 / Niche 3 and provide a response to the NRC in February 2001.	Received
RT.3.07	UZ3	Provide sensitivity studies to test the importance of colloid transport parameters and models to performance for UZ and SZ. Consider techniques to test colloid transport in the Alcove 8/Niche 3 test (for example, microspheres). DOE will perform sensitivity studies as the basis for consideration of the importance of colloid transport parameters and models to performance for the unsaturated and saturated zones and will document the results in updates to appropriate AMRs, and in the TSPA-LA document, all to be available in FY 2003. DOE will evaluate techniques to test colloidal transport in Alcove 8 / Niche 3 and provide a response to the NRC in February 2001.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
RT.3.08	SZ2	Provide justification that microspheres can be used as analogs for colloids (for example, equivalent ranges in size, charge, etc.). DOE will provide documentation in the C-Wells AMR to provide additional justification that microspheres can be used as analogs for colloids. The C-Wells AMR will be available to the NRC in October 2001.	Received
RT.3.08	UZ3	Provide justification that microspheres can be used as analogs for colloids (for example, equivalent ranges in size, charge, etc.). DOE will provide documentation in the C-Wells AMR to provide additional justification that microspheres can be used as analogs for colloids. The C-Wells AMR will be available to the NRC in October 2001.	Received
RT.3.09	SZ2	Provide the documentation for the C-wells testing. Use the field test data or provide justification that the data from the laboratory tests is consistent with the data from the field tests. DOE will provide the C-Wells test documentation and will either use the test data or provide a justified reconciliation of the lab and field test data in the C-Wells AMR available in October 2001.	Complete
RT.3.10	UZ3	Provide analog radionuclide data from the tracer tests for Calico Hills at Busted Butte and from similar analog and radionuclide data (if available) from test blocks from Busted Butte. DOE will provide data from analog tracers used at Busted Butte and data from (AECL) test blocks from Busted Butte in an update to the AMR In Situ Field Testing of Processes in FY 2002.	Received
RT.4.01	SZ2	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
RT.4.01	UZ3	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
RT.4.01	TSPAI	Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001.	Received
RT.4.02	TSPAI	Provide the updated FEPs database. DOE stated that it would provide the FEPs AMRs and the FEPs database to NRC during January 2001.	Complete
RT.4.03	ENG3	Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received
RT.4.03	SZ2	Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
RT.4.03	UZ3	Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary.	Received
SDS.1.01	TSPAI	Provide the updated FEPs: Disruptive Events AMR. DOE will provide the updated FEPs AMR to the NRC. Expected availability is January 2001.	Complete
SDS.1.02	ENG2	Consistent with proposed 10 CFR Part 63, the NRC believes the use of the mean is appropriate, however, DOE may use any statistic as long as it is consistent with site data and technically defensible. DOE will either provide technical justification for use of median values or another statistical measure, such as the mean, or will evaluate and implement an alternative approach. The DOE-proposed approach and its basis will be provided to NRC prior to September 2001. The approach will be implemented prior to any potential LA.	Complete
SDS.2.01	ENG2	Regarding ground motion, provide documentation, or point the NRC to the documentation on the expert elicitation process, regarding the feedback to the subject matter experts following the elicitation of their respective judgements. DOE will provide documentation demonstrating the adequacy of the elicitation feedback process by December 2000.	Received
SDS.2.02	TSPAI	Provide the updated FEPs: Disruptive Events AMR, the Seismic Design Input Report, and the update to the Seismic Topical Report. DOE will provide the updated FEPs AMR to NRC. Expected availability is January 2001. DOE will provide STR 3 to the NRC for their review. Expected availability is January 2002. The Seismic Design Inputs Report is expected to be available to the NRC by September 2001.	Received
SDS.2.02	PRE	Provide the updated FEPs: Disruptive Events AMR, the Seismic Design Input Report, and the update to the Seismic Topical Report. DOE will provide the updated FEPs AMR to NRC. Expected availability is January 2001. DOE will provide STR 3 to the NRC for their review. Expected availability is January 2002. The Seismic Design Inputs Report is expected to be available to the NRC by September 2001.	Received
SDS.2.03	ENG2	Consistent with proposed 10 CFR Part 63, the NRC believes the use of the mean is appropriate, however, DOE may use any statistic as long as it is consistent with site data and technically defensible. DOE will either provide technical justification for use of median values or another statistical measure, such as the mean, or will evaluate and implement an alternative approach. The DOE-proposed approach and its basis will be provided to NRC prior to September 2001. The approach will be implemented prior to any potential LA.	Complete
SDS.2.04	ENG2	The approach to evaluate seismic risk, including the assessment of seismic fragility and evaluation of event sequences is not clear to the NRC, provide additional information. DOE believes the approach contained in the FEPs AMR will be sufficient to support the Site Recommendation. The updated FEPs AMR is expected to be available in January 2001.	Received
SDS.3.01	UZ2	The ECRB long-term test and the Alcove 8 Niche 3 test need to be "fractured-informed" (i.e., observation of seepage needs to be related to observed fracture patterns). Provide documentation which discusses this aspect. DOE responded that for the passive test, any observed seepage will be related to full periphery maps and other fracture data in testing documentation. The documentation will be available by any potential LA. For Niche 3, fracture characterization is complete and a 3-D representation will be included in testing documentation. The documentation will be available August 2001.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
SDS.3.01	UZ3	The ECRB long-term test and the Alcove 8 Niche 3 test need to be "fractured-informed" (i.e., observation of seepage needs to be related to observed fracture patterns). Provide documentation which discusses this aspect. DOE responded that for the passive test, any observed seepage will be related to full periphery maps and other fracture data in testing documentation. The documentation will be available by any potential LA. For Niche 3, fracture characterization is complete and a 3-D representation will be included in testing documentation. The documentation will be available August 2001.	Received
SDS.3.02	UZ3	The NRC needs DOE to document the pre-test predictions for the Alcove 8 Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.	Complete
SDS.3.02	UZ2	The NRC needs DOE to document the pre-test predictions for the Alcove 8 Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.	Complete
SDS.3.03	ENG3	The NRC needs to review the Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon AMR. The NRC will provide feedback and proposed agreements to DOE, if needed, by December 2000.	Received
SDS.3.04	UZ2	The NRC needs DOE to document the discussion of excavation-induced fractures. DOE responded that observations of excavation-induced fractures will be documented in a report or AMR revision by June 2001.	Complete
SDS.3.04	ENG2	The NRC needs DOE to document the discussion of excavation-induced fractures. DOE responded that observations of excavation-induced fractures will be documented in a report or AMR revision by June 2001.	Complete
SDS.3.04	ENG3	The NRC needs DOE to document the discussion of excavation-induced fractures. DOE responded that observations of excavation-induced fractures will be documented in a report or AMR revision by June 2001.	Complete
SDS.3.04	PRE	The NRC needs DOE to document the discussion of excavation-induced fractures. DOE responded that observations of excavation-induced fractures will be documented in a report or AMR revision by June 2001.	Complete
TEF.1.01	TSPAI	Provide the FEPs AMRs relating to TEF. The DOE will provide the following updated FEPs AMRs related to thermal effects on flow to the NRC: Disruptive Events FEPs (ANL-NBS-MD-000005) Rev 00 ICN 01; Features, Events, and Processes: System Level (ANL-WIS-MD-000019) Rev 00; Features, Events, and Processes in UZ Flow and Transport (ANL-NBS-MD-000001) Rev 01; Features, Events, and Processes in SZ Flow and Transport (ANL-NBS-MD-000002) Rev 01; Features, Events, and Processes in Thermal Hydrology and Coupled Processes (ANL-NBS-MD-000004) Rev 00 ICN 01; Miscellaneous Waste Form FEPs (ANL-WIS-MD-000009) Rev 00 ICN 01; and Engineered Barrier System Features, Events, and Processes (ANL-WIS-PA-000002) Rev 01. Expected availability: January 2001.	Complete
TEF.1.01	ENG3	Provide the FEPs AMRs relating to TEF. The DOE will provide the following updated FEPs AMRs related to thermal effects on flow to the NRC: Disruptive Events FEPs (ANL-NBS-MD-000005) Rev 00 ICN 01; Features, Events, and Processes: System Level (ANL-WIS-MD-000019) Rev 00; Features, Events, and Processes in UZ Flow and Transport (ANL-NBS-MD-000001) Rev 01; Features, Events, and Processes in SZ Flow and Transport (ANL-NBS-MD-000002) Rev 01; Features, Events, and Processes in Thermal Hydrology and Coupled Processes (ANL-NBS-MD-000004) Rev 00 ICN 01; Miscellaneous Waste Form FEPs (ANL-WIS-MD-000009) Rev 00 ICN 01; and Engineered Barrier System Features, Events, and Processes (ANL-WIS-PA-000002) Rev 01. Expected availability: January 2001.	Complete
TEF.1.02	TSPAI	Provide the FEPs database. The DOE will provide the FEPs data base to the NRC during March 2001.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TEF.2.01	UZ2	Consider measuring losses of mass and energy through the bulkhead of the drift-scale test (DST) and provide the technical basis for any decision or method decided upon (include the intended use of the results of the DST such as verifying assumptions in FEP exclusion arguments or providing support for TSPA models. The DOE should analyze uncertainty in the fate of thermally mobilized water in the DST and evaluate the effect this uncertainty has on conclusions drawn from the DST results. The DOE's position is that measuring mass and energy losses through the bulkhead of the DST is not necessary for the intended use of the DST results. The DST results are intended for validation of models of thermally-driven coupled processes in the rock, and measurements are not directly incorporated into TSPA models. Results of the last two years of data support the validation of DST coupled-process models and the current treatment of mass and energy loss through the bulkhead. The DOE will provide the NRC a white paper on the technical basis for the DOE's understanding of heat and mass losses through the bulkhead and their effects on the results by April 2001. This white paper will include the DOE's technical basis for its decision regarding measurements of heat and mass losses through the DST bulkhead. This white paper will address uncertainty in the fate of thermally mobilized water in the DST and also the effect this uncertainty has on conclusions drawn from the DST results. The NRC will provide comments on this white paper. The DOE will provide analyses of the effects of this uncertainty on the uses of the DST in response to NRC comments.	Complete
TEF.2.01	ENG3	Consider measuring losses of mass and energy through the bulkhead of the drift-scale test (DST) and provide the technical basis for any decision or method decided upon (include the intended use of the results of the DST such as verifying assumptions in FEP exclusion arguments or providing support for TSPA models. The DOE should analyze uncertainty in the fate of thermally mobilized water in the DST and evaluate the effect this uncertainty has on conclusions drawn from the DST results. The DOE's position is that measuring mass and energy losses through the bulkhead of the DST is not necessary for the intended use of the DST results. The DST results are intended for validation of models of thermally-driven coupled processes in the rock, and measurements are not directly incorporated into TSPA models. Results of the last two years of data support the validation of DST coupled-process models and the current treatment of mass and energy loss through the bulkhead. The DOE will provide the NRC a white paper on the technical basis for the DOE's understanding of heat and mass losses through the bulkhead and their effects on the results by April 2001. This white paper will include the DOE's technical basis for its decision regarding measurements of heat and mass losses through the DST bulkhead. This white paper will address uncertainty in the fate of thermally mobilized water in the DST and also the effect this uncertainty has on conclusions drawn from the DST results. The NRC will provide comments on this white paper. The DOE will provide analyses of the effects of this uncertainty on the uses of the DST in response to NRC comments.	Complete
TEF.2.02	ENG3	Provide the location and access to the Multi-Scale Thermohydrologic Model input and output files. The output files are in the Technical Data Management System. The DTNs are LL000509112312.003, LL000509012312.002, and LL000509212312.004. The input files are located in the Project records system. The document identification number is MOL.20000706.0396. The DOE will provide the requested information to the NRC in January 2001.	Complete
TEF.2.03	ENG1	Provide the following references: Multi-Scale Thermohydrologic Model AMR, ICN 01; Abstraction of Near Field Environment Drift Thermodynamic and Percolation Flux AMR, ICN 01; Engineered Barrier System Degradation Flow and Transport PMR, Rev. 01; and Near Field Environment PMR, ICN 03. DOE will provide to the NRC the following documents: Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 00 ICN 01 (January 2001); Abstraction of Near-Field Environment Drift Thermodynamic and Percolation Flux AMR (ANL-EBS-HS-000003) Rev 00 ICN 01 (January 2001); Engineered Barrier System Degradation, Flow and Transport PMR (TDR-EBS-MD-000006) Rev 01 (September 2001); Near-Field Environment PMR (TDR-NBS-MD-000001) Rev 00 ICN 03 (January 2001)	Complete
TEF.2.04	ENG1	Provide the Multi-Scale Thermohydrologic Model AMR, Rev. 01. The DOE will provide the Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 01 to the NRC. Expected availability is FY 02.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TEF.2.05	ENG3	Represent the cold-trap effect in the appropriate models or provide the technical basis for exclusion of it in the various scale models (mountain, drift, etc.) considering effects on TEF and other abstraction/models (chemistry). See page 11 of the Open Item (OI) 2 presentation. The DOE will represent the "cold-trap" effect in the Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 01, expected to be available in FY 02. This report will provide technical support for inclusion or exclusion of the cold-trap effect in the various scale models. The analysis will consider thermal effects on flow and the in-drift geochemical	Received
TEF.2.06	ENG3	Provide the detailed test plan for Phase III of the ventilation test, and consider NRC comments, if any. The DOE will provide a detailed test plan for the Phase III ventilation test in March 2001. The NRC comments will be provided no later than two weeks after receipt of the test plan, and will be considered by the DOE prior to test initiation.	Complete
TEF.2.06	PRE	Provide the detailed test plan for Phase III of the ventilation test, and consider NRC comments, if any. The DOE will provide a detailed test plan for the Phase III ventilation test in March 2001. The NRC comments will be provided no later than two weeks after receipt of the test plan, and will be considered by the DOE prior to test initiation.	Complete
TEF.2.06	UZ2	Provide the detailed test plan for Phase III of the ventilation test, and consider NRC comments, if any. The DOE will provide a detailed test plan for the Phase III ventilation test in March 2001. The NRC comments will be provided no later than two weeks after receipt of the test plan, and will be considered by the DOE prior to test initiation.	Complete
TEF.2.07	ENG3	Provide the Ventilation Model AMR, Rev. 01 and the Pre-Test Predictions for Ventilation Test Calculation, Rev. 00. The DOE will provide the Ventilation Model AMR (ANL-EBS-MD-000030) Rev 01 to the NRC in March 2001. Note that ventilation test data will not be incorporated in the AMR until FY02. The DOE will provide the Pre-test Predictions for Ventilation Tests (CAL-EBS-MD-000013) Rev 00 to the NRC in February 2001. Test results will be provided in an update to the Ventilation Model AMR (ANL-EBS-MD-000030) in FY 02.	Received
TEF.2.07	PRE	Provide the Ventilation Model AMR, Rev. 01 and the Pre-Test Predictions for Ventilation Test Calculation, Rev. 00. The DOE will provide the Ventilation Model AMR (ANL-EBS-MD-000030) Rev 01 to the NRC in March 2001. Note that ventilation test data will not be incorporated in the AMR until FY02. The DOE will provide the Pre-test Predictions for Ventilation Tests (CAL-EBS-MD-000013) Rev 00 to the NRC in February 2001. Test results will be provided in an update to the Ventilation Model AMR (ANL-EBS-MD-000030) in FY 02.	Received
TEF.2.07	UZ2	Provide the Ventilation Model AMR, Rev. 01 and the Pre-Test Predictions for Ventilation Test Calculation, Rev. 00. The DOE will provide the Ventilation Model AMR (ANL-EBS-MD-000030) Rev 01 to the NRC in March 2001. Note that ventilation test data will not be incorporated in the AMR until FY02. The DOE will provide the Pre-test Predictions for Ventilation Tests (CAL-EBS-MD-000013) Rev 00 to the NRC in February 2001. Test results will be provided in an update to the Ventilation Model AMR (ANL-EBS-MD-000030) in FY 02.	Received
TEF.2.08	ENG3	Provide the Mountain Scale Coupled Processes AMR, or an other appropriate AMR, documenting the results of the outlined items on page 20 of the OI 7 presentation (considering the NRC suggestion to compare model results to the O.M. Phillips analytical solution documented in Water Resources Research, 1996). The DOE will provide the updated Mountain-Scale Coupled Processes Model AMR (MDL-NBS-HS-000007) Rev 01 to the NRC in FY 02, documenting the results of the outlined items on page 20 of DOE's Open Item 7 presentation at this meeting. The DOE will consider the NRC suggestion of comparing the numerical model results to the O.M. Phillips analytical solution documented in WRR (1996).	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
TEF.2.08	UZ2	Provide the Mountain Scale Coupled Processes AMR, or an other appropriate AMR, documenting the results of the outlined items on page 20 of the OI 7 presentation (considering the NRC suggestion to compare model results to the O.M. Phillips analytical solution documented in Water Resources Research, 1996). The DOE will provide the updated Mountain-Scale Coupled Processes Model AMR (MDL-NBS-HS-000007) Rev 01 to the NRC in FY 02, documenting the results of the outlined items on page 20 of DOE's Open Item 7 presentation at this meeting. The DOE will consider the NRC suggestion of comparing the numerical model results to the O.M. Phillips analytical solution documented in WRR (1996).	Complete
TEF.2.09	ENG1	Provide the Multi-Scale Thermohydrologic Model AMR, ICN 03. The DOE will provide the Multi-Scale Thermohydrologic Model AMR (ANL-EBS-MD-00049) Rev 00 ICN 03 to the NRC. Expected availability July 2001.	Complete
TEF.2.10	UZ2	Represent the full variability/uncertainty in the results of the TEF simulations in the abstraction of thermodynamic variables to other models, or provide technical basis that a reduced representation is appropriate (considering risk significance). The DOE will discuss this issue during the TSPAI technical exchange tentatively scheduled for April 2001.	Received
TEF.2.10	ENG3	Represent the full variability/uncertainty in the results of the TEF simulations in the abstraction of thermodynamic variables to other models, or provide technical basis that a reduced representation is appropriate (considering risk significance). The DOE will discuss this issue during the TSPAI technical exchange tentatively scheduled for April 2001.	Received
TEF.2.11	ENG3	Provide the Calibrated Properties AMR, incorporating uncertainty from all significant sources. The DOE will provide an updated Calibrated Properties Model AMR (MDL-NBS-HS-000003) Rev 01 that incorporates uncertainty from significant sources to the NRC in FY 02.	Received
TEF.2.11	UZ2	Provide the Calibrated Properties AMR, incorporating uncertainty from all significant sources. The DOE will provide an updated Calibrated Properties Model AMR (MDL-NBS-HS-000003) Rev 01 that incorporates uncertainty from significant sources to the NRC in FY 02.	Received
TEF.2.12	UZ2	Provide the Unsaturated Zone Flow and Transport PMR, Rev. 00, ICN 02, documenting the resolution of issues on page 5 of the OI 8 presentation. The DOE will provide the Unsaturated Zone Flow and Transport PMR (TDR-NBS-HS-000002) Rev 00 ICN 02 to the NRC in February 2001. It should be noted, however, that not all of the items listed on page 5 of the DOE's Open Item 8 presentation at this meeting are included in that revision. The DOE will include all the items listed on page 5 of the DOE's Open Item 8 presentation in Revision 02 of the Unsaturated Zone Flow and Transport PMR, scheduled to be available in FY 02.	Received
TEF.2.12	UZ3	Provide the Unsaturated Zone Flow and Transport PMR, Rev. 00, ICN 02, documenting the resolution of issues on page 5 of the OI 8 presentation. The DOE will provide the Unsaturated Zone Flow and Transport PMR (TDR-NBS-HS-000002) Rev 00 ICN 02 to the NRC in February 2001. It should be noted, however, that not all of the items listed on page 5 of the DOE's Open Item 8 presentation at this meeting are included in that revision. The DOE will include all the items listed on page 5 of the DOE's Open Item 8 presentation in Revision 02 of the Unsaturated Zone Flow and Transport PMR, scheduled to be available in FY 02.	Received
TEF.2.13	UZ3	Provide the Conceptual and Numerical Models for Unsaturated Zone Flow and Transport AMR, Rev. 01 and the Analysis of Hydrologic Properties Data AMR, Rev. 01. The DOE will provide updates to the Conceptual and Numerical Models for UZ Flow and Transport (MDL-NBS-HS-000005) Rev 01 and the Analysis of Hydrologic Properties Data (ANL-NBS-HS-000002) Rev 01 AMRs to the NRC. Scheduled availability is FY 02.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TEF.2.13	UZ2	Provide the Conceptual and Numerical Models for Unsaturated Zone Flow and Transport AMR, Rev. 01 and the Analysis of Hydrologic Properties Data AMR, Rev. 01. The DOE will provide updates to the Conceptual and Numerical Models for UZ Flow and Transport (MDL-NBS-HS-000005) Rev 01 and the Analysis of Hydrologic Properties Data (ANL-NBS-HS-000002) Rev 01 AMRs to the NRC. Scheduled availability is FY 02.	Received
TSPAI.1.01	TSPAI	Provide enhanced descriptive treatment for presenting barrier capabilities in their final approach for demonstrating multiple barriers. Provide discussion of the capabilities of individual barriers, in light of existing parameter uncertainty (e.g., in barrier and system characteristics) and model uncertainty. DOE will provide enhanced descriptive treatment for presenting barrier capabilities in the final approach for demonstrating multiple barriers. DOE will also provide discussion of the capabilities of individual barriers, in light of existing parameter uncertainty (e.g., in barrier and system characteristics) and model uncertainty. The information will be documented in TSPA Methods and Assumptions document, expected to be available to NRC in FY 2002, for any potential license application.	Complete
TSPAI.1.02	TSPAI	Provide a discussion of the following in documentation of barrier capabilities and the corresponding technical bases: (1) parameter uncertainty, (2) model uncertainty (i.e., the effect of viable alternative conceptual models), (3) spatial and temporal variability in the performance of the barriers, (4) independent and interdependent capabilities of the barriers (e.g., including a differentiation of the capabilities of barriers performing similar functions), and (5) barrier effectiveness with regard to individual radionuclides. Analyze and document barrier capabilities, in light of existing data and analyses of the performance of the repository system. DOE will provide a discussion of the following in documentation of barrier capabilities and the corresponding technical bases: (1) parameter uncertainty, (2) model uncertainty (i.e., the effect of viable alternative conceptual models), (3) spatial and temporal variability in the performance of the barriers, (4) independent and interdependent capabilities of the barriers (e.g., including a differentiation of the capabilities of barriers performing similar functions), and (5) barrier effectiveness with regard to individual radionuclides. DOE will also analyze and document barrier capabilities, in light of existing data and analyses of the performance of the repository system. The information will be documented in TSPA for any potential license application expected to be available in FY 2003.	Received
TSPAI.2.01	SZ2	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	DOSE3	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	DOSE2	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	DOSE1	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	UZ3	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received

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TSPAI.2.01	TSPAI	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	SZ1	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	ENG4	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	ENG3	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	ENG1	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	UZ2	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.01	UZ1	Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. 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 FY03.	Received
TSPAI.2.02	SZ2	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	TSPAI	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	DOSE3	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received

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TSPAI.2.02	DOSE2	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	DOSE1	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	DIRECT1	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	SZ1	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	UZ2	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	UZ1	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	ENG4	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received

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TSPAI.2.02	ENG3	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	ENG2	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	ENG1	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	UZ3	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.02	DIRECT2	Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. 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 FY03.	Received
TSPAI.2.03	DOSE1	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received
TSPAI.2.03	TSPAI	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received
TSPAI.2.03	SZ2	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received
TSPAI.2.03	SZ1	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received

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TSPAI.2.03	UZ3	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received
TSPAI.2.03	DOSE3	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received
TSPAI.2.03	DOSE2	Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. 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 FY03.	Received
TSPAI.2.04	DOSE3	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 FY03.	Received
TSPAI.2.04	TSPAI	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 FY03.	Received
TSPAI.2.04	ENG2	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 FY03.	Received
TSPAI.2.04	ENG1	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 FY03.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TSPAI.2.05	TSPAI	It is not clear to the NRC that the current list of FEPs (i.e., the list of FEPs documented in TDR-WIS-MD-000003, 00/01) is sufficiently comprehensive or exhibits the necessary attribute of being auditable (e.g., transparent and traceable). As discussed in the two TSPAI technical exchanges, there are unclear aspects of the approach that DOE plans to use to develop the necessary documentation of those features, events, and processes that they have considered. Accordingly, to provide additional confidence that the DOE will provide NRC with: (1) auditable documentation of what has been considered by the DOE, (2) the technical basis for excluding FEPs, and (3) an indication of the way in which included FEPs have been incorporated in the performance assessment; DOE will provide NRC with a detailed plan (the Enhanced FEP Plan) for comment. In the Enhanced FEP Plan, DOE will address the following items: (1) the approach used to develop a pre-screening set of FEPs (i.e., the documentation of those things that DOE considered and which the DOE would use to provide support for a potential license application), (2) the guidance on the level-of-detail that DOE will use for redefining FEPs during the enhanced FEP process, (3) the form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions), (4) the approach DOE would use for the ongoing evaluation of FEPs (e.g., how to address potentially new FEPs), (5) the approach that DOE would use to evaluate and update the existing scope and description of FEPs, (6) the approach that DOE would use to improve the consistency in the level of detail among FEPs, (7) how the DOE would evaluate the results of its efforts to update the existing scope and definition of FEPs, (8) how the Enhanced FEP process would support assertions that the resulting set of FEPs will be sufficiently comprehensive (e.g., represents a wide range of both beneficial and potential adverse effects on performance) to reflect clearly what DOE has considered, (9) how DOE would indicate their disposition of included FEPs in the performance assessment, (10) the role and definition of the different hierarchical levels used to document the information (e.g., "components of FEPs" and "modeling issues"), (11) how the hierarchical levels used to document the information would be used within DOE's enhanced FEP process, (12) how the Enhanced FEP Plan would result in documentation that facilitates auditing (i.e., lead to a process that is transparent and traceable), (13) DOE's plans for using configuration management controls to identify FEP dependencies on ongoing work and design changes. DOE will provide the Enhanced Plan to NRC by March 2002.	Complete
TSPAI.2.06	TSPAI	Provide justification for the approach to: (1) the level of detail used to define FEPs; (2) the degree of consistency among FEPs; and (3) comprehensiveness of the set of FEPs initially considered (i.e., before screening). DOE proposes to meet with NRC periodically to provide assessments of the DOE's progress, once it has initiated the Enhanced FEP process, and on changes to the approach documented in the Enhanced FEP Plan. During these progress meetings DOE agrees to provide a justification for their approach to: (1) the level of detail used to define FEPs; (2) the degree of consistency among FEPs; and (3) comprehensiveness of the pre-screening set of FEPs.	Complete
TSPAI.2.07	TSPAI	Provide results of the implementation of the Enhanced FEP Plan (e.g., the revised FEP descriptions, screening arguments, the mapping of FEPs to TSPA keywords, and a searchable index of FEP components), in updates to the FEP AMR documents and the FEP Database. DOE agrees to provide the results of their implementation of the Enhanced FEP Plan (e.g., the revised FEP descriptions, screening arguments, improved database navigation through, for example, the mapping of FEPs to TSPA keywords, a searchable index of FEP components, etc.), information requested in updates to the FEP documents and the FEP Database (or other suitable documents) in FY03.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.01	TSPAI	Propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments. Specific sources of uncertainty that should be propagated (or strong technical basis provided as to why it is insignificant) include: (1) the uncertainty from measured crevice and weight-loss samples general corrosion rates and the statistical differences between the populations, (2) the uncertainty from alternative explanations for the decrease in corrosion rates with time (such as silica coatings that alter the reactive surface area), (3) the uncertainty from utilizing a limited number of samples to define the correction for silica precipitation, (4) the confidence in the upper limit of corrosion rates resulting from the limited sample size, and (5) the uncertainty from alternative statistical representations of the population of empirical general corrosion rates. The technical basis for sources of uncertainty will be established upon completion of existing agreement items CLST 1.4, 1.5, 1.6, and 1.7. DOE will then propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments. This technical basis will be documented in a future revision of the General and Localized Corrosion of Waste Package Outer Barrier AMR (ANL-EBS-MD-000003) expected to be available consistent with the scope and schedules for the specified CLST agreements. The results of the AMR analyses will be propagated into future TSPA analyses for any potential license application.	Received
TSPAI.3.01	ENG1	Propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments. Specific sources of uncertainty that should be propagated (or strong technical basis provided as to why it is insignificant) include: (1) the uncertainty from measured crevice and weight-loss samples general corrosion rates and the statistical differences between the populations, (2) the uncertainty from alternative explanations for the decrease in corrosion rates with time (such as silica coatings that alter the reactive surface area), (3) the uncertainty from utilizing a limited number of samples to define the correction for silica precipitation, (4) the confidence in the upper limit of corrosion rates resulting from the limited sample size, and (5) the uncertainty from alternative statistical representations of the population of empirical general corrosion rates. The technical basis for sources of uncertainty will be established upon completion of existing agreement items CLST 1.4, 1.5, 1.6, and 1.7. DOE will then propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments. This technical basis will be documented in a future revision of the General and Localized Corrosion of Waste Package Outer Barrier AMR (ANL-EBS-MD-000003) expected to be available consistent with the scope and schedules for the specified CLST agreements. The results of the AMR analyses will be propagated into future TSPA analyses for any potential license application.	Received
TSPAI.3.02	TSPAI	Provide the technical basis for resampling the general corrosion rates and the quantification of the impact of resampling of general corrosion rates in revised documentation (ENG1.1.1). DOE will provide the technical basis for resampling the general corrosion rates and the quantification of the impact of resampling of general corrosion rates in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001). This AMR is expected to be available to NRC in FY 2003.	Complete
TSPAI.3.02	ENG1	Provide the technical basis for resampling the general corrosion rates and the quantification of the impact of resampling of general corrosion rates in revised documentation (ENG1.1.1). DOE will provide the technical basis for resampling the general corrosion rates and the quantification of the impact of resampling of general corrosion rates in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001). This AMR is expected to be available to NRC in FY 2003.	Complete
TSPAI.3.03	TSPAI	Provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the impact of SCC of the drip shield and waste package in revised documentation (ENG1.1.2 and ENG1.4.1). DOE will provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the stress corrosion cracking of the drip shield and waste package in an update to the Stress Corrosion Cracking of the Drip Shield, Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) in accordance with the scope and schedule for existing agreement item CLST.1.12.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TSPAI.3.03	ENG1	Provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the impact of SCC of the drip shield and waste package in revised documentation (ENG1.1.2 and ENG1.4.1). DOE will provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the stress corrosion cracking of the drip shield and waste package in an update to the Stress Corrosion Cracking of the Drip Shield, Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) in accordance with the scope and schedule for existing agreement item CLST 1.12.	Received
TSPAI.3.04	TSPAI	Provide the technical basis that the representation of the variation of general corrosion rates (if a significant portion is "lack of knowledge" uncertainty) does not result in risk dilution of projected dose responses (ENG1.3.3). DOE will provide the technical basis that the representation of the variation of general corrosion rates results in reasonably conservative projected dose rates. The technical basis will be documented in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001). This AMR is expected to be available to NRC in FY 2003. These results will be incorporated into future TSPA documentation for any potential license application.	Received
TSPAI.3.04	ENG1	Provide the technical basis that the representation of the variation of general corrosion rates (if a significant portion is "lack of knowledge" uncertainty) does not result in risk dilution of projected dose responses (ENG1.3.3). DOE will provide the technical basis that the representation of the variation of general corrosion rates results in reasonably conservative projected dose rates. The technical basis will be documented in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001). This AMR is expected to be available to NRC in FY 2003. These results will be incorporated into future TSPA documentation for any potential license application.	Received
TSPAI.3.05	ENG1	Provide the technical basis for the representation of uncertainty/variability in the general corrosion rates in revised documentation. This technical basis should provide a detailed discussion and analyses to allow independent reviewers the ability to interpret the representations of 100% uncertainty, 100% variability, and any intermediate representations in the DOE model (ENG1.3.6). DOE will provide the technical basis for the representation of uncertainty/variability in the general corrosion rates. This technical basis will include the results of 100% uncertainty, 100% variability, and selected intermediate representations used in the DOE model. These results will be documented in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001) or other document. This AMR is expected to be available to NRC in FY 2003.	Received
TSPAI.3.05	TSPAI	Provide the technical basis for the representation of uncertainty/variability in the general corrosion rates in revised documentation. This technical basis should provide a detailed discussion and analyses to allow independent reviewers the ability to interpret the representations of 100% uncertainty, 100% variability, and any intermediate representations in the DOE model (ENG1.3.6). DOE will provide the technical basis for the representation of uncertainty/variability in the general corrosion rates. This technical basis will include the results of 100% uncertainty, 100% variability, and selected intermediate representations used in the DOE model. These results will be documented in an update to the WAPDEG Analysis of Waste Package and Drip Shield Degradation AMR (ANL-EBS-PA-000001) or other document. This AMR is expected to be available to NRC in FY 2003.	Received
TSPAI.3.06	ENG2	Provide the technical basis for the methodology used to implement the effects of seismic effects on cladding in revised documentation. DOE will demonstrate that the methodology used to represent the seismic effects of cladding does not result in an underestimation of risk in the regulatory timeframe (ENG2.1.1). DOE will provide the technical basis for the methodology used to implement the effects of seismic effects on cladding in revised documentation. DOE will demonstrate that the methodology used to represent the seismic effects of cladding does not result in an underestimation of risk in the regulatory timeframe in TSPA-LA. The documentation is expected to be available to NRC in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.06	TSPAI	Provide the technical basis for the methodology used to implement the effects of seismic effects on cladding in revised documentation. DOE will demonstrate that the methodology used to represent the seismic effects of cladding does not result in an underestimation of risk in the regulatory timeframe (ENG2.1.1). DOE will provide the technical basis for the methodology used to implement the effects of seismic effects on cladding in revised documentation. DOE will demonstrate that the methodology used to represent the seismic effects of cladding does not result in an underestimation of risk in the regulatory timeframe in TSPA-LA. The documentation is expected to be available to NRC in FY 2003.	Received
TSPAI.3.07	TSPAI	Provide technical basis for representation of or the neglect of dripping from rockbolts in the ECRB in performance assessment, including the impacts on hydrology, chemistry, and other impacted models. Appropriate consideration will be given to the uncertainties in the source of the moisture, and how those uncertainties impact other models (ENG3.1.1). DOE will provide technical basis for determination of future sources of water in the ECRB, will evaluate the possibility of preferential dripping from engineered materials, and will give appropriate consideration to the uncertainties of the water sources, as well as their potential impact on other models. The work done to date as well as the additional work will be documented in the AMR on In-Situ Field Testing Processes (ANL-NBS-HS-000005) or other documents. This AMR will be available to NRC in FY 2003. DOE will evaluate the role of condensation as a source of water and any impacts of this on hydrologic and chemical conitions in the drift, and DOE will document this work. The effects of condensation will be included in TSPA if found to be potentially important to performance.	Received
TSPAI.3.07	ENG3	Provide technical basis for representation of or the neglect of dripping from rockbolts in the ECRB in performance assessment, including the impacts on hydrology, chemistry, and other impacted models. Appropriate consideration will be given to the uncertainties in the source of the moisture, and how those uncertainties impact other models (ENG3.1.1). DOE will provide technical basis for determination of future sources of water in the ECRB, will evaluate the possibility of preferential dripping from engineered materials, and will give appropriate consideration to the uncertainties of the water sources, as well as their potential impact on other models. The work done to date as well as the additional work will be documented in the AMR on In-Situ Field Testing Processes (ANL-NBS-HS-000005) or other documents. This AMR will be available to NRC in FY 2003. DOE will evaluate the role of condensation as a source of water and any impacts of this on hydrologic and chemical conitions in the drift, and DOE will document this work. The effects of condensation will be included in TSPA if found to be potentially important to performance.	Received
TSPAI.3.07	UZ2	Provide technical basis for representation of or the neglect of dripping from rockbolts in the ECRB in performance assessment, including the impacts on hydrology, chemistry, and other impacted models. Appropriate consideration will be given to the uncertainties in the source of the moisture, and how those uncertainties impact other models (ENG3.1.1). DOE will provide technical basis for determination of future sources of water in the ECRB, will evaluate the possibility of preferential dripping from engineered materials, and will give appropriate consideration to the uncertainties of the water sources, as well as their potential impact on other models. The work done to date as well as the additional work will be documented in the AMR on In-Situ Field Testing Processes (ANL-NBS-HS-000005) or other documents. This AMR will be available to NRC in FY 2003. DOE will evaluate the role of condensation as a source of water and any impacts of this on hydrologic and chemical conitions in the drift, and DOE will document this work. The effects of condensation will be included in TSPA if found to be potentially important to performance.	Received
TSPAI.3.08	TSPAI	Provide the technical basis (quantification) for the abstraction of in-package chemistry and it's implementation into the TSPA which will demonstrate that the utilization of the weighted-moving-average methodology will not result in an underestimation of risk (ENG3.1.3). DOE will provide the technical basis (quantification) for the abstraction of in-package chemistry and its implementation into the TSPA, which will demonstrate that the implementation methodology will not result in an underestimation of risk. The technical basis will be documented in TSPA-LA and is expected to be available in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.08	ENG3	Provide the technical basis (quantification) for the abstraction of in-package chemistry and it's implementation into the TSPA which will demonstrate that the utilization of the weighted-moving-average methodology will not result in an underestimation of risk (ENG3.1.3). DOE will provide the technical basis (quantification) for the abstraction of in-package chemistry and its implementation into the TSPA, which will demonstrate that the implementation methodology will not result in an underestimation of risk. The technical basis will be documented in TSPA-LA and is expected to be available in FY 2003.	Received
TSPAI.3.09	TSPAI	Provide the documentation that presents the representation of uncertainty and variability in the near-field environment abstractions in the TSPA (ENG3.1.4). DOE will present the representation of uncertainty and variability in water and gas chemistry entering the drift in the near-field environment abstractions for the TSPA. This will be documented in the Abstraction of Drift-Scale Coupled Processes (ANL-NBS-HS-000029) or other document expected to be available in FY 2003.	Received
TSPAI.3.09	ENG3	Provide the documentation that presents the representation of uncertainty and variability in the near-field environment abstractions in the TSPA (ENG3.1.4). DOE will present the representation of uncertainty and variability in water and gas chemistry entering the drift in the near-field environment abstractions for the TSPA. This will be documented in the Abstraction of Drift-Scale Coupled Processes (ANL-NBS-HS-000029) or other document expected to be available in FY 2003.	Received
TSPAI.3.10	ENG3	Provide the documentation of the integrated analyses and comprehensive uncertainty analyses related to the Physical and Chemical Environmental Abstraction Model (ENG3.1.5). DOE will provide the documentation of the integrated analyses and comprehensive uncertainty analyses related to the EBS physical and chemical environment in documentation associated with TSPA for any potential license application. The documentation is expected to be available to NRC in FY 2003.	Received
TSPAI.3.10	TSPAI	Provide the documentation of the integrated analyses and comprehensive uncertainty analyses related to the Physical and Chemical Environmental Abstraction Model (ENG3.1.5). DOE will provide the documentation of the integrated analyses and comprehensive uncertainty analyses related to the EBS physical and chemical environment in documentation associated with TSPA for any potential license application. The documentation is expected to be available to NRC in FY 2003.	Received
TSPAI.3.11	TSPAI	DOE should account for appropriate integration between the 3D UZ flow model, the MSTH model, and the drift seepage model. In particular, DOE should ensure that relevant spatial distributions are propagated appropriately between the UZ flow model, the thermohydrology model, and the seepage model (ENG3.1.6). DOE will compare the infiltration flux used for the infiltration bins with the 3D Unsaturated Zone flow model and the multi-scale thermohydrologic (MSTH) model results. The technical basis for any approximations in the spatial distribution of flow rates involved in this abstraction will be provided in Abstraction of NFE Drift Thermodynamic Environment and Percolation Flow AMR (ANL-EBS-HS-000003) or other suitable document. In particular, DOE will ensure that the MSTH model output to the seepage abstraction (or any other model that may provide percolation flux to the seepage abstraction) does not lead to underestimation of seepage. This AMR is expected to be available to NRC in FY 2003.	Received
TSPAI.3.11	ENG3	DOE should account for appropriate integration between the 3D UZ flow model, the MSTH model, and the drift seepage model. In particular, DOE should ensure that relevant spatial distributions are propagated appropriately between the UZ flow model, the thermohydrology model, and the seepage model (ENG3.1.6). DOE will compare the infiltration flux used for the infiltration bins with the 3D Unsaturated Zone flow model and the multi-scale thermohydrologic (MSTH) model results. The technical basis for any approximations in the spatial distribution of flow rates involved in this abstraction will be provided in Abstraction of NFE Drift Thermodynamic Environment and Percolation Flow AMR (ANL-EBS-HS-000003) or other suitable document. In particular, DOE will ensure that the MSTH model output to the seepage abstraction (or any other model that may provide percolation flux to the seepage abstraction) does not lead to underestimation of seepage. This AMR is expected to be available to NRC in FY 2003.	Received

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TSPAI.3.11	UZ2	DOE should account for appropriate integration between the 3D UZ flow model, the MSTH model, and the drift seepage model. In particular, DOE should ensure that relevant spatial distributions are propagated appropriately between the UZ flow model, the thermohydrology model, and the seepage model (ENG3.1.6). DOE will compare the infiltration flux used for the infiltration bins with the 3D Unsaturated Zone flow model and the multi-scale thermohydrologic (MSTH) model results. The technical basis for any approximations in the spatial distribution of flow rates involved in this abstraction will be provided in Abstraction of NFE Drift Thermodynamic Environment and Percolation Flow AMR (ANL-EBS-HS-000003) or other suitable document. In particular, DOE will ensure that the MSTH model output to the seepage abstraction (or any other model that may provide percolation flux to the seepage abstraction) does not lead to underestimation of seepage. This AMR is expected to be available to NRC in FY 2003.	Received
TSPAI.3.12	ENG3	DOE should complete testing of corrosion in the chemical environments predicted by the model or provide technical basis why it is not needed (ENG3.1.8). DOE will conduct testing of corrosion in the credible range of chemical environments predicted by the model in accordance with the scope and schedule for existing agreements CLST 1.4 and 1.6 or provide a technical basis why it is not needed.	Received
TSPAI.3.12	TSPAI	DOE should complete testing of corrosion in the chemical environments predicted by the model or provide technical basis why it is not needed (ENG3.1.8). DOE will conduct testing of corrosion in the credible range of chemical environments predicted by the model in accordance with the scope and schedule for existing agreements CLST 1.4 and 1.6 or provide a technical basis why it is not needed.	Received
TSPAI.3.13	ENG3	Provide a comparison of the environments for corrosion predicted in the models, to the testing environments used to define empirical corrosion rates in revised documentation (ENG3.2.1). DOE will provide a comparison of the environments for corrosion predicted in the models, to the testing environments utilized to define empirical corrosion rates in revised documentation consistent with the scope and schedule for existing agreement item CLST 1.1.	Complete
TSPAI.3.13	TSPAI	Provide a comparison of the environments for corrosion predicted in the models, to the testing environments used to define empirical corrosion rates in revised documentation (ENG3.2.1). DOE will provide a comparison of the environments for corrosion predicted in the models, to the testing environments utilized to define empirical corrosion rates in revised documentation consistent with the scope and schedule for existing agreement item CLST 1.1.	Complete
TSPAI.3.14	TSPAI	DOE should account for the full range of environmental conditions for the in-package chemistry model (ENG4.1.1). DOE will update the in-package chemistry model to account for scenarios and their associated uncertainties required by TSPA. This will be documented in the In-Package Chemistry AMR (ANL-EBS-MD-000056) expected to be available to NRC in FY 2003.	Received
TSPAI.3.14	ENG4	DOE should account for the full range of environmental conditions for the in-package chemistry model (ENG4.1.1). DOE will update the in-package chemistry model to account for scenarios and their associated uncertainties required by TSPA. This will be documented in the In-Package Chemistry AMR (ANL-EBS-MD-000056) expected to be available to NRC in FY 2003.	Received
TSPAI.3.15	TSPAI	Define a reference EQ3/6 database for the Yucca Mountain Project. DOE will provide documentation of all deviations from the reference database and justification for those deviations used by different geochemical modeling activities (ENG4.1.2). DOE will define a reference EQ3/6 database for the Yucca Mountain Project. DOE will provide documentation of all the deviations from the reference database and justification for those deviations used by different geochemical modeling activities. The database will be available in FY 2003.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.15	ENG4	Define a reference EQ3/6 database for the Yucca Mountain Project. DOE will provide documentation of all deviations from the reference database and justification for those deviations used by different geochemical modeling activities (ENG4.1.2). DOE will define a reference EQ3/6 database for the Yucca Mountain Project. DOE will provide documentation of all the deviations from the reference database and justification for those deviations used by different geochemical modeling activities. The database will be available in FY 2003.	Complete
TSPAI.3.16	TSPAI	DOE should include the possibility of localized flow pathways in the engineered barrier system in TSPA calculations, including the influence of introduced materials on water and gas chemistry on these preferential flow pathways (ENG4.1.6). DOE will evaluate the effect of localized flow pathways on water and gas chemistry in the engineered barrier system as input to TSPA calculations, including the influence of introduced materials on these preferential flow pathways consistent with existing agreements ENFE 2.4, 2.5, and 2.6. This will be documented in an update to the Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033) or other suitable document. This AMR is expected to be available to NRC in FY 2003.	Received
TSPAI.3.16	ENG4	DOE should include the possibility of localized flow pathways in the engineered barrier system in TSPA calculations, including the influence of introduced materials on water and gas chemistry on these preferential flow pathways (ENG4.1.6). DOE will evaluate the effect of localized flow pathways on water and gas chemistry in the engineered barrier system as input to TSPA calculations, including the influence of introduced materials on these preferential flow pathways consistent with existing agreements ENFE 2.4, 2.5, and 2.6. This will be documented in an update to the Physical and Chemical Environment Model AMR (ANL-EBS-MD-000033) or other suitable document. This AMR is expected to be available to NRC in FY 2003.	Received
TSPAI.3.17	TSPAI	Provide an uncertainty analysis of the diffusion coefficient governing transport of dissolved and colloidal radionuclides through the invert. The analysis should include uncertainty in the modeled invert saturation (ENG4.4.1). DOE will provide an uncertainty analysis of the diffusion coefficient governing transport of dissolved and colloidal radionuclides through the invert. The analysis will include uncertainty in the modeled invert saturation. The uncertainty analysis will be documented in the EBS Radionuclide Transport Abstraction AMR (ANL-WIS-PA-000001) expected to be available to NRC in FY 2003.	Received
TSPAI.3.17	ENG4	Provide an uncertainty analysis of the diffusion coefficient governing transport of dissolved and colloidal radionuclides through the invert. The analysis should include uncertainty in the modeled invert saturation (ENG4.4.1). DOE will provide an uncertainty analysis of the diffusion coefficient governing transport of dissolved and colloidal radionuclides through the invert. The analysis will include uncertainty in the modeled invert saturation. The uncertainty analysis will be documented in the EBS Radionuclide Transport Abstraction AMR (ANL-WIS-PA-000001) expected to be available to NRC in FY 2003.	Received
TSPAI.3.18	TSPAI	Provide a technical basis that the water-balance plug-flow model adequately represents the non-linear flow processes represented by Richard's equation, particularly over the repository where there is thin soil (UZ1.2.1). DOE will provide a technical basis that the water-balance plug-flow model adequately represents the non-linear flow processes represented by Richard's equation, particularly over the repository where there is thin soil. The technical basis will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032). The AMR is expected to be	Received
TSPAI.3.18	UZ1	Provide a technical basis that the water-balance plug-flow model adequately represents the non-linear flow processes represented by Richard's equation, particularly over the repository where there is thin soil (UZ1.2.1). DOE will provide a technical basis that the water-balance plug-flow model adequately represents the non-linear flow processes represented by Richard's equation, particularly over the repository where there is thin soil. The technical basis will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032). The AMR is expected to be	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.19	TSPAI	DOE will provide justification for the use of its evapotranspiration model, and defend the use of the analog site temperature data (UZ1.3.1). DOE will provide justification for the use of the evapotranspiration model, and justify the use of the analog site temperature data. The justification will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and the Future Climate Analysis AMR (ANL-NBS-GS-000008). The AMRs are expected to be available to NRC in FY 2003.	Received
TSPAI.3.19	UZ1	DOE will provide justification for the use of its evapotranspiration model, and defend the use of the analog site temperature data (UZ1.3.1). DOE will provide justification for the use of the evapotranspiration model, and justify the use of the analog site temperature data. The justification will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and the Future Climate Analysis AMR (ANL-NBS-GS-000008). The AMRs are expected to be available to NRC in FY 2003.	Received
TSPAI.3.20	TSPAI	Provide access to data supporting the synthetic meteorologic records (4JA.s01 and Area12.s01) (UZ1.3.2). DOE will provide data supporting the synthetic meteorologic records (specifically, data files 4JA.s01 and Area12.s01). These data files will be provided to NRC September 2001.	Complete
TSPAI.3.20	UZ1	Provide access to data supporting the synthetic meteorologic records (4JA.s01 and Area12.s01) (UZ1.3.2). DOE will provide data supporting the synthetic meteorologic records (specifically, data files 4JA.s01 and Area12.s01). These data files will be provided to NRC September 2001.	Complete
TSPAI.3.21	TSPAI	Demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered (UZ1.5.1). DOE will demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006). These AMRs are expected to be available to NRC	Received
TSPAI.3.21	UZ1	Demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered (UZ1.5.1). DOE will demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006). These AMRs are expected to be available to NRC	Received
TSPAI.3.22	TSPAI	Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1). DOE will provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received
TSPAI.3.22	UZ2	Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1). DOE will provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.19	TSPAI	DOE will provide justification for the use of its evapotranspiration model, and defend the use of the analog site temperature data (UZ1.3.1). DOE will provide justification for the use of the evapotranspiration model, and justify the use of the analog site temperature data. The justification will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and the Future Climate Analysis AMR (ANL-NBS-GS-000008). The AMRs are expected to be available to NRC in FY 2003.	Received
TSPAI.3.19	UZ1	DOE will provide justification for the use of its evapotranspiration model, and defend the use of the analog site temperature data (UZ1.3.1). DOE will provide justification for the use of the evapotranspiration model, and justify the use of the analog site temperature data. The justification will be documented in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and the Future Climate Analysis AMR (ANL-NBS-GS-000008). The AMRs are expected to be available to NRC in FY 2003.	Received
TSPAI.3.20	TSPAI	Provide access to data supporting the synthetic meteorologic records (4JA.s01 and Area12.s01) (UZ1.3.2). DOE will provide data supporting the synthetic meteorologic records (specifically, data files 4JA.s01 and Area12.s01). These data files will be provided to NRC September 2001.	Complete
TSPAI.3.20	UZ1	Provide access to data supporting the synthetic meteorologic records (4JA.s01 and Area12.s01) (UZ1.3.2). DOE will provide data supporting the synthetic meteorologic records (specifically, data files 4JA.s01 and Area12.s01). These data files will be provided to NRC September 2001.	Complete
TSPAI.3.21	TSPAI	Demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered (UZ1.5.1). DOE will demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006). These AMRs are expected to be available to NRC	Received
TSPAI.3.21	UZ1	Demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered (UZ1.5.1). DOE will demonstrate that effects of near surface lateral flow on the spatial variability of net infiltration are appropriately considered in an update to the Simulation of Net Infiltration for Modern and Potential Future Climates AMR (ANL-NBS-HS-000032) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006). These AMRs are expected to be available to NRC	Received
TSPAI.3.22	TSPAI	Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1). DOE will provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received
TSPAI.3.22	UZ2	Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1). DOE will provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.25	UZ2	DOE should use the Passive Cross Drift Hydrologic test, the Alcove 8 - Niche 3 tests, the Niche 5 test, and other test data to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or a provide technical basis for not using it (UZ2.3.4). DOE will utilize field test data (e.g., the Passive Cross Drift Hydrologic test, the Alcove 8 - Niche 3 tests, the Niche 5 test, and other test data) to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or provide technical basis for not using it. This will be documented in Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) expected to be available to NRC in FY 2003.	Complete
TSPAI.3.25	TSPAI	DOE should use the Passive Cross Drift Hydrologic test, the Alcove 8 - Niche 3 tests, the Niche 5 test, and other test data to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or a provide technical basis for not using it (UZ2.3.4). DOE will utilize field test data (e.g., the Passive Cross Drift Hydrologic test, the Alcove 8 - Niche 3 tests, the Niche 5 test, and other test data) to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or provide technical basis for not using it. This will be documented in Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) expected to be available to NRC in FY 2003.	Complete
TSPAI.3.26	TSPAI	Calibrate the UZ flow model using the most recent data on saturations and water potentials, and clearly document the sources of calibration data and data collection methods (UZ2.3.5). DOE will calibrate the UZ flow model using the most recent data on saturations and water potentials, and document the sources of calibration data and data collection methods. The results will be documented in the Calibrated Properties Model AMR (MDL-NBS-HS-000003) expected to be available to NRC in FY 2003.	Received
TSPAI.3.26	UZ2	Calibrate the UZ flow model using the most recent data on saturations and water potentials, and clearly document the sources of calibration data and data collection methods (UZ2.3.5). DOE will calibrate the UZ flow model using the most recent data on saturations and water potentials, and document the sources of calibration data and data collection methods. The results will be documented in the Calibrated Properties Model AMR (MDL-NBS-HS-000003) expected to be available to NRC in FY 2003.	Received
TSPAI.3.27	TSPAI	Provide an overview of water flow rates used in the UZ model above and below the repository, in the MSTHM, in the seepage abstraction, and in the in-drift flow path models, to ensure appropriate integration between the various models (UZ2.TT.3). DOE will provide an overview of water flow rates used in the UZ model above and below the repository, in the Multi-Scale Thermohydrologic Model (MSTHM), in the seepage abstraction, and in the in drift flow path models, to ensure appropriate integration between the various models. This will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.27	UZ2	Provide an overview of water flow rates used in the UZ model above and below the repository, in the MSTHM, in the seepage abstraction, and in the in-drift flow path models, to ensure appropriate integration between the various models (UZ2.TT.3). DOE will provide an overview of water flow rates used in the UZ model above and below the repository, in the Multi-Scale Thermohydrologic Model (MSTHM), in the seepage abstraction, and in the in drift flow path models, to ensure appropriate integration between the various models. This will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.28	TSPAI	DOE needs to provide independent lines of evidence to provide additional confidence in the use of the active-fracture continuum concept in the transport model (UZ3.5.1). DOE will provide independent lines of evidence to provide additional confidence in the use of the active fracture continuum concept in the transport model. This will be documented in Radionuclide Transport Models under Ambient Conditions AMR (MDL-NBS-HS-000008) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received
TSPAI.3.28	UZ3	DOE needs to provide independent lines of evidence to provide additional confidence in the use of the active-fracture continuum concept in the transport model (UZ3.5.1). DOE will provide independent lines of evidence to provide additional confidence in the use of the active fracture continuum concept in the transport model. This will be documented in Radionuclide Transport Models under Ambient Conditions AMR (MDL-NBS-HS-000008) and UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received
TSPAI.3.29	TSPAI	Provide verification that the integration of the active fracture model with matrix diffusion in the transport model is properly implemented in the TSPA abstraction (UZ3.TT.3). DOE will provide verification that the integration of the active fracture model with matrix diffusion in the transport model is properly implemented in the TSPA abstraction. This verification will be documented in the Particle Tracking Model and Abstraction of Transport Processes (ANL-NBS-HS-000026) expected to be available to NRC in FY 2003.	Received
TSPAI.3.29	UZ3	Provide verification that the integration of the active fracture model with matrix diffusion in the transport model is properly implemented in the TSPA abstraction (UZ3.TT.3). DOE will provide verification that the integration of the active fracture model with matrix diffusion in the transport model is properly implemented in the TSPA abstraction. This verification will be documented in the Particle Tracking Model and Abstraction of Transport Processes (ANL-NBS-HS-000026) expected to be available to NRC in FY 2003.	Received
TSPAI.3.30	TSPAI	Provide the technical basis for the contrasting concentrations of colloids available for reversible attachment in the engineered barrier system and the saturated zone. Sensitivity analyses planned in response to RT Agreement 3.07 should address the effect of colloid concentration on Kc. Update, as necessary, the Kc parameter as new data become available from the Yucca Mountain region (SZ2.3.1). DOE will provide the technical basis for the contrasting concentrations of colloids available for reversible attachment in the engineered barrier system and the saturated zone. The sensitivity analyses planned in response to RT Agreement 3.07 will address the effect of colloid concentration on the Kc parameter. The technical basis will be documented in the Waste Form Colloid Associated Concentration Limits: Abstractions and Summary (ANL-WIS-MD-000012) in FY 2003. The Kc parameter will be updated as new data become available from the Yucca Mountain region in the Uncertainty Distribution for Stochastic Parameters AMR (ANL-NBS-MD-000011) in FY2003.	Received
TSPAI.3.30	SZ2	Provide the technical basis for the contrasting concentrations of colloids available for reversible attachment in the engineered barrier system and the saturated zone. Sensitivity analyses planned in response to RT Agreement 3.07 should address the effect of colloid concentration on Kc. Update, as necessary, the Kc parameter as new data become available from the Yucca Mountain region (SZ2.3.1). DOE will provide the technical basis for the contrasting concentrations of colloids available for reversible attachment in the engineered barrier system and the saturated zone. The sensitivity analyses planned in response to RT Agreement 3.07 will address the effect of colloid concentration on the Kc parameter. The technical basis will be documented in the Waste Form Colloid Associated Concentration Limits: Abstractions and Summary (ANL-WIS-MD-000012) in FY 2003. The Kc parameter will be updated as new data become available from the Yucca Mountain region in the Uncertainty Distribution for Stochastic Parameters AMR (ANL-NBS-MD-000011) in FY2003.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.31	TSPAI	Evaluate the effects of temporal changes in saturated zone chemistry on radionuclide concentrations (SZ2.3.2). DOE will reexamine the FEPs, currently included in the performance assessment, that may lead to temporal changes in saturated zone hydrochemistry. If the DOE determines that these FEPs can be excluded, the results will be documented in the FEP Saturated Zone Flow and Transport AMR (ANL-NBS-MD-000002) in FY 2003. If the DOE determines that these FEPs cannot be excluded from the performance assessment, the DOE will evaluate the effects of temporal changes in the saturated zone chemistry on radionuclide concentrations and will document this evaluation in above mentioned AMR.	Received
TSPAI.3.31	SZ2	Evaluate the effects of temporal changes in saturated zone chemistry on radionuclide concentrations (SZ2.3.2). DOE will reexamine the FEPs, currently included in the performance assessment, that may lead to temporal changes in saturated zone hydrochemistry.. If the DOE determines that these FEPs can be excluded, the results will be documented in the FEP Saturated Zone Flow and Transport AMR (ANL-NBS-MD-000002) in FY 2003. If the DOE determines that these FEPs cannot be excluded from the performance assessment, the DOE will evaluate the effects of temporal changes in the saturated zone chemistry on radionuclide concentrations and will document this evaluation in above mentioned AMR.	Received
TSPAI.3.32	TSPAI	Provide the technical basis that the representation of uncertainty in the saturated zone as essentially all lack-of-knowledge uncertainty (as opposed to real sample variability) does not result in an underestimation of risk when propagated to the performance assessment (SZ2.4.1). DOE will provide the technical basis that the representation of uncertainty (i.e., lack-of-knowledge uncertainty) in the saturated zone does not result in an underestimation of risk when propagated to the performance assessment. A deterministic case from Saturated Zone Flow Patterns and Analyses AMR (ANL-NBS-HS-000038) will be compared to TSPA analyses. The comparison will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.32	SZ2	Provide the technical basis that the representation of uncertainty in the saturated zone as essentially all lack-of-knowledge uncertainty (as opposed to real sample variability) does not result in an underestimation of risk when propagated to the performance assessment (SZ2.4.1). DOE will provide the technical basis that the representation of uncertainty (i.e., lack-of-knowledge uncertainty) in the saturated zone does not result in an underestimation of risk when propagated to the performance assessment. A deterministic case from Saturated Zone Flow Patterns and Analyses AMR (ANL-NBS-HS-000038) will be compared to TSPA analyses. The comparison will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.33	TSPAI	Provide justification that the Kd values used for radionuclides in the soil in Amargosa valley based on the results of a literature review are realistic or conservative for actual conditions at the receptor location (DOSE2.2.1). DOE will provide justification that the Kd values used for radionuclides in the soil in Amargosa Valley are realistic or conservative for actual conditions at the receptor location. The justification will be provided in Evaluate Soil/Radionuclide Removal by Erosion and Leaching AMR (ANL-NBS-MD-000009) or other document expected to be available to NRC in FY 2003.	Complete
TSPAI.3.33	DOSE2	Provide justification that the Kd values used for radionuclides in the soil in Amargosa valley based on the results of a literature review are realistic or conservative for actual conditions at the receptor location (DOSE2.2.1). DOE will provide justification that the Kd values used for radionuclides in the soil in Amargosa Valley are realistic or conservative for actual conditions at the receptor location. The justification will be provided in Evaluate Soil/Radionuclide Removal by Erosion and Leaching AMR (ANL-NBS-MD-000009) or other document expected to be available to NRC in FY 2003.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.31	TSPAI	Evaluate the effects of temporal changes in saturated zone chemistry on radionuclide concentrations (SZ2.3.2). DOE will reexamine the FEPs, currently included in the performance assessment, that may lead to temporal changes in saturated zone hydrochemistry. If the DOE determines that these FEPs can be excluded, the results will be documented in the FEP Saturated Zone Flow and Transport AMR (ANL-NBS-MD-000002) in FY 2003. If the DOE determines that these FEPs cannot be excluded from the performance assessment, the DOE will evaluate the effects of temporal changes in the saturated zone chemistry on radionuclide concentrations and will document this evaluation in above mentioned AMR.	Received
TSPAI.3.31	SZ2	Evaluate the effects of temporal changes in saturated zone chemistry on radionuclide concentrations (SZ2.3.2). DOE will reexamine the FEPs, currently included in the performance assessment, that may lead to temporal changes in saturated zone hydrochemistry. If the DOE determines that these FEPs can be excluded, the results will be documented in the FEP Saturated Zone Flow and Transport AMR (ANL-NBS-MD-000002) in FY 2003. If the DOE determines that these FEPs cannot be excluded from the performance assessment, the DOE will evaluate the effects of temporal changes in the saturated zone chemistry on radionuclide concentrations and will document this evaluation in above mentioned AMR.	Received
TSPAI.3.32	TSPAI	Provide the technical basis that the representation of uncertainty in the saturated zone as essentially all lack-of-knowledge uncertainty (as opposed to real sample variability) does not result in an underestimation of risk when propagated to the performance assessment (SZ2.4.1). DOE will provide the technical basis that the representation of uncertainty (i.e., lack-of-knowledge uncertainty) in the saturated zone does not result in an underestimation of risk when propagated to the performance assessment. A deterministic case from Saturated Zone Flow Patterns and Analyses AMR (ANL-NBS-HS-000038) will be compared to TSPA analyses. The comparison will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.32	SZ2	Provide the technical basis that the representation of uncertainty in the saturated zone as essentially all lack-of-knowledge uncertainty (as opposed to real sample variability) does not result in an underestimation of risk when propagated to the performance assessment (SZ2.4.1). DOE will provide the technical basis that the representation of uncertainty (i.e., lack-of-knowledge uncertainty) in the saturated zone does not result in an underestimation of risk when propagated to the performance assessment. A deterministic case from Saturated Zone Flow Patterns and Analyses AMR (ANL-NBS-HS-000038) will be compared to TSPA analyses. The comparison will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.33	TSPAI	Provide justification that the Kd values used for radionuclides in the soil in Amargosa valley based on the results of a literature review are realistic or conservative for actual conditions at the receptor location (DOSE2.2.1). DOE will provide justification that the Kd values used for radionuclides in the soil in Amargosa Valley are realistic or conservative for actual conditions at the receptor location. The justification will be provided in Evaluate Soil/Radionuclide Removal by Erosion and Leaching AMR (ANL-NBS-MD-000009) or other document expected to be available to NRC in FY 2003.	Complete
TSPAI.3.33	DOSE2	Provide justification that the Kd values used for radionuclides in the soil in Amargosa valley based on the results of a literature review are realistic or conservative for actual conditions at the receptor location (DOSE2.2.1). DOE will provide justification that the Kd values used for radionuclides in the soil in Amargosa Valley are realistic or conservative for actual conditions at the receptor location. The justification will be provided in Evaluate Soil/Radionuclide Removal by Erosion and Leaching AMR (ANL-NBS-MD-000009) or other document expected to be available to NRC in FY 2003.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
TSPAI.3.37	TSPAI	Provide a quantitative analysis that the sampling method including the correlations to NP used by the TSPA code to abstract the GENII-S process model code adequately represent the uncerrtainty and variability and correlations for the biosphere process model (DOSE3.4.1). DOE will provide a quantitative analysis that the sampling method including the correlations between BDCFs utilized by the TSPA code to abstract the GENII-S process model data adequately represent the uncertainty and variability and correlations for the biosphere process model. This will be documented in Nominal Performance Biosphere Dose Conversion Factor Analysis AMR (ANL-MGR-MD-000009), Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or other document expected to be available to NRC in FY 2003. Results of these analyses will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.37	DOSE3	Provide a quantitative analysis that the sampling method including the correlations to NP used by the TSPA code to abstract the GENII-S process model code adequately represent the uncerrtainty and variability and correlations for the biosphere process model (DOSE3.4.1). DOE will provide a quantitative analysis that the sampling method including the correlations between BDCFs utilized by the TSPA code to abstract the GENII-S process model data adequately represent the uncertainty and variability and correlations for the biosphere process model. This will be documented in Nominal Performance Biosphere Dose Conversion Factor Analysis AMR (ANL-MGR-MD-000009), Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or other document expected to be available to NRC in FY 2003. Results of these analyses will be documented in the TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.38	TSPAI	DOE will develop guidance in the model abstraction process that can be adhered to by all model developers so that (1) the abstraction process, (2) the selection of conservatism in components, and (3) representation of uncertainty are systematic across the TSPA model. DOE will evaluate and define approaches to deal with: (1) evaluating non-linear models as to what their most conservative settings may be if conservatism is being used to address uncertainty, and (2) trying to utilize human intuition in a complex system. In addition, DOE will consider adding these items to the internal/external reviewer's checklists to ensure proper implementation of the improved methodology (TSPA0002). DOE will develop written guidance in the model abstraction process for model developers so that (1) the abstraction process, (2) the selection of conservatism in components, and (3) representation of uncertainty, are systematic across the TSPA model. These guidelines will address: (1) evaluation of non-linear models when conservatism is being utilized to address uncertainty, and (2) utilization of decisions based on technical judgement in a complex system. These guidelines will be developed, implemented, and be made available to the NRC in FY 2002.	Need Additional Information
TSPAI.3.39	TSPAI	In future performance assessments, DOE should document the simplifications used for abstractions per TSPAI.3.38 activities. Justification will be provided to show that the simplifications appropriately represent the necessary processes and appropriately propagate process model uncertainties. Comparisons of output from process models to performance assessment abstractions will be provided, with the level of detail in the comparisons commensurate with any reduction in propagated uncertainty and the risk significance of the model (TSPA0003). DOE will document the simplifications utilized for abstractions per TSPAI.3.38 activities for all future performance assessments. Justification will be provided to show that the simplifications appropriately represent the necessary processes and appropriately propagate process model uncertainties. Comparisons of output from process models to performance assessment abstractions will be provided, with the level of detail in the comparisons commensurate with any reduction in propagated uncertainty and the risk significance of the model. The documentation of the information will be provided in abstraction AMRs in FY 2003.	Need Additional Information

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.3.40	TSPAI	DOE will implement effective controls to ensure that the abstractions defined in the AMR's are consistently propagated into the TSPA, or ensure that the TSPA documentation describes any differences. Specific examples of needed revisions (if still applicable) include: (1) the implementation of flux splitting in the TSPA model, (2) the propagation of thermohydrology uncertainty/variability into the WAPDEG corrosion model calculations, and (3) the implementation of the in-package chemistry abstraction. DOE will implement program improvements to ensure that the abstractions defined in the AMRs are consistently propagated into the TSPA, or ensure that the TSPA documentation describes any differences. Program improvements may include, for example, upgrades to work plans, procedural upgrades, preparation of desktop guides, worker training, increased review and oversight. The program improvements will be implemented and be made available to the NRC during FY 2002.	Complete
TSPAI.3.41	TSPAI	To provide support for the mathematical representation of data uncertainty in the TSPA, the DOE will provide technical basis for the data distributions used in the TSPA. An example of how this may be accomplished is the representation on a figure or chart of the data plotted as an empirical distribution and the probability distribution assigned to fit these data. DOE will provide the technical basis for the data distributions utilized in the TSPA to provide support for the mathematical representation of data uncertainty in the TSPA. The documentation of the technical basis will be incorporated in documentation associated with TSPA for any potential license application. The documentation is expected to be available to NRC in FY 2003.	Need Additional Information
TSPAI.3.42	TSPAI	DOE should provide a sensitivity analysis on the potentially abrupt changes in colloid concentrations due to shifts in modeled pH and ionic strength across uncertain stability boundaries. This analysis may be combined with plans to address ENFE Agreement 4.06 and RT Agreement 3.07. DOE will complete sensitivity analyses to investigate the effects of varying colloid concentration due to shifts in model predicted pH and ionic strength across uncertain stability boundaries. These analyses will be documented in TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.3.42	ENG4	DOE should provide a sensitivity analysis on the potentially abrupt changes in colloid concentrations due to shifts in modeled pH and ionic strength across uncertain stability boundaries. This analysis may be combined with plans to address ENFE Agreement 4.06 and RT Agreement 3.07. DOE will complete sensitivity analyses to investigate the effects of varying colloid concentration due to shifts in model predicted pH and ionic strength across uncertain stability boundaries. These analyses will be documented in TSPA for any potential license application expected to be available to NRC in FY 2003.	Received
TSPAI.4.01	TSPAI	DOE will document the methodology that will be used to incorporate alternative conceptual models into the performance assessment. The methodology will ensure that the representation of alternative conceptual models in the TSPA does not result in an underestimation of risk. DOE will document the guidance given to process-level experts for the treatment of alternative models. The implementation of the methodology will be sufficient to allow a clear understanding of the potential effect of alternative conceptual models and their associated uncertainties on the performance assessment. The methodology will be documented in the TSPA-LA methods and assumptions document in FY02. The results will be documented in the appropriate AMRs or the TSPA for any potential license application in FY 2003.	Need Additional Information
TSPAI.4.02	TSPAI	DOE will provide the documentation that supports the representation of distribution coefficients (Kd's) in the performance assessment as uncorrelated is consistent with the physical processes and does not result in an underestimation of risk. This will be documented in the TSPA for any potential license application in FY03.	Complete
TSPAI.4.03	TSPAI	DOE will document the method that will be used to demonstrate that the overall results of the TSPA are stable. DOE will provide documentation that submodels (including submodels used to develop input parameters and transfer functions) are also numerically stable. DOE will address in the method the stability of the results with respect to the number of realizations. DOE will describe in the method the statistical measures that will be used to support the argument of stability. The method will be documented in TSPA LA Methods and Assumptions Document in FY02. The results of the analyses will be provided in the TSPA (or other appropriate documentation) for any potential license application in FY 2003.	Partly Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
TSPAI.4.04	TSPAI	DOE will conduct appropriate analyses and provide documentation that demonstrates the results of the performance assessment are stable with respect to discretization (e.g. spatial and temporal) of the TSPA model. This will be documented in the TSPA for any potential license application in FY 2003.	Received
TSPAI.4.05	TSPAI	DOE will document the process used to develop confidence in the TSPA models (e.g., steps similar to those described in NUREG-1636). The detailed process is currently documented in the model development procedures that are being evaluated for process improvement in response to the model validation corrective action report CAR-BSC-01-C-001. The upgraded model validation procedures will be available for NRC review in FY 2002.	Complete
TSPAI.4.06	TSPAI	DOE will document the implementation of the process for model confidence building and demonstrate compliance with model confidence criteria in accordance with the applicable procedures. This will be documented in the respective AMR revisions and made available to NRC in FY 2003.	Received
TSPAI.4.07	TSPAI	DOE's software qualification requirements are currently documented in procedure AP SI.1Q which is under review for process improvement as part of software CAR-BSC-01-C-002. During its review of AP SI.1Q, DOE will consider: 1) the procedure it would follow to conduct a systematic and uniform verification — all areas of a code analyzed at a consistent level, 2) the process it would follow to ensure correct implementation of algorithms, and 3) the process it would follow for the full disclosure of calculations and results. DOE will document compliance with the improved process in the verification documentation required by AP SI.1Q. Software qualification record packages for the affected programs will be available for NRC review in FY 2003.	Complete
USFIC.3.01	UZ1	Provide the documentation sources and schedule for the Monte Carlo method for analyzing infiltration. DOE will provide the schedule and identify documents expected to contain the results of the Monte Carlo analyses in February 2002.	Received
USFIC.3.02	UZ1	Provide justification for the parameters in Table 4-1 of the Analysis of Infiltration Uncertainty AMR (for example, bedrock permeability in the infiltration model needs to be reconciled with the Alcove 1 results/observations. Also, provide documentation (source, locations, tests, test results) for the Alcove 1 and Pagany Wash tests. DOE will provide justification and documentation in a Monte Carlo analyses document. The information will be available in February 2002.	Received

Agreement	Related ISIs	NRC/DOE Agreement	Status
USFIC.4.01	UZ2	The ongoing and planned testing are a reasonable approach for a licensing application with the following comments: (i) consider a mass balance of water for alcove 8/Niche 3 cross over test; (ii) monitor evaporation during all testing; (iii) provide the documentation of the test plan for the Passive Cross Drift Hydrologic test; (iv) provide the NRC with any Cross Drift seepage predictions that may have been made for the Passive Cross Drift Hydrologic test; (v) provide documentation of the results obtained and the analysis for the Passive Cross Drift Hydrologic test. This documentation should include the analysis of water samples collected during entries into the Cross Drift (determination whether the water comes from seepage or condensation); (vi) provide documentation of the results obtained and the analysis for the Alcove 7 test. This documentation should include the analysis of water samples collected during entries into Alcove 7 (determination whether the water comes from seepage or condensation); (vii) provide the documentation of the test plan for the Niche 5 test; (viii) provide documentation of the results obtained and the analysis for the Niche 5 test; (ix) provide documentation of the results obtained and the analysis for the Systematic Hydrologic Characterization test; (x) provide documentation of the results obtained and the analysis for the Niche 4 test; and (xi) provide documentation of the results obtained from the calcite filling test. Include interpretation of the observed calcite deposits found mostly at the bottom of the lithophysal cavities. DOE stated that: (1) a mass balance of water for the Alcove 8/Niche 3 test has been considered, but is not feasible due to the size of the collection system that would be required. A collection system to obtain a mass balance is being developed for the Niche 5 test (i); (2) evaporation will be monitored for all tests where evaporation is a relevant process (ii); (3) test plans for Niche 5 and the Cross Drift Hydrologic tests are expected to be available to NRC FY 2002 (iii, vii); (4) the Cross Drift seepage predictions will be documented in the Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) expected to be available to NRC by FY 2003 (iv); (5) DOE will document the results for the tests identified above (except calcite filling observations) in the In-Situ Field Testing of Processes AMR (ANL-NBS-HS-000005) expected to be available to NRC in FY 2003 (v), (vi), (viii),(ix),(x); (6) results of the calcite filling observations will be documented in Analysis of Geochemical Data for the Unsaturated Zone (ANL-NBS-HS-000017) and the UZ Flow Models and Submodels (MDL-NBS-HS-000006) expected to be available to NRC FY 2003 (xi).	Complete
USFIC.4.01	UZ3	The ongoing and planned testing are a reasonable approach for a licensing application with the following comments: (i) consider a mass balance of water for alcove 8/Niche 3 cross over test; (ii) monitor evaporation during all testing; (iii) provide the documentation of the test plan for the Passive Cross Drift Hydrologic test; (iv) provide the NRC with any Cross Drift seepage predictions that may have been made for the Passive Cross Drift Hydrologic test; (v) provide documentation of the results obtained and the analysis for the Passive Cross Drift Hydrologic test. This documentation should include the analysis of water samples collected during entries into the Cross Drift (determination whether the water comes from seepage or condensation); (vi) provide documentation of the results obtained and the analysis for the Alcove 7 test. This documentation should include the analysis of water samples collected during entries into Alcove 7 (determination whether the water comes from seepage or condensation); (vii) provide the documentation of the test plan for the Niche 5 test; (viii) provide documentation of the results obtained and the analysis for the Niche 5 test; (ix) provide documentation of the results obtained and the analysis for the Systematic Hydrologic Characterization test; (x) provide documentation of the results obtained and the analysis for the Niche 4 test; and (xi) provide documentation of the results obtained from the calcite filling test. Include interpretation of the observed calcite deposits found mostly at the bottom of the lithophysal cavities. DOE stated that: (1) a mass balance of water for the Alcove 8/Niche 3 test has been considered, but is not feasible due to the size of the collection system that would be required. A collection system to obtain a mass balance is being developed for the Niche 5 test (i); (2) evaporation will be monitored for all tests where evaporation is a relevant process (ii); (3) test plans for Niche 5 and the Cross Drift Hydrologic tests are expected to be available to NRC FY 2002 (iii, vii); (4) the Cross Drift seepage predictions will be documented in the Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) expected to be available to NRC by FY 2003 (iv); (5) DOE will document the results for the tests identified above (except calcite filling observations) in the In-Situ Field Testing of Processes AMR (ANL-NBS-HS-000005) expected to be available to NRC in FY 2003 (v), (vi), (viii),(ix),(x); (6) results of the calcite filling observations will be documented in Analysis of Geochemical Data for the Unsaturated Zone (ANL-NBS-HS-000017) and the UZ Flow Models and Submodels (MDL-NBS-HS-000006) expected to be available to NRC FY 2003 (xi).	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
USFIC.4.02	UZ2	Include the effect of the low-flow regime processes (e.g., film flow) in DOE's seepage fraction and seepage flow, or justify that it is not needed. DOE will include the effect of the low-flow regime processes (e.g., film flow) in the seepage fraction and seepage flow, or justify that it is not needed. These studies will be documented in Seepage Models for PA Including Drift Collapse AMR (MDL-NBS-HS-000002) expected to be available to NRC in FY 2003.	Complete
USFIC.4.03	UZ2	When conducting seepage studies, consider smaller scale tunnel irregularities in drift collapse or justify that it is not needed. When conducting seepage studies, DOE will consider smaller scale tunnel irregularities in drift collapse or justify that it is not needed. These studies will be documented in Seepage Models for PA Including Drift Collapse AMR (MDL-NBS-HS-000002) expected to be available to NRC in FY 2003.	Complete
USFIC.4.04	UZ2	Provide final documentation for the effectiveness of the PTn to dampen episodic flow, including reconciling the differences in chloride-36 studies. DOE will provide final documentation for the effectiveness of the PTn to dampen episodic flow, including reconciling the differences in chlorine-36 studies These studies will be documented in UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003.	Received
USFIC.4.05	UZ2	Provide the analysis of geochemical data used for support of the flow field below the repository.	Complete
USFIC.4.06	UZ2	Provide documentation of the results obtained from the Comparison of Continuum and Discrete Fracture Network Models modeling study. Alternatively, provide justification of the continuum approach at the scale of the seepage model grid (formerly June 20 letter, item xiii). DOE will provide documentation of the results obtained from the Comparison of Continuum and Discrete Fracture Network Models modeling study or provide justification of the continuum approach at the scale of the seepage model grid. This will be documented in Seepage Calibration Model and Seepage Testing Data AMR (MDL-NBS-HS-000004) or other suitable document expected to be available to NRC in FY 2003.	Complete
USFIC.4.07	UZ2	Provide documentation of the results obtained from the Natural Analogs modeling study. The study was to apply conceptual models and numerical approaches developed from Yucca Mountain to natural analog sites with observations of seepage into drifts, drift stability, radionuclide transport, geothermal effects, and preservation of artifacts. DOE will provide documentation of the results obtained from the Natural Analogs modeling study. The study was to apply conceptual models and numerical approaches developed from Yucca Mountain to natural analog sites with observations of seepage into drifts, drift stability, radionuclide transport, geothermal effects, and preservation of artifacts. This will be documented in the Natural Analogs for the Unsaturated Zone AMR (ANL-NBS-HS-000007) expected to be available to NRC FY 2002.	Complete
USFIC.5.01	SZ1	The NRC believes that the incorporation of horizontal anisotropy in the site scale model should be reevaluated to ensure that a reasonable range for uncertainty is captured. The data from the C-wells testing should provide a technical basis for an improved range.. As part of the C-wells report, DOE should include an analysis of horizontal anisotropy for wells that responded to the long-term tests. Results should be included for the tuffs in the calibrated site scale model. DOE will provide the results of the requested analyses in C-wells report(s) in October 2001, and will carry the results forward to the site-scale model, as appropriate.	Complete
USFIC.5.02	SZ1	Provide the update to the SZ PMR, considering the updated regional flow model. A revision to the Saturated Zone Flow and Transport PMR is expected to be available and will reflect the updated United States Geological Survey (USGS) Regional Groundwater Flow Model in FY 2002, subject to receipt of the model report from the USGS (reference item 9).	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
USFIC.5.03	SZ1	DOE's outline for collecting data in the alluvium appears reasonable but lacks detail. Provide a detailed testing plan for alluvial testing to reduce uncertainty (for example, the plan should give details about hydraulic and tracer tests at the well 19 complex and it should also identify locations for alluvium complex testing wells and tests and logging to be performed). NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for this meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Complete
USFIC.5.03	SZ2	DOE's outline for collecting data in the alluvium appears reasonable but lacks detail. Provide a detailed testing plan for alluvial testing to reduce uncertainty (for example, the plan should give details about hydraulic and tracer tests at the well 19 complex and it should also identify locations for alluvium complex testing wells and tests and logging to be performed). NRC will review the plan and provide comments, if any, for DOE's consideration. In support and preparation for this meeting, DOE provided work plans for the Alluvium Testing Complex and the Nye County Drilling Program (FWP-SBD-99-002, Alluvial Tracer Testing Field Work Package, and FWP-SBD-99-001, Nye County Early Warning Drilling Program, Phase II and Alluvial Testing Complex Drilling). DOE will provide test plans of the style of the Alcove 8 plan as they become available. In addition, the NRC On Site Representative attends DOE/Nye County planning meetings and is made aware of all plans and updates to plans as they are made.	Complete
USFIC.5.04	SZ1	Provide additional information to further justify the uncertainty distribution of flow path lengths in the alluvium. This information currently resides in the Uncertainty Distribution for Stochastic Parameters AMR. DOE will provide additional information, to include Nye County data as available, to further justify the uncertainty distribution of flowpath lengths in alluvium in updates to the Uncertainty Distribution for Stochastic Parameters AMR and to the Saturated Zone Flow and Transport PMR, both expected to be available in FY 2002.	Complete
USFIC.5.05	SZ1	Provide the hydro-stratigraphic cross-sections that include the Nye County data. DOE will provide the hydrostratigraphic cross sections in an update to the Hydrogeologic Framework Model for the Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available during FY 2002, subject to availability of the Nye County data.	Received
USFIC.5.06	SZ1	Provide a technical basis for residence time (for example, using C-14 dating on organic carbon in groundwater from both the tuffs and alluvium). DOE will provide technical basis for residence time in an update to the Geochemical and Isotopic Constraints on Groundwater Flow Directions, Mixing, and Recharge at Yucca Mountain, Nevada AMR during FY 2002.	Complete
USFIC.5.07	SZ1	Provide all the data from SD-6 and WT-24. Some of this data currently resides in the Technical Data Management System, which is available to the NRC and CNWRA staff. DOE will include any additional data from SD-6 and WT-24 in the Technical Data Management System in February 2001.	Complete
USFIC.5.08	SZ1	Taking into account the Nye County information, provide the updated potentiometric data and map for the regional aquifer, and an analysis of vertical hydraulic gradients within the site scale model. DOE will provide an updated potentiometric map and supporting data for the uppermost aquifer in an update to the Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model AMR expected to be available in October 2001, subject to receipt of data from the Nye County program. Analysis of vertical hydraulic gradients will be addressed in the site-scale model and will be provided in the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002.	Complete

Agreement	Related ISIs	NRC/DOE Agreement	Status
USFIC.5.09	SZ1	Provide additional information in an updated AMR or other document for both the regional and site scale model (for example, grid construction, horizontal and vertical view of the model grid, boundary conditions, input data sets, model output, and the process of model calibration). The updated USGS Regional Groundwater Flow Model is a USGS Product, not a Yucca Mountain Site Characterization Project product. It is anticipated that this document will be available in September 2001. DOE believes that the requested information is now available in the current version of the Calibration of the Site-Scale Saturated Zone Flow Model AMR and will be carried forward in future AMR revisions.	Complete
USFIC.5.10	SZ1	Provide in updated documentation of the HFM that the noted discontinuity at the interface between the GFM and the HFM does not impact the evaluation of repository performance. DOE will evaluate the impact of the discontinuity between the Geologic Framework Model and the Hydrogeologic Framework Model on the assessment of repository performance and will provide the results in an update to the Hydrogeologic Framework Model for the Saturated-Zone Site-Scale Flow and Transport Model AMR during FY 2002.	Complete
USFIC.5.11	SZ1	In order to test an alternative conceptual flow model for Yucca Mountain, run the SZ flow and transport code assuming a north-south barrier along the Solitario Canyon fault whose effect diminishes with depth or provide justification not to. DOE will run the saturated zone flow and transport model assuming the specified barrier and will provide the results in an update to the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002.	Complete
USFIC.5.12	SZ1	Provide additional supporting arguments for the Site-Scale Saturated Zone Flow model validation or use a calibrated model that has gone through confidence building measures. The model has been calibrated and partially validated in accordance with AP 3.10Q, which is consistent with NUREG-1636. Additional confidence-building activities will be reported in a subsequent update to the Calibration of the Site-Scale Saturated Zone Flow Model AMR, expected to be available during FY 2002.	Complete
USFIC.5.13	SZ1	Provide the evaluation of the ongoing fluid inclusion studies (for example, UNLV, State of Nevada, and USGS). DOE's consideration of the fluid inclusion studies will be documented in an update to the Saturated Zone Flow and Transport PMR expected to be available in FY 2002, subject to availability of the studies.	Complete
USFIC.5.14	TSPAI	Provide the updated SZ FEPs AMR. DOE will provide the updated Features, Events, and Processes in Saturated Zone Flow and Transport AMR in February 2001.	Complete
USFIC.5.14	SZ1	Provide the updated SZ FEPs AMR. DOE will provide the updated Features, Events, and Processes in Saturated Zone Flow and Transport AMR in February 2001.	Complete
USFIC.6.01	UZ3	The DOE will provide the final sensitivity analysis on matrix diffusion (for UZ) in the TSPA-SR, Rev. 0. Due date: December 2000. The saturated zone information will be available in TSPA-SR, Rev.1, expected to be available in June 2001.	Complete
USFIC.6.02	UZ3	The DOE will provide the final detailed testing plan for Alcove 8. The testing plan will be provided by August 28, 2000. The NRC staff will provide comments, if any, no later than two weeks after receiving the testing plan.	Complete
USFIC.6.03	UZ3	The DOE will complete the Alcove 8 testing, taking into consideration the NRC staff comments, if any, and document the results in a DOE-approved AMR, due date: May 2001.	Received
USFIC.6.04	SZ2	Provide the documentation for the C-wells testing. Use the field test data or provide justification that the data from the laboratory tests is consistent with the data from the field tests. DOE will provide the C-wells test documentation and will either use the test data or provide a justified reconciliation of the lab and field test data in C-wells document(s) in October 2001.	Complete

Agreement	*Related ISIs*	*NRC/DOE Agreement*	*Status*
USFIC.6.04	SZ1	Provide the documentation for the C-wells testing. Use the field test data or provide justification that the data from the laboratory tests is consistent with the data from the field tests. DOE will provide the C-wells test documentation and will either use the test data or provide a justified reconciliation of the lab and field test data in C-wells document(s) in October 2001.	Complete

APPENDIX B

NRC COMMENTS ON FEATURES, EVENTS, AND PROCESSES, INCLUDING DOE AND NRC AGREEMENTS

This appendix summarizes previous U.S. Nuclear Regulatory Commission (NRC) comments on the U.S. Department of Energy (DOE) consideration of features, events, and processes in a series of technical exchanges held in 2001. DOE is in the process of updating its screening of features, events, and processes, but the update was not available at the time of this report. The evaluation, based on available information, is presented in the form of a table (Table B–1) with the following fields:

Comment An explanation of issues identified by NRC staff at the 2001 Technical Exchanges.

DOE response to 2001 technical exchanges
Comments were discussed with DOE at the DOE and NRC Technical Exchanges on May 15–17 and August 6–10, 2001. Agreements on items related to Igneous Activity were reached at the September 5, 2001, DOE and NRC Technical Exchange (Reamer, 2001a,b). The language agreed upon by DOE and NRC at the 2001 technical exchanges is provided here for reference.

Table B–1. NRC Comments on Features, Events, and ProcessesIncluding, DOE and NRC Agreements

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
Direct1	75	Various features, events, and processes 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 1.1.02.00.00 (Excavation/Construction) changes to the rock around the repository from 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. 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 that is relied on for performance calculations, failure to complete these seals could affect repository performance. 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 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 Alloy 22 from the long-term exposure to elevated temperatures are not considered. 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. 2.3.01.00.00 (Topography and Morphology) the topography may affect dike propagation near the surface; dike propagation probably should be discussed as part of this feature, event, and process.	The following agreements reached at the September 5, 2001, DOE and NRC Technical Exchange (Reamer, 2001c) address the NRC comments: 1.1.02.00.00 (Excavation/Construction)—Igneous Activity Subissue 2, Agreement 18 1.1.04.01.00 (Incomplete Closure)—Igneous Activity Subissue 2, Agreement 18 2.1.03.12.00 [Canister Failure (Long-Term)]—Igneous Activity Subissue 2, Agreement 19 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift)—Igneous Activity Subissue 2, Agreement 18 2.3.01.00.00 (Topography and Morphology)—Igneous Activity Subissue 2, Agreement 18 Igneous Activity Subissue 2, Agreement 18: DOE will evaluate how the presence of repository structures may affect magma ascent, conduit localization, and evolution of the conduit and flow system. The evaluation will include the potential effects of topography and stress, strain response on existing or new geologic structures resulting from thermal loading of high-level waste, and a range of physical conditions appropriate for the duration of igneous events. DOE will also evaluate how the presence of engineered repository structures in the license application design (e.g., drifts, waste packages, and backfill) could affect magma flow processes for the duration of an igneous event. The evaluation will include the mechanical strength and durability of natural or engineered barriers that could restrict magma flow within intersected drifts. The results of this investigation will be documented in an update to the Analysis Model Report titled Dike Propagation and Interaction with Drifts, ANL–WIS–MD–000015, expected to be available in fiscal year 2003, or another appropriate technical document. Igneous Activity Subissue 2, Agreement 19: DOE will evaluate waste package response to stresses from thermal and mechanical effects associated with exposure to basaltic magma, considering the results of evaluations attendant to Igneous Activity Subissue 2, Agreement 18. As currently planned, the evaluation, if implemented, would include (i) appropriate at-condition strength properties and magma flow paths, for duration of an igneous event; and (ii) aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event, which will include the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE will also evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gases at conditions appropriate for an igneous event, considering the results of evaluations attendant to Igneous Activity Subissue 2, Agreement 18. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. The results

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
			of this investigation would be documented in an update to the technical product Waste Package Behavior in Magma, CA-EBS-ME-000002, which would be available by the end of fiscal year 2003, or another appropriate technical document.
Direct1 Dose2	IA-1	2.3.02.02.00 (Radionuclide Accumulation in Soil) is included for irrigation deposition only; however, this screening argument is too limited because it excludes transport of volcanic ash from other areas to the critical group location (CRWMS M&O, 2001a). DOE indicated that redistribution will be accounted for by conservatively assuming that the wind is blowing toward the critical group and maintaining a high mass load in years after the event. DOE has not provided a demonstration that these conservatisms actually bound the effects of redistribution. Similar comment applies to the following items: 2.3.02.03.00 (Soil and Sediment Transport). In the screening argument, it is claimed that 100-percent south-blowing wind direction assumption accounts for aeolian and fluvial transport processes. Additional technical basis for this statement should be provided. 2.3.13.02.00 (Biosphere Transport) excludes transport in surface water. 2.3.11.02.00 (Surface Runoff and Flooding) 2.3.01.00.00 (Topography and Morphology). The effect of this item on redistribution of radionuclides after an igneous event should be considered.	Igneous Activity Subissue 2, Agreement 17 addresses the NRC comments. DOE will evaluate conclusions that the risk effects (i.e., effective annual dose) of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the document Total System Performance Assessment for Site Recommendation, Rev. 00, ICN1. DOE will examine rates of eolian and fluvial mobilization off slopes, rates of transport in Fortymile Wash, and rates of deposition or removal at the proposed critical group location. DOE will evaluate changes in grain size caused by these processes for effects on airborne particle concentrations. DOE will also evaluate the inherent assumption in the mass loading model that the concentration of radionuclides on soil in the air is equivalent to the concentration of radionuclides on soil on the ground does not underestimate dose (i.e., radionuclides important to dose do not preferentially attach to smaller particles). DOE will document the results of investigations in the Analysis Model Report titled Eruptive Processes and Soil Redistribution, ANL-MGR-GS-000002, expected to be available in fiscal year 2003 and in the Analysis Model Report titled Input Parameter Values for External and Inhalation Radiation Exposure Analysis, ANL-MGR-MD-000001, to be available in fiscal year 2003, or another appropriate technical document.
Dose1 Dose2 Dose3	17	DOE selected a subset of the full list of features, events, and processes as applicable for biosphere screening in CRWMS M&O (2001a). Some entries potentially applicable to biosphere dose conversion factor calculations (that should be considered for screening) have not been included in the scope of the document (CRWMS M&O, 2001a). These include 2.3.11.04.00 (Groundwater Discharge to Surface) 1.3.07.02.00 (Water Table Rise) 3.2.10.00.00 (Atmospheric Transport of Contaminants) 1.2.04.01.00 (Igneous Activity) 2.2.08.01.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone) (i.e., chemical species can impact dose coefficient selection) 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere) 3.1.01.01.00 (Radioactive Decay and Ingrowth) 1.2.04.07.00 (Ash Fall).	DOE will provide a technical basis in the Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL-MGR-MD-000011, to address the NRC comments for 2.3.11.04.00 (Groundwater Discharge to Surface), 1.3.07.02.00 (Water Table Rise), and 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere). No further action is required for 3.2.10.00.00 (Atmospheric Transport of Contaminants) and 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, ANL-MGR-MD-000011, for 2.2.08.01.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone), to address the NRC comment. DOE will add links to the Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL-MGR-MD-000011, for 3.1.01.01.00 (Radioactive Decay and Ingrowth) and 1.2.04.07.00 (Ashfall), to address the NRC comment.
ENG1 ENG4 UZ3	57	1.1.02.03.00 (Undesirable Materials Left) is screened out on the basis of low consequences (CRWMS M&O, 2001b). Although a report cited by the DOE (CRWMS M&O, 1995) provides an analysis of appropriate upper bounds on materials introduced into the repository, no analysis has been conducted to determine if the current design will meet these limits. DOE should provide	DOE agreed to provide the technical basis for the screening argument in the Engineered Barrier Subsystem Features, Events, and Processes, ANL-WIS-PA-000002, to address the NRC comment. The technical basis involves use of the Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		additional technical basis for the effect of introduced materials on water chemistry.	Exploratory Studies Facility Construction, BABE00000–01717–2200–00007, Rev. 04. As part of Container Life and Source Term Subissue 1, Agreement 1, DOE also agreed to provide additional justification on the effect of introduced materials on water chemistry in a revision to the analysis and model report, Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR, ANL–EBS–MD–000001, before license application.
UZ2	68	1.2.02.01.00 (Fractures) Is screened as included for seepage and is screened as excluded on the basis of low consequence for permanent effects (CRWMS M&O, 2001c). Generation of new fractures and reactivation 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 toward drifts. See also comment on 2.2.06.01.00 [Changes in Stress (Due to Thermal, Seismic, or Tectonic Effects) Change Porosity and Permeability of Rock].	The thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). The FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion to meet this agreement.
ENG2 UZ2 SZ1	J-25	1.2.02.02.00 (Faulting). Changes of fault characteristics have been screened as excluded on the basis of low consequence (CRWMS M&O, 2000b); formation of new faults has been excluded on the basis of low probability. 1.2.02.03.00 (Fault Movement Shears Waste Container) has been excluded on the basis of low probability. 1.2.03.02.00 (Seismic Vibration Causes Container Failure) has been excluded on the basis of low consequence (CRWMS M&O, 2000a). *In these items, the DOE screening argument relies, in large part, on the median values of fault displacements and ground motions for postclosure (less than 10^{-8}/year), rather than the mean values. The staff consider that the mean more reliably incorporates uncertainty and is a more reasonable and prudent statistical measure than the median. DOE should provide additional technical basis for this approach.* DOE agreed to address this concern in a forthcoming Request for Additional Information.	This issue is addressed by existing agreements between DOE and NRC (Structural Deformation and Seismicity Subissue 1 Agreement 2) and an NRC letter dated August 3, 2001 (Reamer, 2001d). Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, will be revised on completion of this work.
ENG2	J-26	The screening argument for 1.2.02.03.00 (Fault Movement Shears Waste Container) is based, in part, on specific setback distances that will be used by DOE in the repository design (CRWMS M&O, 2000a). The setback distances are a function of fault displacement magnitudes. Thus, the setback values used in the design may need to be reassessed after the displacement issue is resolved.	This issue is addressed by existing agreements between DOE and NRC (Structural Deformation and Seismicity Subissue 1 Agreement 2) and an NRC letter dated August 3, 2001 (Reamer, 2001d). Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, will be revised on completion of this work.
ENG2 UZ2 SZ1	J-27	1.2.03.01.00 (Seismic Activity) was screened as excluded on the basis of low consequence of effects on such components as the drip shield and waste package and included with regard to effects on cladding (CRWMS M&O, 2000a). The distributions for ground-motion parameters were developed using the Probabilistic Seismic Hazard Assessment Expert	This issue is addressed by existing agreements between DOE and NRC (Structural Deformation and Seismicity Subissue 2 Agreement 1) and an NRC letter dated August 3, 2001. Features, Events, and Processes: Screening for Disruptive Events, ANL–WIS–MD–000005, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		Elicitation. Additional technical basis on the use of expert judgment should be provided.	
ENG2	78	1.2.03.02.00 (Seismic Vibration Causes Container Failure) features, events, and processes have been excluded from consideration in the total system performance assessment code (CRWMS M&O, 2000a, 2001d). The screening argument cites preliminary seismic analyses of the drip shield and waste package as the basis for this screening decision (CRWMS M&O, 2000b). It is not clear whether the appropriate combinations of dead loads (caused by drift collapse, fallen rock blocks, or both), rock block impacts, and seismic excitation were considered. Moreover, the ability of these loads to initiate cracks, propagate preexisting cracks, or both may not have been adequately addressed. In addition, DOE has not demonstrated that the drip shield, pallet, and waste package will respond in a purely elastic manner when subjected to the aforementioned loading conditions. The screening argument for 1.2.03.02.00 (Seismic Vibration Causes Container Failure) also states "... 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 DOE (CRWMS M&O, 2000c). DOE, however, did not provide a description of the technical basis that the drip shield has, in fact, been designed to withstand 6-MT rock blocks {see the comments on 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 Engineered Barrier Subsystem) for additional discussion relevant to rockfall and seismic analyses}. See also comment on 1.2.02.02.00 (Faulting).	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 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, to address the NRC comment.
UZ3 Direct1	J-22	1.2.04.02.00 (Igneous Activity Causes Changes to Rock Properties) is screened as excluded from the radionuclide transport in the unsaturated zone abstraction, on the basis of low consequence (CRWMS M&O, 2000d, 2001e).Natural analogs (CRWMS M&O, 2000e) suggest alteration time scales of thousands of years (Ratcliff, et al., 1994) and alteration scales of tens of meters. Furthermore, modeling studies of the effects of silica redistribution on fracture porosity and permeability (CRWMS M&O, 2000e) have yielded conflicting results (Matyskiela, 1997). Additional clarification should be provided. Probability may also be an aspect to use in developing screening arguments for 1.2.04.02.00 (Igneous Activity Causes Changes to Rock Properties) provided probability is consistent with the probabilities used for the igneous disruptive scenario.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in Unsaturated Zone Flow and Transport, ANL-NBS-MD-000001, will be revised on completion of this work.
SZ1 Dose1 Dose2	8	1.2.04.07.00 (Ash Fall). DOE assumes that ash fall blankets the region between the repository and the compliance boundary (CRWMS M&O, 2000b). Radionuclides associated with ash fall are then assumed to be transported instantaneously into the saturated zone. DOE presented only the case for uniform distribution. Parameter values and models used in the ash fall analysis are not clear. Some parameters used in the model are not well documented and other parameters, such as the number of waste packages that fail, are not viewed as conservative.	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.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		DOE should provide additional bases for the choice of models and parameters used to screen this item.	
Dose1 Dose2	J-24	1.2.04.07.00 (Ash Fall). The screening argument in CRWMS M&O (2000f) for ash fall impacting the saturated zone [i.e., secondary 1.2.04.07.01 (Soil Leaching Following Ash Fall)] includes a three order-of-magnitude error in calculation of the concentration of radionuclides in the well water. Although conservative assumptions are used in the analysis, the error found in Table 6-1 would cause the calculated dose to be 0.161Sv[16.1 rem], instead of 1.61×10^{-2} [1.61×10^{-4}], and would not support a low-consequence screening argument.	DOE agreed to provide the technical basis for the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, screening argument, to address the NRC comment.
SZ2 ENG3	4	1.2.06.00.00 (Hydrothermal Activity). [Saturated Zone]: In CRWMS M&O (2001f), this item is excluded on the basis of low consequence. For saturated zone transport, the adopted K_d distributions account for possible lithologic changes and thermal effects, with reference to CRWMS M&O (2000g). However, the latter document does not provide a clear technical basis *that the K_ds 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, 2001f). This also relates to the geothermal gradient in 2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)]. DOE should provide a stronger technical basis for the assertion that possible hydrothermal effects on K_d values are accounted for in the total system performance assessment. [Unsaturated Zone]: This item is excluded in the unsaturated zone on the basis of low consequence and low probability (CRWMS M&O, 2000h). DOE should provide a sufficient technical basis for models explaining elevated temperatures in the unsaturated zone that adequately address the timing and mode of formation of Type B faults, which record elevated temperatures.	[Saturated Zone]: This issue is addressed by existing DOE and NRC agreements (Radionuclide Transport Subissue 1, Agreement 5, and Subissue 2, Agreement 10). 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. *[Unsaturated Zone]*: As part of the Evolution of the Near-Field Environment Subissue 2, Agreement 3, DOE agreed to provide additional technical bases for the screening of 1.2.06.00 (Hydrothermal Activity), addressing points discussed at the January 2001 Evolution of the Near-Field Environment Technical Exchange (Reamer, 2001c). DOE agreed to revise the screening argument in a future revision of Features, Events, and Processes in UZ Flow and Transport AMR, (ANL–NBS–MD–000001), expected to be available in fiscal year 2002.
UZ2	J-23	1.2.06.00.00 (Hydrothermal Activity). Excluded on the basis of low consequence for basaltic magmatism and low probability for silicic magmatism (CRWMS M&O, 2001e). A consistent approach for the screening arguments is needed. The screening argument is considered incomplete because (i) past hydrothermal activity in the Yucca Mountain region is not clearly related to basaltic igneous activity and (ii) probability screening arguments in CRWMS M&O (2001e) are incomplete with respect to silicic magmatism. In addition, DOE cites unpublished studies by the *U.S. Geological Survey and the University of Nevada*, Las Vegas that reportedly demonstrates hydrothermal activity was a site characteristic until about 2 million years ago. Additional unpublished work by Dublyanski and others, however, does not support this conclusion. None of the unpublished work, however, has supported the conclusion that the likelihood of hydrothermal activity at Yucca Mountain during the next 10,000 years is clearly <1:10,000. Absent a clear linkage to the consequences of basaltic igneous activity, or a demonstrated technical basis for probability values below 1 in 10,000 in 10,000 years, DOE should provide	This issue is addressed by existing DOE/NRC agreements (Radionuclide Transport Subissue 1 Agreement 5 and Subissue 2 Agreement 10). 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.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		additional technical basis to screen 1.2.06.00.00 (Hydrothermal Activity) from further consideration.	
UZ1 Dose2 Dose3	J-16	1.2.07.01.00 (Erosion/Denudation) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001d). The rationale for exclusion from the unsaturated zone on the basis of low consequence is incomplete. DOE should consider onset and extent of erosion caused by construction and characterization activities at the ground surface and the long-term effects on shallow infiltration.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, to address the NRC comment.
UZ1	J-17	1.2.10.02.00 (Hydrologic Response to Igneous Activity). Excluded based on low consequence (CRWMS M&O, 2001e). Argument to exclude focuses on intrusive events. It should be noted that extrusive events could increase shallow infiltration for the repository in two ways: (i) lava flow would modify or dam a wash overlying the repository and (ii) volcanic fragment and ash layer, which would be highly permeable, may act to trap infiltrating water, shield it from evaporation, and reduce transpiration—all leading to increased shallow infiltration across the repository. There are no data to support or exclude the temporal extent of increased shallow infiltration, though this could be bounded from decades to thousands of years.	DOE agreed to provide the technical basis for the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, screening argument, to address the NRC comment.
UZ1	J-18	1.3.04.00.00 (Periglacial Effects). Excluded by low probability (CRWMS M&O, 2001e). Although other periglacial processes will not likely occur at Yucca Mountain, the freeze/thaw process is currently active. Freeze/thaw mechanical erosion will likely increase as the climate cools, however. The magnitude of erosion will not likely be significant even during the cooler climate condition. The screening argument should be clarified to acknowledge the current freeze/thaw process.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, to address the NRC comment.
SZ1 SZ2 Dose1 Dose3	11	1.3.07.01.00 (Drought/Water Table Decline). According to information in CRWMS M&O (2001f), this item is excluded because of low consequence. DOE states "... 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 water table decline. Current flow models assume that ground water 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 elevation of the water table? It is likely that the transport times will stay the same or increase from water table decline, however, the exclusion argument provided seems insufficient. DOE should provide additional technical justification to exclude 1.3.07.01.00 (Drought/Water Table Decline).	This issue is addressed by existing DOE and NRC agreements (Radionuclide Transport Subissue 2, Agreement 8, and Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 5, Agreement 4). 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 to clarify the screening argument.
SZ2	7	1.4.06.01.00 (Altered Soil or Surface Water Chemistry). This item is excluded on the basis of low probability (CRWMS M&O, 2001e), but it is not addressed as part of the scope of document ANL–NBS–MD–000002 (CRWMS M&O, 2000f). The probability argument is not supported by a calculation or estimate. This item is	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comments. The analysis and model report will also address the aggregate effects of 1.4.06.01.00 (Altered

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		possibly relevant for the Integrated Subissue Radionuclide Transport in the Saturated Zone because of possible changes in ground water chemistry.	Soil or Surface Water Chemistry) on the unsaturated and saturated zones.
Dose3 Dose1	18	The biosphere analysis and model report on features, events, and processes (CRWMS M&O, 2001a) indicates that any future changes in 1.4.07.01.00 (Water Management Activities) can be excluded based on 10 CFR Part 63. This item includes well pumping from an aquifer as a water management activity. The conclusion that changes to water management activities may be excluded is not supported by the regulation. 10 CFR Part 63 indicates the behaviors and characteristics of the farming community are to 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 may 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 because the community would still be raising similar crops using similar farming methods.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.
ENG1	48	2.1.01.04.00 (Spatial Heterogeneity of Emplaced Waste) is screened as excluded on the basis of low consequence (CRWMS M&O, 2000i). 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, however, the heterogeneity within a waste package is implicitly included in the evaluation of in-package temperature used to determine perforation of the commercial spent nuclear fuel cladding. Spatial variability that may affect degradation of engineering barriers, such as conditions leading to crevice corrosion versus passive corrosion of an outer container, is not considered in this feature-event-process.	Spatial variability that may affect degradation of the waste package will be addressed as part of the resolution of an existing agreement (Container Life and Source Term Subissue 1, Agreement 1). The scope of the agreement includes evaluation of the range of chemical environments on the waste package.
ENG 4	50	2.1.02.13.00 (General Corrosion of Cladding). Excluded based on low probability of occurrence (CRWMS M&O, 2000j). Although general corrosion of cladding could expose large areas of irradiated fuel matrix and produce hydrides, it is argued that this corrosion is a slow process. The arguments are based on extrapolation to low temperatures at test data obtained at temperatures above 250 °C [482 °F] and in measurements of oxide thickness from specific fuel rods after reactor operation and exposure to water in reactor pool storage.	DOE agreed to provide clarification of the screening argument in Clad Degradation Features, Events, and Processes Analysis and Model Report, ANL–WIS–MD–000008, to address the NRC comment.
ENG4	51	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 (CRWMS M&O, 2000j). It is stated, however, that microbially induced corrosion resulting from sulfide produced by sulfate-reducing bacteria and organic acid-producing bacteria is not expected to occur, because of resistance of zirconium to these species. The arguments are poorly worded stating that microbially induced corrosion 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.	This issue is addressed by an existing DOE and NRC agreement (Container Life and Source Term Subissue 3, Agreement 7). DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, Analysis and Model Report to address the NRC comment. The new cladding local corrosion model will reference In-Drift Microbial Communities Analysis and Model Report, ANL–EBS–MD–000038, which includes discussion of iron oxidizing bacteria. Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, Analysis and Model Report will be revised to be consistent with

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		The argument of local acidic pH such as might be caused by microbial activity resulting in localized corrosion of cladding contradicts experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, the argument contradicts other DOE arguments to screen out pitting corrosion by chloride anions {see 2.1.02.16.00 [Localized Corrosion (Pitting) of Cladding]}. DOE screening arguments for inclusion or exclusion should be consistent with screening decisions for related entries [see 2.1.02.15.00 (Acid Corrosion of Cladding from Radiolysis)]. A third group of bacteria iron oxidizers should also be considered in the analysis (NRC, 2001).	the updated Summary-Abstraction Analysis and Model Report.
ENG4	49	2.1.02.15.00 (Acid Corrosion of Cladding from Radiolysis). Included as part of the localized corrosion model on the basis that formation of HNO_3 and H_2O_2 ions [sic] by radiolysis can enhance corrosion of cladding (CRWMS M&O, 2000j). 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 waste package failure; then, the gamma dose will be too low to produce sufficient HNO_3 and H_2O_2 to promote general corrosion, however, localized corrosion could be possible. The argument of local acidic pH such as might result from microbial activity causing localized corrosion of cladding contradicts experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, the argument contradicts other DOE arguments to screen out pitting corrosion by chloride anions {see 2.1.02.16.00 [Localized Corrosion (Pitting) of Cladding]}. In the Basis for Screening, undue consideration is given to alkaline conditions arising from the concrete liner, whereas the possibility of acidic conditions (pH< 2) is not discussed.	Radiolysis is addressed by an existing DOE and NRC agreement (Container Life and Source Term Subissue 3, Agreement 7). DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL-WIS-MD-000008, to address the NRC comment.
ENG4	47	2.1.02.17.00 [Localized Corrosion (Crevice Corrosion) of Cladding]. Excluded based on low probability of occurrence (CRWMS M&O, 2000j). Experimental evidence is cited to indicate that crevice corrosion has not been observed in zirconium alloys exposed to chloride solutions, including NRC and 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, Clad Degradation—Local Corrosion of Zirconium and Its Alloys Under Repository Conditions (CRWMS M&O, 2000k). It is noted that crevice corrosion may occur in the presence of fluoride ions.	DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL-WIS-MD-000008, to address the NRC comment using data relevant to the proposed repository. In addition, Container Life and Source Term Subissue 3, Agreement 7, also addresses part of the concern.
ENG4	41	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 and strain (creep) failures (CRWMS M&O, 2000j). The wording could be more precise in the text where it is stated that helium production from alpha decay is the main source of pressure buildup.	DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL-WIS-MD-000008, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
ENG4	53	2.1.02.22.00 (Hydride Embrittlement of Cladding). Excluded based on low probability of occurrence (CRWMS M&O, 2000j). The DOE screening argument states that the in-package environment and cladding stresses are not conducive to hydride cracking. The NRC staff believe that reorientation of preexisting hydride and embrittlement depends on temperature in addition to the required stresses. Clarification is needed on the cladding temperature and stress distributions used in the analysis. Several of the secondary features, events, and processes related to various processes leading to hydrogen entry into the cladding are listed next. 2.1.02.22.01 [Hydride Embrittlement from Zirconium Corrosion (of Cladding)]. Excluded because of low probability of occurrence because the hydrogen pickup as a result of cladding corrosion is low, because of the low corrosion rate, and because of the relatively small pickup fraction. The experimental hydrogen pickup fraction is provided, and it is argued the corrosion rate is low. The conclusion DOE reached regarding failure of cladding as a result of hydrogen pickup from general corrosion is acceptable. The screening arguments, however, can be justified better using quantitative arguments for the corrosion rate during disposal conditions. 2.1.02.22.02 [Hydride Embrittlement from Waste Package Corrosion and Hydrogen Absorption (of Cladding)]. Excluded because of the low probability of occurrence because the hydrogen generated by corrosion of waste packages and waste package 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 DOE reached regarding failure of cladding as a result of absorption of hydrogen gas generated by corrosion of waste package materials is acceptable. The screening arguments, however, can be better organized. 2.1.02.22.03 (Hydride Embrittlement from Galvanic Corrosion of Waste Package Contacting Cladding). Excluded because of the low probability of occurrence because corrosion of waste package internals will not result in hydriding of cladding. It is argued, using some experimental data as bases, 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 nickel content both in Zircaloy-2 and -4 is not sufficient to induce the necessary hydrogen charging. The conclusion DOE reached regarding failure of cladding as a result of hydrogen entry from galvanic coupling with internal components of the waste packages is, in general, acceptable. The screening arguments, however, could be better supported by more relevant experimental data. 2.1.02.22.04 [Delayed Hydride Cracking (of Cladding)]. Excluded because of the low probability of occurrence. The analysis is based on the use of calculated values for the distribution of the stress intensity factor, which is compared with the threshold stress intensity for	DOE agreed to provide clarification of the screening argument in Clad Degradation—FEPs Screening Arguments, ANL–WIS–MD–000008, to address the NRC comments.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		irradiated Zircaloy-2. The DOE analysis of delayed hydride cracking is based on material properties of cladding containing mostly circumferential hydrides. DOE should provide cladding temperatures and stress distributions and demonstrate these are insufficient to cause hydride reorientation. 2.1.02.22.05 [Hydride Reorientation (of Cladding)]. Excluded because of the low probability of occurrence, since tested fuel rods did not exhibit 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 cladding 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, which are critical parameters needed to evaluate the propensity to hydride reorientation and embrittlement [see 2.1.02.22.00 (Hydride Embrittlement of Cladding)]. 2.1.02.22.06 [Hydride Axial Migration (of Cladding)]. Excluded based on low probability because 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 waste packages. 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 screening arguments, however, should include the combined effects of stress and temperature.	
ENG1 ENG2 ENG3	34	2.1.03.02.00 (Stress Corrosion Cracking of Waste Containers). Screened as included for waste package and as excluded for drip shield on the basis of low consequence (CRWMS M&O, 2001d). The screening argument states ... 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 the overall radionuclide release rate from the underlying failed waste packages ... . Additional technical bases for the screening argument for the drip shield should be provided. Simplified DOE calculations 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 drip shield may propagate, open up, or both when subjected to subsequent loads caused by rockfall/drift collapse, seismic excitation, or both allowing significant ground water infiltration through the drip shield.	This issue is contained in existing DOE and NRC agreement (Container Life and Source Term Subissue 2, Agreement 8). DOE will update FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002, screening argument on completion of the agreement.
ENG1 ENG2 ENG3	30	2.1.03.05.00 (Microbially Mediated Corrosion of Waste Container). Screened as included for waste package and as excluded for drip shield on the basis of low consequence (CRWMS M&O, 2001d). Quantitative data on microbially influenced corrosion of drip shield	This issue is addressed by an existing agreement (Container Life and Source Term Subissue 2, Agreement 8). No additional DOE action is required.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		materials such as Titanium 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 the drip shield have been evaluated and do not affect dose (CRWMS M&O, 2000l).	
ENG1 ENG2 ENG3	35	2.1.03.08.00 (Juvenile and Early Failure of Waste Containers). Screened as included for manufacturing and welding defects in waste container degradation analysis and as excluded for manufacturing defects in drip shield degradation analysis and early failure of the waste package and drip shield from improper quality control during emplacement (CRWMS M&O, 2001d). The screening argument states Manufacturing defects in the drip shield are excluded from TSPA analysis based on low consequence to the expected annual dose rate. The basis for this assessment is that slap-down analysis of a 21-pressurized water reactor waste packages resulted in stresses in the waste package material of less than 90 percent of the ultimate tensile strength. The impact energy associated with the emplacement error is substantially less than that expected in a vertical tip-over. According to DOE, emplacement errors are not expected to result in any damage. The results of the slap-down analysis are cited as the screening analyses of several features, events, and processes. Technical basis for damage reported in the slap-down analyses should be expanded. Although the impact energy of emplacement errors may be substantially less than that experienced in the slap-down analyses, a proper assessment of the extent of waste package damage as a result of emplacement errors should be performed.	Manufacturing defects associated with the drip shield will be addressed during the resolution of an existing agreement item for the waste package (Container Life and Source Term Subissue 2, Agreement 7). 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 resolution of an existing agreement item for the waste package (Container Life and Source Term Subissue 2, Agreement 6). 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 (Container Life and Source Term Subissue 2, Agreement 8). 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. 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 the waste package during emplacement will be addressed by administrative procedures for emplacement operations to be developed before operation of the facility.
ENG2	J-1	2.1.03.11.00 (Container Form) has been excluded from consideration in the total system performance assessment code (CRWMS M&O, 2001d). DOE has not addressed the varying clearance between the drip shield and different waste package designs and the concomitant effects this clearance may have on the consequences of rock block impacts, seismic excitation, or both.	This issue is addressed by existing agreements between DOE and NRC (Container Life and Source Term Subissue 2 Agreement 8). FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002, will be revised on completion of this work.
UZ1 UZ2	J-19	2.1.05.01.00 (Seal Physical Properties). Excluded based on low consequence (CRWMS M&O, 2001e). It is difficult to assess this item solely based on the screening argument provided. The assessment can be performed once the actual design (ventilation tunnel locations) is released, backfill is described, and the analysis of runoff and flooding is incorporated into the screening argument. 2.1.05.02.00 (Groundwater Flow and Radionuclide Transport in Seals) and 2.1.05.03.00 (Seal Degradation). Excluded based on low consequence, using screening argument for 2.1.05.01.00 (Seal Physical Properties). The adequacy of the screening argument cannot be assessed until the actual design (ventilation tunnel locations) is released, backfill is described, and the analysis of runoff and flooding is incorporated into the screening arguments.	DOE stated it would adopt more rigorous configuration controls as the design advances. These controls will identify features, events, and processes screening arguments that could potentially change when design changes occur.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
ENG3 ENG4 UZ3	J-3	2.1.06.01.00 (Degradation of Cementitious Materials in Drift). The effects of degradation of cementitious materials on seepage chemistry are excluded on the basis of low consequence (CRWMS M&O, 2001b). DOE gives its bases its for exclusion in 2.1.09.01.00 (Properties of the Potential Carrier Plume in the Waste and Engineered Barrier Subsystem) (CRWMS M&O 2001b) stating that chemical models show a negligible effect of grout associated with rock bolts. NRC raised questions about these models pertaining to the treatment of evaporation and the chemical divide phenomenon [Evolution of the Near-Field Environment Technical Exchange (Reamer, 2001e). Concerns about grout chemical effects are related to recent observations of dripping from rock bolt holes in the sealed cross drift test. DOE should provide additional technical basis for screening chemical effects of cementitious materials in the drift. Because degradation products may affect water chemistry, and, therefore, radionuclide sorption behavior, the effect of this database entry on radionuclide transport in the unsaturated zone should be evaluated also. Currently, this entry is not addressed for the unsaturated zone (CRWMS M&O, 2001e). Radionuclide Transport Subissue 1, Agreement 5, and Subissue 2, Agreement 10, concern the technical bases for transport parameter uncertainty distributions.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 2 Agreements 6, 10, and 14, and Radionuclide Transport Subissue 1 Agreement 5). Engineered Barrier Subsystem Features, Events, and Processes, ANL-WIS-PA-000002, will be revised on completion of this work.
ENG2 UZ3	J-2 J-4	2.1.06.05.00 (Degradation of Invert and Pedestal) has been screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). [Comment 1]: Rock block impact orientations with the waste package will be affected by degradation of the invert. Comment 2.1.07.01.00 [Rockfall (large block)] stated angled rock block impacts near the closure lid weld may have undesirable consequences. Furthermore, stability of the waste package during seismic excitation will be affected by a degraded invert foundation. Corrosion of the steel pallet components should be considered when evaluating stability of the waste package on its supporting pallet on a degraded invert foundation. [Comment 2]: Invert degradation is excluded on the basis of low consequence (CRWMS M&O, 2001b). The argument that changes to diffusive properties of the invert will be negligible to dose is not supported by demonstration (by sensitivity analyses) of the significant effect of diffusive release through the invert during the first 20,000 years (CRWMS M&O, 2000m, Volume II, Section 3.3). The sensitivity shown in the Repository Safety Strategy also applies to the first 10,000 years. The screening argument contradicts this information. The screening argument should directly address possible effects of degradation on invert diffusive properties.	[Comment 1]: This issue is addressed by existing agreements between DOE and NRC (Container Life and Source Term Subissue 2 Agreement 8). Engineered Barrier Subsystem Features, Events, and Processes, ANL-WIS-PA-000002, will be revised on completion of this work. [Comment 2]: DOE agreed to provide the technical basis for the screening argument in Engineered Barrier Subsystem Features, Events, and Processes, ANL-WIS-PA-000002, to address the NRC comment.
ENG1	39	2.1.06.06.00 (Effects and Degradation of Drip Shield). Excluded based on low consequence (CRWMS M&O, 2001d). The drip shield is an important component of the engineered barrier system, and its function and degradation are explicitly considered in the total system performance assessment. The degradation of the drip shield from corrosion processes is considered directly in the model abstraction for waste package	The ability of the additional loading combinations to initiate, propagate, or both preexisting cracks is being addressed in existing agreements (Container Life and Source Term Subissue 2, Agreements 8 and 9). DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		degradation, whereas remaining aspects of drip shield behavior are considered as part of the engineered barrier system analysis. For the secondary feature-event-process 2.1.06.06.01 (Oxygen Embrittlement of Ti Drip Shield), DOE argues that oxygen embrittlement is explicitly considered in the screening argument, but no discussion is provided. It is noted that this issue is most relevant to mechanical failure of the drip shield, which is discussed in 2.1.07.01.00 (Rockfall) and 2.1.07.02.00 (Mechanical Degradation or Drift Collapse). Although physical and chemical degradation processes have been included in the total system performance assessment, their effects on the ability of the drip shield to withstand dead loads (caused by drift collapse, fallen rock blocks, or both), rock block impacts, and seismic excitation are not accounted for in the screening arguments (CRWMS M&O, 2001b,d). CRWMS M&O (2000n) states the impact of rockfall on the degraded drip shield has been screened as excluded until more detailed structural response calculations for the drip shield under various rock loads are available.	
ENG1	29	2.1.06.07.00 (Effects at Material Interfaces) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001d). The basic chemical processes that occur at phase boundaries (principally liquid/solid) are included in other features, events, and processes. Solid/solid contact occurs or could occur between the drip shield and the invert, backfill, or both, (if included in the Yucca Mountain project design) between the waste package and the invert, backfill, or both, (if included in the Yucca Mountain project design) between the pedestal and the waste package, drip shield, or both, and between the waste form and any other engineered barrier system component materials. Because these materials are all relatively inert, no significant solid/solid interaction mechanisms have been identified relative to the basic seepage water-induced corrosion of the engineered barrier system components and, hence, this feature-event-process 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 the waste package or galvanic coupling of the drip shield to steel components [see screening arguments 2.1.03.01.00 (Corrosion of Waste Containers) and 2.1.03.04.00 (Hydride Cracking of Waste Containers and Drip Shields)].	This issue is addressed by an existing agreement (Container Life and Source Term Subissue 6, Agreement 1). DOE agreed to provide clarification of the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, as necessary, on completion of the agreement item.
ENG2 ENG4	79	2.1.07.01.00 [Rockfall (Large Block)]. [Disruptive Event & Waste Package]: The effects of 2.1.07.01.00 [Rockfall (Large Block)] on the drip shield and waste package have been screened as excluded (CRWMS M&O, 2000a, 2001b,d). The Drift Degradation Analysis and Model Report (CRWMS M&O, 2000o) indicates that thermal loading, seismicity, and time-dependent mechanical degradation of the host rock would have minor effects on the integrity of the drifts through the entire period of regulatory concern. The NRC staff at the DOE and NRC Repository Design and Thermal-Mechanical Effects Technical Exchange (Reamer, 2001f) identified several deficiencies [see the comments on 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) for additional discussion pertaining to the DOE rockfall analyses].	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 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, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		As noted at the Container Life and Source Term and Repository Design and Thermal-Mechanical Effects Technical Exchanges (Reamer, 2001f), the rockfall on drip shield analyses (CRWMS M&O, 2000c) did not consider (i) 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, or (vii) boundary conditions that account for the potential interactions between the drip shield and gantry rails. Consequently, DOE has not provided sufficient information to demonstrate 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, the potential degradation may affect orientation of the waste packages during 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 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. [Cladding]: Mechanical failure of cladding from rockfall is excluded based on low probability because rockfall on an intact waste package will not cause rod failure (CRWMS M&O, 2000j). The main screening argument is based on an intact waste package. The discussion is confusing because arguments based on the presence of backfill are also used in quantitative estimates. The screening arguments should be improved on the basis of appropriate calculations.	
ENG1 ENG2 ENG3	77	2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) has been screened as excluded (CRWMS M&O, 2000a, 2001b) based on CRWMS M&O (2000o), which indicates that the emplacement drifts would essentially maintain their integrity through the period of regulatory concern. The current state of knowledge on unsupported openings in fractured rock indicates most 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* and recent analyses of the behavior of unsupported drifts in fractured rock during seismic loading from an earthquake (Hsiung, et al., 2001). Drift collapse could have implications on temperature, chemistry, seepage into drifts, and drip shield performance. DOE agreed to revise the Drift Degradation Analysis as part of Repository Design and Thermal-Mechanical Effects Agreements 3.17 and 3.19 [DOE and NRC Technical Exchange on Repository Design and Thermal-Mechanical Effects, February 6–8, 2001 (Reamer, 2001f)].	No additional DOE action is required. Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 17 and 19, address concern on drift collapse.
ENG1 ENG2 ENG3	37	2.1.07.05.00 (Creeping of Metallic Materials in the Engineered Barrier Subsystem) has been excluded from consideration in the total-system performance assessment code (CRWMS M&O, 2001b,d). Although DOE correctly points out in the screening argument (CRWMS M&O, 2001d) "... the deformation of many titanium alloys loaded to yield point does not increase with time" (American Society for Metals International, 1990), 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, et al., 1994). Creeping of the titanium drip shield subjected to dead loads caused by	Treatment of creep of the drip shield will be addressed as part of an existing agreement related to drip shield rockfall analyses (Container Life and Source Term Subissue 2, Agreement 8). DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		fallen rock blocks, drift collapse, or both could significantly reduce the clearance between the drip shield and waste package during 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.	
ENG1 ENG2 ENG4	56	2.1.07.06.00 (Floor Buckling) has been screened as excluded in (CRWMS M&O, 2001b) and EBS Radionuclide Transport Abstraction Analyses and Model Report (CRWMS M&O, 2000n) based on analyses documented in Repository Ground Support Analysis for Viability Assessment (CRWMS M&O, 1998a), which indicate that floor heave from thermal-mechanical effects would not exceed approximately 10 mm [0.391 in]. However, to address concerns raised by the NRC staff about appropriateness of the thermal-mechanical properties used in DOE calculations (such as the analyses cited previously), DOE agreed to revise its assessment of floor buckling [Repository Design and Thermal-Mechanical Effects Agreement 3.9 (Reamer, 2001f). Note the screening argument relies on analyses that DOE agreed to address outstanding NRC concerns in Repository Design and Thermal-Mechanical Effects Agreements 3.2–3.13 (Reamer, 2001f)].	This issue is addressed by existing DOE and NRC agreements (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 2–13). DOE agreed to include the analysis of floor buckling for postclosure conditions, consistent with the site-specific parameters and loading conditions used to satisfy Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 2–13. Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be revised to include this information.
UZ2	59	2.1.08.04.00 (Cold Traps) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). 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 engineered barrier system, leading to enhanced dripping on the drip shields, waste packages, or exposed waste material. The DOE Multiscale Thermohydrologic Model does not account for mass transport along the length of drifts. The only Multiscale Thermohydrologic Model 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.	This issue is addressed by an existing DOE and NRC agreement (Thermal Effects on Flow Subissue 2, Agreement 5). Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be revised on completion of this agreement.
ENG1 ENG3	42	2.1.08.07.00 (Pathways for Unsaturated Flow and Transport in the Waste and Engineered Barrier Subsystem) evaluates unsaturated flow and radionuclide transport that may occur along preferential pathways in the waste and engineered barrier system (CRWMS M&O, 2000i). DOE indicates that preferential pathways are already included via "... a series of linked one-dimensional flowpaths and mixing cells through the engineered barrier system, drip shield, waste package, and into the invert" (CRWMS M&O, 2000i). Water has been observed to drip preferentially along grouted rock bolts in the enhanced characterization of the repository block, (e.g., demonstrating that introduced materials 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 description of 2.1.08.07.00 (Pathways for Unsaturated Flow and Transport in the Waste and Engineered Barrier Subsystem) states "Physical and chemical properties of the engineered barrier system and waste form, in both intact and degraded states, should be considered in evaluating [preferential] pathways ...", the screening arguments should be based on an evaluation of these topics.	This issue is addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreements 6, 10, and 14). Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be updated on completion of these agreement items.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
ENG3	54	2.1.09.02.00 (Interaction with Corrosion Products) is excluded in the engineered barrier system (except for colloid-related effects) on the basis of low consequence (CRWMS M&O, 2001b). As noted in the DOE and NRC Technical Exchange on Evolution of the Near-Field Environment (Reamer, 2001e), changes in seepage water chemistry resulting from interactions with engineered materials and their corrosion products were not adequately addressed in CRWMS M&O (2000p). Water has been observed to drip preferentially along grouted rock bolts in the enhanced characterization of the repository block, (e.g., demonstrating that introduced materials 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.	This issue is addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreements 6, 10, and 14). Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be updated on completion of these agreement items.
ENG1	36	2.1.09.03.00 (Volume Increase of Corrosion Products) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001d). The presence of waste package 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 the waste package based on low consequence. These products, however, may have an effect on corrosion processes such as stress corrosion cracking of the outer container, after its initial breaching, that may affect radionuclide release [see 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 stress corrosion cracking. See comment for 2.1.11.05.00 (Differing Thermal Expansion of Repository Components).	DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.
ENG1	55	2.1.09.07.00 (Reaction Kinetics in Waste and Engineered Barrier Subsystem). [Engineered Barrier Subsystem]: Item is screened as excluded on the basis of low consequence (CRWMS M&O, 2001b). 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, however, reaction kinetics are excluded based on low consequence for the engineered barrier system. But these processes may affect composition of the near-field environment, particularly trace elements. The effect on corrosion of container materials could be indirect and should be considered. [Waste Form Miscellaneous]: Item is screened as excluded on the basis of low consequence (CRWMS M&O, 2000i). Additional technical bases should be provided to demonstrate that the combination of transport processes and reaction kinetics in the engineered barrier system will not adversely impact performance by altering the composition of water contacting the drip shield and waste package.	This issue is addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreements 5, 8, 11, and 12). Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be updated on completion of these agreement items.
UZ2	63	2.1.09.12.00 [Rind (Altered Zone) Formation in Waste, Engineered Barrier Subsystem, and Adjacent Rock]. The thermal-hydrological-chemical model is screened as included, and the thermal-hydrological model, effects on transport is screened as excluded on the basis of low consequence (CRWMS M&O, 2001c).	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1, Agreement 3). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion, to meet this agreement.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		Thermal-chemical processes alter the rock forming the drift walls mineralogically. These alterations have hydrological, thermal, and mineralogical properties different from the current country rock.	
ENG4 UZ3 SZ2	5	2.1.09.21.00 (Suspension of Particles Larger Than Colloids). CRWMS M&O (2001f) states these particles will be included and treated as colloids. 2.1.09.21.00 (Suspension of Particles Larger Than Colloids) is not addressed in CRWMS M&O (2001e), however, and is noted as excluded in two other model components in the Yucca Mountain FEP Database (CRWMS M&O, 2001g). It is not clear how the effects of particles are included with colloids. The integration of 2.1.09.21.00 (Suspension of Particles Larger Than Colloids) across the engineered barrier system, unsaturated zone, and saturated zone should be clarified.	DOE agreed to provide clarification for the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.
ENG4 UZ3	J-5	2.1.09.21.00 (Suspensions of Particles Larger than Colloids) is screened excluded from the engineered barrier system transport and waste form release abstractions (CRWMS M&O, 2000q, 2001e). Exclusion is based on the assumption that although particles may be transported through fractures in the unsaturated zone, low ground water velocities through the saturated zone would lead to particle settling (CRWMS M&O, 2000q), suggesting inconsistency in the screening analysis. Without quantitative measures of particle size, pore size, ground water velocity, and chemical variability, however, these qualitative assertions are difficult to evaluate. Because DOE includes colloid formation features, events, and processes in its screening analysis, and because of the large amounts of iron particles that may be introduced in the engineered barrier system, particle transport through the engineered barrier system into the unsaturated zone is plausible.	DOE agreed to provide clarification of the screening argument in Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary ANL–WIS–MD–000012, to address the NRC comment.
UZ2	65	2.1.11.02.00 (Nonuniform Heat Distribution/Edge Effects in Repository). The thermal-hydrological and thermal-hydrological-chemical aspects are screened as included and the (thermal-mechanical effects) are screened as excluded on the basis of low consequence (CRWMS M&O, 2001c). Temperature in homogeneities in the repository lead to localized accumulation of moisture. Uneven heating and cooling at repository edges lead to nonuniform thermal effects during both the thermal peak and the cool-down periods.	Repository-wide, nonuniform heating effects are the subject of existing DOE and NRC agreements (Thermal Effects on Flow Subissue 2, Agreement 5, and Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this agreement. Thermal-Hydrological-Mechanical continuum modeling will address nonuniform effects at a mountain scale. This information will be provided in Coupled Thermal-Hydrological-Mechanical Effects on Permeability Analysis and Model Report, ANL–NBS–HS–000037.
ENG1 ENG2	38	2.1.11.05.00 (Differing Thermal Expansion of Repository Components) has been excluded from consideration in the total-system performance assessment code (CRWMS M&O, 2001b,d). The technical basis for excluding differing thermal expansion effects on repository performance is not comprehensive. For example, the screening arguments (CRWMS M&O, 2001d) do 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 [0.0787 in] according to design drawings (CRWMS M&O, 2000s). In addition, the differential thermal expansion between various invert components and the drift wall (to which they are attached) was not addressed.	DOE agreed to provide the technical basis for the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		2.1.11.05.00 (Differing Thermal Expansion of Repository Components) is excluded on the basis of low consequence (CRWMS M&O, 2001b,d). Peak temperature of waste packages with 0.5-m [19.68-in] spacing and 50-year ventilation is 278 °C [532.4 °F] with backfill and 176 °C [348.8 °F] without backfill. The screening argument is that the temperature differential between the inner type 316NG barrier and the outer Alloy 22 barrier is 5C° [41 °F] with a corresponding strain of 2.15×10^{-5}. This calculation is performed using the difference between the thermal expansion coefficients for Type 316NG stainless steel and Alloy 22 using the maximum expected temperature difference between the waste package barriers. There will be at least a 1-mm [0.0394-in] gap between the barriers, and no thermal stresses are predicted. Calculations should use a temperature of the waste package rather than the difference between waste package barriers. The clearance between the inner type 316NG barrier and the outer Alloy 22 barrier is 0 to 4 mm [0.1575 in] as specified in the waste package design and fabrication process report (CRWMS M&O, 2000r). It is implicit that this clearance is specified at ambient temperature [i.e., 25 °C (77 °F)] because (i) no temperature is specified and (ii) the Alloy 22 waste package outer barrier will be heated to 371 °C [700 °F] for inner 316NG barrier cylinder installation. Using a temperature of 186 °C [366.8 °F], the calculated strain is 7.99×10^{-4}. For a waste package with clearance gaps of 1 mm [0.0394 in] or less at 25 °C [77 °F], thermal stresses will occur as a result of the differences in thermal expansion.	
ENG3	60	The exclusion of 2.1.12.01.00 (Gas Generation) and 2.1.12.05.00 (Gas Generation from Concrete) in CRWMS M&O (2000i, 2001b) should have additional technical bases to justify the characterization of chemical environments in the engineered barrier system in terms of bulk water and gas compositions. The possibility of local heterogeneity in gas composition in the drift, altering the chemistry of the drip shield/waste package 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.	This issue is partially addressed by an existing DOE and NRC agreement (Evolution of the Near-Field Environment Subissue 2, Agreement 6). DOE agreed to provide the technical basis for the screening argument in Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, to address the NRC comment.
ENG1 ENG3 ENG4	32	2.1.13.01.00 (Radiolysis) is excluded based on low consequence (CRWMS M&O, 2000i, 2001d). [Waste Package]: Alpha, beta, gamma, and neutron irradiations of air saturated water can cause changes in chemical conditions (Eh, pH, and concentration of reactive radicals) and positive shifts in corrosion potential from the formation of hydrogen peroxide. DOE, on the bases of experimental work, concluded that radiolysis will not lead to localized corrosion of Alloy 22. Additional work, however, is necessary to complete the evaluation of the critical potentials related to localized corrosion of Alloy 22. [Waste Form Miscellaneous]: 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 nuclear fuel is expected to have higher dissolution rates at lower pH, thus, ignoring nitric acid may underestimate radionuclide release. Potential production of nitric	DOE agreed to provide additional information on critical potentials for localized corrosion at the DOE and NRC Container Life and Source Term Technical Exchange (Schlueter, 2000). DOE agreed to provide clarification of the screening argument in FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL–EBS–PA–000002, to address the NRC comment.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		acid from radiolysis of N_2 in air should be considered. DOE should consider potential effect of acid environments on the corrosion of Alloy 22 and titanium.	
ENG4 UZ3 SZ2	74	2.1.14.01.00 (Criticality in Waste and Engineered Barrier Subsystem) was preliminarily excluded in the document (CRWMS M&O, 2000t) based on low probability. A preliminary screening status was assigned because the criticality calculations were not complete for DOE spent nuclear fuel after igneous intrusion and near-field and far-field criticality of all waste types following igneous disruption. The excluded screening analysis should provide additional technical basis on the calculation of the probability for criticality are addressed. Because 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 referenced the document, Probability of Criticality In 10,000 Years (CRWMS M&O, 2000u), for addressing the criticality probability from early failure by stress corrosion cracking, waste package damage after igneous intrusion, and seismic events. DOE referenced the screening argument for rockfall [2.1.07.01 (Rockfall)] for screening damage to the waste package and drip shield from seismically induced rockfall. In general, DOE should address the concerns raised on the waste package and mechanical disruption related features, events, and processes, and the issues raised at the Container Life and Source Term Technical Exchange (Schlueter, 2000) before it can conclude there is no waste package breach before 10,000 years. The concerns on the probability calculation in the document, Probability of Criticality In 10,000 Years (CRWMS M&O, 2000u) are • The conclusion of waste package failure probability of 2.7×10^{-11} from stress corrosion cracking, based on the equation in Section 6.1.1, is contrary to the total system performance assessment results that indicate the first waste package failure, using the upper-bound curve, from stress corrosion cracking at approximately 10,000 years. • The screening argument for 1.2.03.02.00 (Seismic Vibration Causes Container Failure) fails to consider the appropriate combinations of dead loads (caused by drift collapse, fallen rock blocks, or both), rock block impact, and seismic excitation or the ability of these loads to initiate cracks, propagate preexisting cracks, or both. • 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 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 to form a more reactive geometry. • 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 and Model Report (CRWMS M&O 2000o) and 2.1.07.01.00 [Rockfall (Large Block)]. Other concerns related to the impact of rockfall on the waste package are	The current criticality agreements encompass NRC comments. The following entries are also considered closed-pending in light of existing criticality agreements: 2.1.14.02.00 (Criticality *In Situ*, Nominal Configuration, Top Breach) 2.1.14.03.00 (Criticality *In Situ*, Waste Package Internal Structures Degrade Faster Than Waste Form, Top Breach) 2.1.14.04.00 (Criticality *In Situ*, Waste Package Internal Structures Degrade at Same Rate as Waste Form, Top Breach) 2.1.14.05.00 (Criticality *In Situ*, Waste Package Internal Structures Degrade Slower Than Waste Form, Top Breach) 2.1.14.06.00 (Criticality *In Situ*, Waste Form Degrades in Place and Swells, Top Breach) 2.1.14.07.00 (Criticality *In Situ*, Bottom Breach Allows Flow Through Waste Package, Fissile Material Collects at Bottom of Waste Package) 2.1.14.08.00 (Criticality *In Situ*, Bottom Breach Allows Flow Through Waste Package, Waste Form Degrades in Place) 2.1.14.09.00 (Near-Field Criticality, Fissile Material Deposited in Near-Field Pond) 2.1.14.10.00 (Near-Field Criticality, Fissile Solution Flows into Drift Lowpoint) 2.1.14.11.00 (Near-Field Criticality, Fissile Solution Is Adsorbed or Reduced in Invert) 2.1.14.12.00 (Near-Field Criticality, Filtered Slurry, or Colloidal Stream Collects on Invert Surface) 2.1.14.13.00 (Near-Field Criticality Associated with Colloidal Deposits) 2.2.14.01.00 (Critical Assembly Forms Away from Repository) 2.2.14.02.00 (Far-Field Criticality, Precipitation in Organic Reducing Zone in or Near Water Table) 2.2.14.03.00 (Far-Field Criticality, Sorption on Clay/Zeolite in Topopah Springs Basal Vitrophyre) 2.2.14.04.00 (Far-Field Criticality, Precipitation Caused by Hydrothermal Upwell or Redox Front in the Saturated Zone) 2.2.14.05.00 (Far-Field Criticality, Precipitation in Perched Water Above Topopah Springs Basal Vitrophyre) 2.2.14.06.00 (Far-Field Criticality, Precipitation in Fractures of Topopah Springs Welded Rock) 2.2.14.07.00 (Far-Field Criticality, Dryout Produces Fissile Salt in a Perched Water Basin) 2.2.14.08.00 (Far-Field Criticality Associated with Colloidal Deposits)

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		reflected in the comments on the related features, events, and processes. • The calculation of the criticality probability does not fully consider mechanisms that could result in accelerated degradation of the fuel during an igneous event, such as burning Zircaloy or creep of the fuel at high temperatures. • The analysis of damage to DOE Zone 2 waste packages (CRWMS M&O, 2000u) 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., 2000) or the differences in thermal expansion between the inner barrier type 316NG stainless steel and the outer barrier Alloy 22 causing significant hoop-stress on waste package walls, in addition to the internal pressurization effects analyzed in CRWMS M&O (2000u). Analyses in CRWMS M&O (2000u) 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-cm² [1.55-in²] hole currently assumed for waste packages located in DOE Zone 2 during basaltic igneous events. • 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 1,170 °C [2,138 °F] magma so current parameters may no longer be valid. • The criticality probability document is inconsistent when discussing the water content of the magma in Section 5.3.2. The text indicates the magma would consist of a conservative 5-wt% water content, but Table 5-1 lists the water content as only 0.05 wt%. The computer files provided with the document that contained the actual calculations used a more realistic water content of 1.6 percent. A water content of 5 wt% would clearly be conservative, but justification should be provided if a lower water content is used in the calculations.	
UZ2	69	2.2.01.01.00 (Excavation and Construction-Related Changes in the Adjacent Host Rock). Initial effects on seepage are screened as included, and permanent thermal-hydrological-chemical and thermal-mechanical effects are screened as excluded on the basis of low consequence (CRWMS M&O, 2001c). Stress relief leading to dilation of joints and fractures is expected in an axial zone of up to one diameter-width surrounding the tunnels.	Thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this agreement.
ENG2 UZ2	62	2.2.01.02.00 (Thermal and Other Waste and Engineered Barrier Subsystem-Related Changes in the Adjacent Host Rock) is screened as excluded on the basis of low consequence (thermal-mechanical effects) and low probability (thermal-hydrological-chemical and backfill effects) (CRWMS M&O, 2001c). Changes in host rock properties result from thermal effects or other factors related to emplacement of the waste and engineered barrier system, such as mechanical or chemical effects of backfill. Properties that may be affected include rock strength, fracture spacing and	Thermal-mechanical effects on fractures will be addressed by existing agreements between DOE and NRC (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this agreement. Long-term degradation of the host rock is addressed by existing agreements between DOE and NRC (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 11 and 19).

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		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 might increase the severity of mechanical failure (Ofoegbu, 2000). DOE agreed to reevaluate its assessment of long-term mechanical degradation(Reamer, 2001f) The DOE should account for long-term mechanical degradation of the host rock mass in the assessment of drift degradation, rockfall, and changes in hydrological properties and their effects on repository performance.	DOE will provide an improved technical basis for 2.2.01.02.00 (Thermal and Other Waste and Engineered Barrier Subsystem-Related Changes in the Adjacent Host Rock) by performing a postclosure drift deformation analysis that incorporates postclosure loads and rock properties using relevant information from existing agreements (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 2–13). Engineered Barrier Subsystem Features, Events, and Processes, ANL–WIS–PA–000002, will be revised to include this information.
UZ2 ENG3	66	2.2.06.01.00 [Changes in Stress (Due to Thermal, Seismic, or Tectonic Effects), Change Porosity, and Permeability of Rock] is screened as excluded on the basis of low consequence and low probability (for one secondary entry) (CRWMS M&O, 2001b). Even small changes in the fracture openings cause large changes in permeability. The rock deforms according to the rock stress field. Changes in the ground water flow and in the temperature field will change the stress acting on the rock, which will, in turn, change the ground water flow. 2.2.06.01.00 [Change in Stress (Due to Thermal, Seismic, or Tectonic Effects), Change Porosity, and Permeability of Rock] is excluded as having low consequence to dose (CRWMS M&O, 2000a). However, the DOE analyses used to support the screening argument (CRWMS M&O, 2000v) 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.	Thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). 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 on completion of this agreement.
UZ2	J-20	2.2.07.05.00 (Flow and Transport in the Unsaturated Zone from Episodic Infiltration). Excluded based on low consequence (CRWMS M&O, 2001e). Screening argument asserts that episodic infiltration is expected to be attenuated by flow in the paintbrush nonwelded tuff layer such that unsaturated zone flow beneath this layer is effectively steady-state. Analyses to support this assertion, however, have only considered episodic infiltration with an average of 5 mm/yr [0.197 in/yr] infiltration flux. Area-average infiltration flux over the proposed repository horizon at Yucca Mountain is expected to exceed 20 mm/yr [0.787 in/yr] during future wetter climate conditions.	This issue is addressed by existing agreements between DOE and NRC (Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 4 Agreement 4). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ3 SZ1 SZ2	J-6	2.2.07.15.00 (Advection and Dispersion). As defined, this item does not apply to the unsaturated zone and is not discussed in CRWMS M&O (2001e). Given that advection and dispersion are key components of the DOE radionuclide transport in the unsaturated zone model abstraction, the definition of 2.2.07.15.00 (Advection and Dispersion) should be extended to include these aspects (advection and dispersion) in the unsaturated zone.	DOE will add this features, events, processes to Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, and present the DOE discussion in the screening argument.
UZ2	USFIC-1	2.2.07.18.00 (Film Flow into Drifts) is screened as included on the basis of low consequence (low film flow rates). Higher film flow rates into drifts are considered included (CRWMS M&O, 2001e). Technical bases for the screening argument for 2.2.07.18.00 (Film Flow into Drifts) will derive from work needed to satisfy the	At the Unsaturated and Saturated Flow Under Isothermal Conditions DOE and NRC Technical Exchange (Reamer, 2000), DOE agreed to include the effect of the low-flow regime processes (e.g., film flow) in the DOE seepage fraction and seepage flow, or justify that it is not needed (Subissue 4, Agreement 2). No additional work is

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 4, Agreement 2.	required to derive the technical basis for the screening argument for 2.2.07.18.00 (Film Flow into Drifts).
UZ3	J-7	2.2.08.01.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone) is excluded. DOE included the current ambient ground water conditions in the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone, but has excluded future changes (CRWMS M&O, 2000w, 2001e). DOE asserts that thermal effects on chemistry are minimal, but assertion focuses mainly on the effects of dissolution and precipitation on hydrologic properties. The screening argument refers to a model of thermal-chemical effects on seepage water chemistry at the drift wall (CRWMS M&O, 2000x). Because modeled effects fell within the range of variation included in total system performance assessment, it is asserted that effects farther from the drift would be smaller, based on an unverified assumption (CRWMS M&O, 2001e). This argument does not address chemical changes below the repository, which are likely to be more significant than changes above, because of interactions with the engineered barrier system and waste materials. Even so, predicted changes in key geochemical parameters (pH and total carbon) in seepage water are large enough to have an effect on sorption coefficients. Without the details on how expert judgment was used to derive the Total System Performance Assessment–Site Recommendation sorption parameters, it is not clear how the effects of changes in the ambient chemistry system are incorporated into the transport calculations.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, Radionuclide Transport Subissue 1 Agreement 5, and Subissue 2 Agreement 10). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ3 SZ2	J-8	2.2.08.02.00 (Radionuclide Transport Occurs in a Carrier Plume in Geosphere) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001e). The key assumption (CRWMS M&O, 2001e; Assumption 11) is that results from the near-field thermal-hydrological-chemical coupled processes model (CRWMS M&O, 2000x) can be used to bound the effects of similar coupled processes on far-field flow and transport. This assumption has not yet been verified. Because the screening argument for this item is focused primarily on thermal effects on the chemistry of seepage water entering the emplacement drifts, it does not appear to include other potential effects (colloids, interactions with waste forms, and engineered barrier system materials). Also, 2.1.09.01.00 (Properties of a Carrier Plume in the Engineered Barrier Subsystem) is included in the process model report (CRWMS M&O, 2001b, 2000y), suggesting that radionuclide transport in a carrier plume should be included in transport beyond the engineered barrier system.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
UZ2 UZ3	J-9	2.2.08.03.00 [Geochemical Interactions in Geosphere (Dissolution, Precipitation, Weathering) and Effects on Radionuclide Transport] is excluded (CRWMS M&O, 2000d, 2001e) from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence. The key assumption (CRWMS M&O, 2001e; Assumption 11) is that results from the near-field thermal-hydrological-chemical coupled processes model (CRWMS M&O, 2000x) can be used to bound the effects of similar coupled	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreements 4 and 7, and Subissue 2 Agreement 6). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		processes on far-field flow and transport. This assumption has not yet been verified. Predicted mineralogical changes (CRWMS M&O, 2000x) in response to the thermal effects of the repository are small (calcite only). Predicted changes in porosity and permeability are also small. Transport through fractures is conservatively modeled in the Total System Performance Assessment–Site Recommendation, assuming no retardation. The screening argument, however, only addresses changes in seepage water chemistry. It does not address the possibility of reduced (or enhanced) matrix diffusion through precipitation and dissolution. Diffusion into the matrix and sorption on matrix minerals can be an important retardation mechanism. The effect of small-volume changes on fracture armoring and diffusion into the matrix may be important. The current screening arguments will depend, in part, on the demonstration of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001e). Effects on flow are excluded based on low consequence. Problems with modeling of drift-scale coupled processes (CRWMS M&O, 2000x) used to support this screening argument have been raised by NRC. The DOE has agreed to provide additional technical basis for the screening argument (Reamer, 2001e).	
UZ3	J-10	2.2.08.06.00 (Complexation in Geosphere) is excluded. DOE included the effects of ambient condition complexation in the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone, but has excluded future changes (CRWMS M&O, 2000d, 2001e). The effects of complexation are "implicitly included in the radionuclide sorption coefficients," but there is no clear technical basis regarding the effects of organics or other ligands provided in establishing the K_d distributions (CRWMS M&O 2001e). Experimental results reported in Triay, et al. (1997) that form much of the basis for the sorption coefficient distributions only address the effects of organics on neptunium and plutonium sorption. The analysis and model report (CRWMS M&O, 2000w) does not provide additional information on the effect of organics on other radionuclides. The current process models do not address the effects of complexation on transport parameters, and the exclusion of changes to complex formation does not have sufficient support. In addition, the screening argument refers to modeling results on repository effects on seepage chemistry, which may not be relevant to transport conditions below the repository (CRWMS M&O, 2001e).	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
Dose2 Dose3	20	The Yucca Mountain Project Database (CRWMS, 2001g) does not indicate that 2.2.08.07.00 (Radionuclide Solubility Limits in the Geosphere) is relevant to the biosphere. This item is relevant for limiting the quantity of radioactive material that can leach radionuclides out of the soil or tephra deposit in the biosphere compared with the quantity of radionuclides that would be predicted to leach out of the deposit using only leach rate limits.	DOE will add this item to Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes, ANL–MGR–MD–000011, and present the DOE discussion in the screening argument.
UZ3	J-11	2.2.08.07.00 (Radionuclide Solubility Limits in the Geosphere) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 4 Agreement 3). Features, Events, and Processes in UZ Flow and Transport,

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		zone on the basis of low consequence (CRWMS M&O, 2000d, 2001e). The DOE screening argument assumes that radionuclide solubility limits in the geosphere may be different and indicates that radionuclide solubility limits in the geosphere are conservatively ignored with respect to solubility reduction in the far field (CRWMS M&O, 2000d). The possibility of increasing solubility limits, however, should also be considered. Solubility limits in the geosphere will be determined by interaction between the contaminant plume and the host rock.	ANL–NBS–MD–000001, will be revised on completion of this work.
UZ3 SZ2	J-12	2.2.10.01.00 (Repository-Induced Thermal Effects in Geosphere) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001e). The screening argument is only partially supported by near-field thermal-chemical modeling for a limited number of hydrochemical constituents and minerals (CRWMS M&O, 2000x) and is not directly related to the effects on radionuclide transport. The exclusion of 2.2.10.01.00 (Repository-Induced Thermal Effects in Geosphere) will depend, in part, on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001e).	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.
SZ1	13	2.2.10.02.00 (Thermal Convection Cell Develops in Saturated Zone) is screened as excluded on the basis of low consequence (CRWMS M&O, 2000b). DOE indicates that temperatures at the water table are expected to approach 80 °C [176 °F]. DOE further points out the resulting concern is that thermally driven water flow in the upper tuff aquifer could increase ground water velocities relative to the system without heat sources. Additional justification for exclusion should be provided.	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in Saturated Zone Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment.
UZ2 SZ1 SZ2	3	2.2.10.03.00 (Natural Geothermal Effects). It is stated that natural geothermal effects are included because the current geothermal gradient is addressed in the saturated zone flow and transport model (CRWMS M&O, 2001f). This discussion, however, does not address the potential for spatial and temporal variations in that gradient, which is part of the description of 2.2.10.03.00 (Natural Geothermal Effects). Resolution of this issue is necessary to address changes in the geothermal gradient in 2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)].	This issue is addressed by an existing DOE and NRC agreement (Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 5, Agreement 13). Features, Events, and Processes in Saturated Zone Flow and Transport, ANL–NBS–MD–000002, will be updated, as necessary, to reflect the results of this existing agreement.
ENG2 ENG3 UZ2	70	2.2.10.04.00 (Thermal-Mechanical Alteration of Fractures Near Repository) is screened excluded on the basis of low consequence (CRWMS M&O, 2000h, 2001c). See discussion in 2.2.06.01.00 [Changes in Stress (Due to Thermal, Seismic, or Tectonic Effects), Change Porosity, and Permeability of Rock]. 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.	The thermal-mechanical effects on rock properties are addressed by an existing DOE and NRC agreement (Repository Design and Thermal-Mechanical Effects Subissue 3, Agreements 20 and 21). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this work.
UZ2	67	2.2.10.05.00 (Thermal-Mechanical Alteration of Rocks Above and Below the Repository) is screened as excluded on the basis of low consequence (CRWMS M&O, 2001c). Thermal-mechanical compression at the repository produces tension-fracturing in the paintbrush nonwelded tuff and other units above the repository. These fractures alter unsaturated zone flow between	DOE planned to analyze the effects of thermal-hydrological-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, thermal-hydrological-mechanical continuum

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)			
Integrated Subissue	**Technical Exchange**	**Comment**	**DOE Responses to 2001 Technical Exchanges**
		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.	modeling will address thermal- mechanical effects in rocks above and below the repository at a mountain scale in an update to the Coupled Thermal-Hydrological-Mechanical Effects on Permeability Analysis and Model Report, ANL–NBS–HS–000037. DOE will clarify the screening arguments in the FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, on completion of this agreement.
ENG3 UZ2 UZ3 SZ1 SZ2 UZ3	64 9	2.2.10.06.00 [Thermal-Chemical Alteration (Solubility Speciation, Phase Changes, and Precipitation/Dissolution)] [Near-Field Environment]: Screened as excluded on the basis of low consequence (CRWMS M&O, 2001c). Changes in the ground water temperature in the farfield, if significant, may change the solubility and speciation of certain radionuclides. This change could 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. [Saturated Zone]: Screened as excluded on the basis of low consequence (CRWMS M&O, 2001f) with reference to the screening argument for 2.2.07.10.00 (Condensation Zone Forms Around Drifts) in (CRWMS M&O, 2001e). The argument that repository thermal effects on saturated zone radionuclide transport will be minimal is based on a to-be-verified assumption (CRWMS M&O, 2001e). There is no explicit technical basis presented that rock alteration or temperature effects on geochemical properties and processes will negligibly affect saturated zone transport. In addition, it is asserted in CRWMS M&O (2001f) that any such effects would be within the bounds of uncertainty ranges established for transport properties such as K_d. However, the relevant analysis and model report (CRWMS M&O, 2000w) does not provide a clear technical basis that this is the case. DOE should provide additional technical justification for exclusion. Same comment applies to 2.2.10.08.00 (Thermal-Chemical Alteration of the Saturated Zone). [Unsaturated Zone]: DOE has not provided the technical basis for excluding entrained colloids in the analysis of 2.2.10.06.00 [Thermo-Chemical Alteration (Solubility Speciation, Phase Changes, and Precipitation/Dissolution)] or an alternative database entry (CRWMS M&O, 2001e). DOE has not considered possible entrainment of colloids and particulates in convecting/advecting boiling fluids or by otherwise vigorous water movement in the drift.	[Near-Field Environment]: This issue is addressed by an existing agreement between DOE and NRC (Evolution of the Near-Field Environment Subissue 1, Agreement 3). FEPs in Thermal Hydrology and Coupled Processes, ANL–NBS–MD–000004, will be revised on completion of this work. [Saturated Zone]: DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000002, to address the NRC comment. [Unsaturated Zone]: At the Evolution of the Near-Field Environment Technical Exchange, DOE agreed to provide the technical basis for excluding entrained colloids in the analysis of 2.2.10.06.00 (Thermal-Chemical Alteration) or an alternative features, events, and processes (Evolution of the Near-Field Environment Subissue 1, Agreement 6). DOE will provide the technical basis for screening entrained colloids in the analysis of 2.2.10.06.00 (Thermal-Chemical Alteration) in a future revision of Features, Events, and Processes in SZ Flow and Transport, ANL–NBS–MD–000001, expected to be available in fiscal year 2002.
UZ3	J-13	2.2.10.06.00 [Thermal-Chemical Alteration (Solubility, Speciation, Phase Changes, Precipitation/Dissolution)] is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001e). Thermal effects on chemistry at the mountain scale are expected to be low, based on near-field coupled thermal-hydrological-chemical models that indicate the thermal effects of the repository result in only small changes in major hydrochemical constituents and limited changes in mineralogy, however, model results in the cited report (CRWMS M&O, 2000x) only	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		consider a few components in hydrochemistry important to container life (e.g., pH, total carbon, and calcium). The model is limited to calcite precipitation/dissolution and addresses only seepage water chemistry. Thermal-chemical effects on transport beneath the repository, which could reflect the influence of the engineered barrier system and waste form materials, are not considered. In addition, although the assumption that far-field changes are likely to be less than near-field changes is reasonable, it has not been verified (CRWMS M&O, 2001e). The technical basis should be strengthened to demonstrate low consequence. The evaluation of this exclusion will depend in part on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001e).	
UZ2 UZ3	J-14	2.2.10.07.00 (Thermal-Chemical Alteration of the Calico Hills Unit) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2001e). The screening argument is based on the prediction of small changes in aqueous geochemistry and mineralogy in response to coupled thermal-hydrological-chemical processes in the near field (CRWMS M&O, 2000x). Thermal-chemical changes in the far field, including the Calico Hills unit, will be even less significant (CRWMS M&O, 2001e; Assumption 11). The screening argument indicates that temperatures in the zeolite-bearing Calico Hills unit, will not be high enough to cause significant zeolite alteration. Final evaluation of this exclusion will depend, in part, on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than the calculated near-field changes (CRWMS M&O, 2001e). Alteration of the uppermost nonwelded layers below the repository could significantly reduce the fraction of matrix flow below the repository. Nonwelded vitric horizons, either basal Topopah Springs vitrophyre or the uppermost Calico Hills unit, cover nearly half the repository. In the southwestern portion of the repository footprint, the nonwelded, nonaltered tuffs lie as little as 45 m [147.64 ft] below the repository. The screening argument (CRWMS M&O, 2001e) includes the assertion that temperatures in the Calico Hills unit will remain below 70 °C [158 °F], which is not high enough to cause significant zeolite alteration. According to the cited reference, however, it appears temperatures can exceed 70 °C [158 °F] {up to 85 °C [185 °F]} is estimated from figures in the cited section of CRWMS M&O, 2000z} where the nonwelded, nonaltered tuff is closest to the repository.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work. DOE also stated that alteration of vitric rock has not been addressed and will need to be included in the overall thermal-hydrological-chemical analyses.
SZ1 SZ2	9	2.2.10.08.00 (Thermal-Chemical Alteration of the Saturated Zone). See comment on 2.2.10.06.00 [Thermal-Chemical alteration (solubility speciacion, phase changes, precipitation/dissolution)].	See comment on 2.2.10.06.00 [Thermal-Chemical Alteration (solubility speciacion, phase changes, precipitation/dissolution)].
UZ2 UZ3	J-15	2.2.10.09.00 (Thermal-Chemical Alteration of the Topopah Spring Basal Vitrophyre) is excluded from the Total System Performance Assessment–Site Recommendation abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O, 2000d, 2001e). The screening argument is based on predicting small changes in aqueous geochemistry and mineralogy in	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreement 4, and Subissue 4 Agreements 3 and 4, and Radionuclide Transport Subissue 1 Agreement 5). Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, will be revised on completion of this work.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
		response to coupled thermal-hydrological-chemical processes in the near field (CRWMS M&O, 2000x). Thermal-chemical changes in the far field, including the Topopah Spring basal vitrophyre, are expected to be even less significant (CRWMS M&O, 2001e). Although the assumption that far-field changes are likely to be less than near-field changes (Assumption 11) is reasonable, this assumption has not been verified (CRWMS M&O, 2001e). It is important to note that the near-field analyses (CRWMS M&O, 2000x) focus on seepage chemistry and how it might affect container life, rather than considering thermal effects on radionuclide transport. The technical basis should be strengthened to demonstrate low consequence to radionuclide transport. Alteration of the uppermost nonwelded layers below the repository could significantly reduce the fraction of matrix flow below the repository. Nonwelded vitric horizons, either basal Topopah Spring vitrophyre or the uppermost Calico Hills unit, cover nearly half the repository. In the southwestern portion of the repository footprint, the nonwelded, nonaltered tuffs lie as little as 45 m [147.64 ft] below the repository. The screening argument for 2.2.10.07.00 (CRWMS M&O, 2001e) includes the assertion that temperatures in the Calico Hills unit will remain below 70°C [158 °F] which is not high enough to cause significant zeolite alteration. According to the cited reference, however, it appears temperatures can exceed 70°C [158 °F] {up to 85°C [185 °F] is estimated from figures in the cited section of CRWMS M&O (2000z)} where the nonwelded, nonaltered tuff is closest to the repository. Temperatures would be higher in the overlying Topopah Spring basal vitrophyre than in Calico Hills.	
UZ1 UZ2	61	2.2.10.12.00 (Geosphere Dryout Due to Waste Heat). It is necessary to develop a screening argument for this item as part of the scope of the analysis and model report (CRWMS M&O, 2001e). Elevated thermal effects on shallow infiltration from changes in soil water content were not addressed for 2.2.10.12.00 (Geosphere Dryout Due to Waste Heat). The DOE study of a natural thermal gradient on Yucca Mountain addresses this item (CRWMS M&O, 1998b). 2.2.10.12.00 (Geosphere Dryout Due to Waste Heat) is screened as included in CRWMS M&O (2001c) for issues related to the near-field environment, but does not address the effects on infiltration.	DOE agreed to provide the technical basis for the screening argument in Features, Events, and Processes in UZ Flow and Transport, ANL–NBS–MD–000001, to address the NRC comment.
UZ2 SZ1 SZ2	12	2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)]. The analysis and model report (CRWMS M&O, 2001f) addresses this item in two parts: repository-induced effects (excluded, low consequence) and natural geothermal effects (included). Natural effects are included only to the extent that the natural geothermal gradient is applied in the saturated zone flow and transport model. However, changes in thermal gradients are excluded on the basis of low consequence, with reference to 1.2.06.00.00 (Hydrothermal Activity) and 1.2.10.02.00 (Hydrologic Response to Igneous Activity) (CRWMS M&O, 2001f). A clear technical basis is not provided for these items that all possible changes in thermal gradients will be localized. The screening argument for 1.2.06.00.00 (Hydrothermal Activity) focuses on geochemical effects (see separate entry), whereas 1.2.10.02.00 (Hydrologic Response to Igneous Activity) is focused on highly localized igneous intrusions. How these arguments apply to 2.2.10.13.00 [Density-Driven Groundwater Flow (Thermal)] is not entirely clear.	This issue is addressed by an existing DOE and NRC agreement (Unsaturated and Saturated Flow Under Isothermal Conditions Subissue 5, Agreement 13). 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.

Table B–1. NRC Comments on Features, Events, and Processes Including, DOE and NRC Agreements (continued)

Integrated Subissue	Technical Exchange	Comment	DOE Responses to 2001 Technical Exchanges
UZ2	J-21	2.2.11.02.00 (Gas Pressure Effects) is excluded based on low consequence and low probability (CRWMS M&O, 2001e). Consistency is needed in the screening arguments. Buildup of water vapor pressure within rock matrix blocks from waste heat has not been considered. Gas pressure can build up within matrix blocks that have low permeability. This condition can increase the boiling point and keep water in the liquid phase at higher temperatures. Flashing to vapor as liquid water leaves the matrix block can result in mineral deposition that can later affect flow pathways.	This issue is addressed by existing agreements between DOE and NRC (Evolution of the Near-Field Environment Subissue 1 Agreements 5 and 7, and Subissue 4 Agreement 3). *Features, Events, and Processes in UZ Flow and Transport*, ANL-NBS-MD-000001, will be revised on completion of this work.
SZ1 SZ2 Dose1 Dose2 Dose3	10	2.3.11.04.00 (Groundwater Discharge to Surface) is excluded on the basis of low consequence (CRWMS M&O, 2001f). Modeling shows that spring discharge within the 20-km [12.4-mi] radius is not likely, yet past discharges occurred within the 20-km [12.4-mi] radius (e.g., paleospring deposits at 9S and 1S). See discussion of 1.3.07.02.00 (Water Table Rise). Additional technical justification should be provided to fully exclude 2.3.11.04.00 (Groundwater Discharge to Surface).	DOE agreed to provide clarification of the screening argument in Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002, to address the NRC comment.
Dose3 Dose2	21	2.3.13.01.00 (Biosphere Characteristics) screening argument indicates the Yucca Mountain region lacks permanent surface water (CRWMS M&O, 2001a). It is not clear this statement is consistent with the geologic record of past climate change in the area.	DOE agreed to provide clarification of the screening argument in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL-MGR-MD-000011, to address the NRC comment.
Dose3	24	2.3.13.02.00 (Biosphere Transport) contains only two secondary entries related to surface water, gas, and biogeochemical transport processes (CRWMS M&O, 2001a). The Yucca Mountain Project feature, event, and process description and the originator description are different and question whether the focus is transport processes, alterations during transport, or both.	DOE agreed to clarify the description of the primary features, events, and processes in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL-MGR-MD-000011, to address the NRC comment.
Dose3	25	2.4.07.00.00 (Dwellings) includes a secondary entry, household cooling, which has an inappropriate screening argument (CRWMS M&O, 2001a). The screening argument indicates that because use of an evaporative cooler would only increase 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, hence, could have a more significant dose impact.	DOE agreed to provide the technical basis for the screening argument in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL-MGR-MD-000011, to address the NRC comment.
Dose3 Dose2 Direct2	26	The analysis and model report (CRWMS M&O, 2001a) states that 3.3.08.00.00 (Radon and Daughter Exposure) is screened as excluded on the basis the parent radionuclide (Th-230) will not reach the critical group in 10,000 years in the basecase scenario (CRWMS M&O, 2000aa, 2001a). This rationale, however, does not apply to the direct release scenario, where transport times are much shorter.	DOE agreed to provide the technical basis for the screening argument in Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP), ANL-MGR-MD-000011, to address the NRC comment.

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CRWMS M&O—Civilian Radioactive Waste Management System Management and Operating Contractor
DOE—U.S. Department of Energy
FEPs—features, events, and processes
NRC—U.S. Nuclear Regulatory Commission
SZ—saturated zone
TSPA—total system performance assessment
UZ—unsaturated zone

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APPENDIX C

GLOSSARY

This Glossary is provided for information and is not exhaustive.

absorption: The process of taking up by capillary, osmotic, solvent, or chemical action of molecules (e.g., absorption of gas by water) as distinguished from adsorption.

abstracted model: A model that reproduces, or bounds, the essential elements of a more detailed process model and captures uncertainty and variability in what is often, but not always, a simplified or idealized form. See *abstraction*.

abstraction: Representation of the essential components of a process model into a suitable form for use in a total system performance assessment. Model abstraction is intended to maximize the use of limited computational resources while allowing a sufficient range of sensitivity and uncertainty analyses.

adsorb: To collect a gas, liquid, or dissolved substance on a surface as a condensed layer.

adsorption: The adhesion by chemical or physical forces of molecules or ions (as of gases or liquids) to the surface of solid bodies. For example, the transfer of solute mass, such as radionuclides, in ground water to the solid geologic surfaces with which it comes in contact. The term *sorption* is sometimes used interchangeably with this term.

advection: The process in which solutes, particles, or molecules are transported by the motion of flowing fluid. For example, advection in combination with dispersion controls flux into and out of the elemental volumes of the flow domain in ground water transport models.

air mass fraction: The mass of air divided by the total mass of gas (typically air plus water vapor) in the gas phase. This expression gives a measure of the "dryness" of the gas phase, which is important in waste package corrosion models.

Alloy 22: A nickel-base corrosion resistant alloy containing approximately 22 weight percent chromium, 13 weight percent molybdenum, and 3 weight percent tungsten as major alloying elements and that may be used as the outer container material in a waste package design (see *outer barrier*).

alluvium: Detrital deposits made by streams on river beds, flood plains, and alluvial fans; especially a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas and lakes.

alternative: Plausible interpretations or designs based on assumptions other than those used in the base case that could also fit or be applicable, based on the available scientific information. When propagated through a quantitative tool such as performance assessment, alternative interpretations can illustrate the significance of the uncertainty in the base case interpretation chosen to represent the repository's probable behavior.

ambient: Undisturbed, natural conditions such as ambient temperature caused by climate or natural subsurface thermal gradients, and other surrounding conditions.

anisotropy: The condition that physical properties vary when measured in different directions or along different axes. For example, in layered rock the permeability is often greater within the horizontal layers than across the horizontal layers.

annual frequency: The number of occurrences of an event expected in one year.

aqueous: Pertaining to water, such as aqueous phase, aqueous species, or aqueous transport.

aquifer: A subsurface, saturated rock unit (formation, group of formations, or part of a formation) of sufficient permeability to transmit ground water and yield water of sufficient quality and quantity for an intended beneficial use.

ash: Bits of volcanic rock that would be broken-up during an eruption to less than 2 mm [0.08 inches] in diameter.

basalt: A type of igneous rock that forms black, rubbly lavas and black-to-red tephras of the type commonly used as lava rocks for barbecues.

borosilicate glass: A predominantly noncrystalline, relatively homogenous glass formed by melting silica and boric oxide together with other constituents such as alkali oxides. A high-level radioactive waste matrix material in which boron takes the place of the lime used in ordinary glass mixtures.

boundary condition: For a model, the establishment of a set condition, often at the geometric edge of the model, for a given variable. An example is using a specified ground water flux from net infiltration as a boundary condition for an unsaturated flow model.

bound: An analysis or selection of parameter values that yields pessimistic results, such that any actual result is certain to be no worse or could be worse only with an extremely small likelihood.

breach: A penetration in the waste package caused by failure of the outer and inner containers or barriers that allows the spent nuclear fuel or the high-level radioactive waste to be exposed to the external aqueous environment and eventually permits radionuclide release.

burnup: A measure of nuclear reactor fuel consumption expressed either as the percentage of fuel atoms that have undergone fission or as the amount of energy produced per unit weight of fuel.

calibration: (1)The process of comparing the conditions, processes, and parameter values used in a model against actual data points or interpolations (e.g., contour maps) from measurements at or close to the site to ensure that the model is compatible with reality, to the extent feasible. (2) For tools used for field or lab measurements, the process of taking instrument readings on standards known to produce a certain response, to check the accuracy and precision of the instrument.

canister: A cylindrical metal receptacle that facilitates handling, transportation, storage, and/or disposal of high-level radioactive waste. It may serve as (1) a pour mold and container for vitrified high-level radioactive waste or (2) a container for loose or damaged fuel rods, non-fuel components and assemblies, and other debris containing radionuclides.

carbon steel: A steel made of carbon up to about 2 weight percent and only residual quantities of other elements. Carbon steel is a tough but ductile and malleable material used as baskets to maintain the spent fuel assemblies in fixed positions in the current waste package design.

Category 1 event sequences: Those event sequences that are expected to occur one or more times before permanent closure of a geologic repository.

Category 2 event sequences: Event sequences other than Category 1 event sequences that have at least one chance in 10,000 of occurring before permanent closure.

Center for Nuclear Waste Regulatory Analyses: A Federally funded research and development center in San Antonio, Texas, sponsored by the U.S. Nuclear Regulatory Commission, to provide the U.S. Nuclear Regulatory Commission with technical assistance for the repository program.

chain reaction: A continuing series of nuclear fission events that takes place within the fuel of a nuclear reactor. Neutrons produced by a split nucleus collide with and split other nuclei causing a chain of fission events.

cladding: The metal outer sheath of a fuel rod generally made of a zirconium alloy, and in the early nuclear power reactors of stainless steel, intended to protect the uranium dioxide pellets, which are the nuclear fuel, from dissolution by exposure to high temperature water under operating conditions in a reactor.

climate: Weather conditions including temperature, wind velocity, precipitation, and other factors, that prevail in a region.

climate states: Representations of climate conditions.

code (computer): The set of commands used to solve a mathematical model on a computer.

colloid: As applied to radionuclide migration, a colloidal system is a group of large molecules or small particles, having at least one dimension with the size range of 10^{-9} to 10^{-6} meters that are suspended in a solvent. Naturally occurring colloids in ground water arise from clay minerals such as smectites and illites. Colloids that are transported in ground water can be filtered out of the water in small pore spaces or very narrow fractures because of the large size of the colloids.

Colloid-Facilitated, Radionuclide Transport Model: A model that represents the enhanced transport of radionuclides by particles that are colloids.

commercial spent nuclear fuel: Nuclear fuel rods, forming a fuel assembly, that have been removed from a nuclear power plant after reaching the specified burnup.

common cause failure: Two or more failures that result from a single event or circumstance.

conceptual model: A set of qualitative assumptions used to describe a system or subsystem for a given purpose. Assumptions for the model are compatible with one another and fit the existing data within the context of the given purpose of the model.

consequence: A measurable outcome of an event or process that, when combined with the probability of occurrence, gives risk.

conservative: A condition of an analysis or a parameter value such that its use provides a pessimistic result, which is worse than the actual result expected.

continuum model: A model that represents fluid flow through numerous individual fractures and matrix blocks by approximating it as continuous flow fields.

corrosion: The deterioration of a material, usually a metal, as a result of a chemical or electrochemical reaction with its environment.

corrosion model: A theoretical representation of a corrosion process based on the application of a combination of fundamental electrochemical (chemical) and thermodynamic principles (or laws) with empirical parameters resulting from experiments, field measurements, or data obtained through industrial experience. Models can describe the penetration of a pit or a crack through a container wall as a function of time.

corrosion resistant alloy: An alloy that exhibits extremely high resistance to general or uniform corrosion in a given environment as a result of the formation of a protective film on its surface. Alloy 22, and other similar nickel-chromium-molybdenum alloys, are considered corrosion resistant alloys because they are extremely resistant to general corrosion in severe aqueous environments (e.g., high temperature brines containing acidic sulfur species).

coupling: The ability to assemble separate analyses or parameters in a performance assessment so that information can be passed among them to develop an overall analysis of system performance.

crevice corrosion: Localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity between the metal and the surface of another material.

critical event: See *criticality*.

criticality: (1) A condition that would require the original waste form, which is part of the waste package, to be exposed to degradation, followed by conditions that would allow concentration of sufficient nuclear fuel, the presence of neutron moderators, the absence of neutron absorbers, and favorable geometry. (2) The condition in which nuclear fuel sustains a chain reaction. It occurs when the number of neutrons present in one generation cycle equals the number generated in the previous cycle. The state is considered critical when a self-sustaining nuclear chain reaction is ongoing.

criticality accident: The release of energy as a result of accidental production of a self-sustaining or divergent neutron chain reaction.

data: Facts or figures measured or derived from site characteristics or standard references from which conclusions may be drawn. Parameters that have been derived from raw data are sometimes, themselves, considered to be data.

U.S. Department of Energy: A Cabinet-level agency of the U.S. federal government charged with the responsibilities of energy security, national security, and environmental quality.

design concept: An idea of how to design and operate the above-ground and below-ground portions of a repository.

diffusion: (1) The spreading or dissemination of a substance caused by concentration gradients. (2) The gradual mixing of the molecules of two or more substances because of random thermal motion.

diffusive transport: Movement of solutes because of their concentration gradient. The process in which substances carried in ground water move through the subsurface by means of diffusion because of a concentration gradient.

dike: A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks.

dimensionality: Modeling in one, two, or three dimensions.

direct exposure: The manner in which an individual receives dose from being in close proximity to a source of radiation. Direct exposures present an external dose pathway.

dispersion (hydrodynamic dispersion): (1) The tendency of a solute (substance dissolved in ground water) to spread out from the path it is expected to follow if only the bulk motion of the flowing fluid were to move it. The tortuous path the solute follows through openings (pores and fractures) causes part of the dispersion effect in the rock. (2) The macroscopic outcome of the actual movement of individual solute particles through a porous medium. Dispersion causes dilution of solutes, including radionuclides, in ground water, and is usually an important mechanism for spreading contaminants in low flow velocities.

disposal container: A cylindrical metal receptacle designed to contain spent nuclear fuel and high-level radioactive waste that will become an integral part of the waste package when loaded with spent nuclear fuel or high-level radioactive waste. In the current waste package design, the inner container will have spacing structures or baskets to maintain fuel assemblies, shielding components, and neutron absorbing materials in position to control the possibility of criticality.

disruptive event: An unexpected event that, in the case of the potential repository, includes volcanic activity, seismic activity, and nuclear criticality. Disruptive events have two possible effects: (1) direct release of radioactivity to the surface, or (2) alteration of the nominal behavior of the system. For the purposes of screening features, events, and processes for the total system performance assessment, a disruptive event is defined as an event that has a significant effect on the expected annual dose and that has a probability of occurrence during the 10,000-year period of performance less than 1.0, but greater than a cutoff of 0.0001.

disruptive event scenario class: The scenario, or set of related scenarios, that describes the behavior of the system if perturbed by disruptive events. The disruptive scenarios contain all disruptive features, events, and processes that have been retained for analysis.

dissolution: (1) Change from a solid to a liquid state. (2) Dissolving a substance in a solvent.

distribution: The overall scatter of values for a set of observed data. A term used synonymously with frequency distribution or probability distribution function. Distributions have structures that are the probability that a given value occurs in the set.

drift: From mining terminology, a horizontal underground passage. The nearly horizontal underground passageways from the shaft(s) to the alcoves and rooms. Drifts include excavations for emplacement (emplacement drifts) and access (access mains).

drift scale: The scale of an emplacement drift, or approximately 5 meters in diameter.

Drift-Scale Heater Test: A test being conducted in the Exploratory Studies Facility to investigate thermal-hydrologic, thermal-chemical, and thermal-mechanical processes.

drip shield: A metallic structure placed along the extension of the emplacement drifts and above the waste packages to prevent seepage water from directly dripping onto the waste package outer surface.

edge effects: Conditions at the edges of the potential repository that are cooler and wetter because heat dissipates more quickly there than at the center of the repository.

effective porosity: The fraction of a porous medium volume available for fluid flow and/or solute storage, as in the saturated zone. Effective porosity is less than or equal to the total void space (porosity).

empirical: Reliance on experience or experiment rather than on an understanding of the fundamental processes as related to the laws of nature.

emplacement drift: See *drift*.

enrichment: The act of increasing the concentration of ^{235}U from its value in natural uranium. The enrichment (typically reported in atom percent) is a characteristic of nuclear fuel.

equilibrium: The state of a chemical system in which the pnases do not undergo any spontaneous change in properties or proportions with time; a dynamic balance.

events: (1) Occurrences that have a specific starting time and, usually, a duration shorter than the time being simulated in a model. (2) uncertain occurrences that take place within a short time relative to the time frame of the model. For the purposes of screening features, events, and processes for the total system performance assessment, an event is defined to be a natural or human-caused phenomenon that has a potential to affect disposal system performance and that occurs during an interval that is short compared with the period of performance.

event tree: A modeling tool that illustrates the logical sequence of events that follow an initiating event.

expert elicitation: A formal process through which expert judgment is obtained.

Exploratory Studies Facility: An underground laboratory at Yucca Mountain that includes a 7.9-kilometer [4.9-mile] main loop (tunnel); a 2.8-kilometer [1.75-mile] cross-drift; and a research alcove system constructed for performing underground studies during site characterization. The data collected will contribute toward determining the suitability of the Yucca Mountain site for a repository. Some or all of the Exploratory Studies Facility may eventually be incorporated into the potential repository.

fault (geologic): A planar or gently curved fracture across which there has been displacement parallel to the fracture surface.

fault tree: A graphical logic model that depicts the combinations of events that result in the occurrence of an undesired event.

features: Physical, chemical, thermal, or temporal characteristics of the site or potential repository system. For the purposes of screening features, events, and processes for the total system performance assessment, a feature is defined to be an object, structure, or condition that has a potential to affect disposal system performance.

ferritic steel: A subclass of carbon steels characterized by a relatively low strength but good ductility as a result of the ferrite microstructure. A type of ferritic steel, mild steel, or low-carbon steel containing up to about 0.1 weight percent carbon is the metallic material most commonly used for construction purposes.

film flow: Movement of water as a film along a surface such as a fracture plane.

finite element analysis: A commonly used numerical method for solving mechanical deformation problems. A technique in which algebraic equations are used to approximate the partial differential equations that comprise mathematical models to produce a form of the problem that can be solved on a computer. For this type of approximation, the area being modeled is formed into a grid with irregularly shaped blocks. This method provides an advantage in handling irregularly shaped boundaries, internal features such as faults, and surfaces of engineered materials. Values for parameters are frequently calculated at nodes for convenience, but are defined everywhere in the blocks by means of interpolation functions.

flow: The movement of a fluid such as air, water, or magma. Flow and transport are processes that can move radionuclides from the proposed repository to the receptor group location.

flow pathway: The subsurface course that water or a solute (including radionuclides) would follow in a given ground water velocity field, governed principally by the hydraulic gradient.

fracture: A planar discontinuity in rock along which loss of cohesion has occurred. It is often caused by the stresses that cause folding and faulting. A fracture along which there has been displacement of the sides relative to one another is called a fault. A fracture along which no appreciable movement has occurred is called a joint. Fractures may act as fast paths for ground water movement.

fracture aperture: The space that separates the sides of a fracture, and the measured width of the space separating the sides of a fracture.

fracture permeability: The capacity of a rock to transmit fluid that is related to fractures in the rock.

frequency: The number of occurrences of an observed or predicted event during a specific time period.

galvanic: Pertains to an electrochemical process in which two dissimilar electronic conductors are in contact with each other and with an electrolyte, or in which two similar electronic conductors are in contact with each other and with dissimilar electrolytes.

galvanic corrosion: Accelerated corrosion of a metal resulting from electrical contact with a more noble metal or non metallic conductor in a corrosive electrolyte.

geochemical: The distribution and amounts of the chemical elements in minerals, ores, rocks, soils, water, and the atmosphere; and the movement of the elements in nature on the basis of their properties.

geologic-framework model: A digital, scaled, geometrically congruent , three-dimensional model of the geologic system.

ground water: Water contained in pores or fractures in either the unsaturated or saturated zones below ground level.

half-life: The time required for a radioactive substance to lose have its activity due to radioactive decay. At the end of one half-life, 50 percent of the original radioactive material has decayed.

heterogeneity: The condition of being composed of parts or elements of different kinds. A condition in which the value of a parameter such as porosity, which is an attribute of an entity of interest such as the tuff rock containing the potential repository, varies over the space an entity occupies, such as the area around the repository, or with the passage of time.

high-level radioactive waste glass: A waste form produced by melting a mixture of high-level radioactive waste and components of borosilicate glass at a high temperature (approximately 1,100 degrees centigrade).

hydrologic: Pertaining to the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

igneous: (1) A type of rock that has formed from a molten, or partially molten, material. (2) A type of activity related to the formation and movement of molten rock either in the subsurface (intrusive) or on the surface (volcanic).

infiltration: The process of water entering the soil at the ground surface. Infiltration becomes percolation when water has moved below the depth at which it can be removed (to return to the atmosphere) by evaporation or transpiration. See *net infiltration*.

inner barrier: The inner container in the current design of the waste package. Type 316NG stainless steel is the DOE preferred material of construction.

invert: A constructed surface that would provide a level drift floor and enable transport and support of the waste packages.

isothermal: Having a constant temperature.

license application: An application, to the U.S. Nuclear Regulatory Commission for a license to construct and operate a repository.

localized corrosion: Corrosion at discrete sites (e.g., pitting and crevice corrosion).

magma: Molten or partially molten rock that is naturally occurring and is generated within the earth. Magma may contain crystals along with dissolved gasses.

Mathematical Model: A mathematical description of a conceptual model.

matrix: Tuff rock material and its pore space exclusive of fractures. As applied to Yucca Mountain tuff, the ground mass of an igneous rock that contains larger crystals.

matrix diffusion: As used in the Total System Performance Assessment for the Site Recommendation conceptual models, the process by which molecular or ionic solutes, such as radionuclides in ground water, move from areas of higher concentration to areas of lower concentration. This movement is through the pore spaces of the rock material as opposed to movement through the fractures.

matrix permeability: The capability of the matrix to transmit fluid.

mean (arithmetic): For a statistical data set, the sum of the values divided by the number of items in the set. The arithmetic average.

mechanical disruption: Damage to the drip shield or waste package because of external forces.

median: A value such that one-half of the observations are less than that value and one-half are greater than the value.

meteorology: The study of climatic conditions such as precipitation, wind, temperature, and relative humidity.

microbe: An organism too small to be viewed with the unaided eye. Examples of microbes are bacteria, protozoa, and some fungi and algae.

microbial influenced corrosion: Deterioration of metals as a result of the metabolic activity of microorganisms.

migration: Radionuclide movement from one location to another within the engineered barrier system or the environment.

mineral model: A description of the kinds and relative abundances of minerals that is used to approximate the true mineralogical system.

mineralogical: Of or relating to the chemical and physical properties of minerals, their occurrence, and their classification.

model: A depiction of a system, phenomenon, or process, including any hypotheses required to describe the system or explain the phenomenon or process.

near field: The area and conditions within the potential repository including the drifts and waste packages and the rock immediately surrounding the drifts. The region around the potential repository where the natural hydrogeologic system has been significantly impacted by the excavation of the repository and the emplacement of waste.

net infiltration: The amount of infiltration that escapes the zone of evapotranspiration, which is generally the zone below the zone of plant roots. See *infiltration*.

nominal behavior: (1) Expected behavior of the system as perturbed only by the presence of the potential repository. (2) Behavior of the system in the absence of disruptive events.

nominal features, events, and processes: Those features, events, and processes expected, given the site conditions as described from current site characterization information.

nominal scenario class: The scenario, or set of related scenarios, that describes the expected or nominal behavior of the system as perturbed only by the presence of the potential repository. The nominal scenarios contain all expected features, events, and processes that have been retained for analysis.

nuclear criticality safety: Protection against the consequences of a criticality accident, preferably by prevention of the accident.

U.S. Nuclear Regulatory Commission: An independent agency, established by the U.S. Congress under the Energy Reorganization Act of 1974, to ensure adequate protection of the public health and safety, the common defense and security, and the environment, in the use of nuclear materials in the United States. The U.S. Nuclear Regulatory Commission scope of responsibility includes regulation of the transport, storage, and disposal of nuclear materials and waste.

Nuclear Waste Policy Act (42 U.S.C. 10101 et seq.): The Federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a federal system for the management, and geologic disposal, of commercial spent nuclear fuel and other high-level radioactive wastes. The Act also: (1) specified other federal responsibilities for nuclear waste management; (2) established the Nuclear Waste Fund to cover the cost of geologic disposal; (3) authorized interim storage under certain circumstances; and (4) defined interactions between federal agencies and the states, local governments, and Indian tribes. The act was substantially amended in 1987.

Nuclear Waste Policy Amendments Act of 1987: Legislation that amended the Nuclear Waste Policy Act to: (1) limit repository site characterization activities to Yucca Mountain, Nevada; (2) establish the Office of the Nuclear Waste Negotiator to seek a state or Indian tribe willing to host a repository or monitored retrievable storage facility; (3) create the Nuclear Waste Technical Review Board; and (4) increase state and local government participation in the waste management program.

numerical model: An approximate representation of a mathematical model that is constructed using a numerical description method such as finite volumes, finite differences, or finite elements. A numerical model is typically represented by a series of program statements that are executed on a computer.

Office of Civilian Radioactive Waste Management: A U.S. Department of Energy office created by the Nuclear Waste Policy Act of 1982 to implement the responsibilities assigned by the Act.

outer barrier: The outer container in the current design of the waste package. Alloy 22 is the U.S. Department of Energy preferred material of construction.

oxidation: (1) A corrosion reaction in which the corroded metal forms an oxide, usually applied to reaction with a gas containing elemental oxygen, such as air. (2) An electrochemical reaction in which there is an increase in the valence of an element resulting from the loss of electrons.

parameter: Data, or values, such as those that are input to computer codes for a total system performance assessment calculation.

patch: A circumscribed area of a surface. In the DOE modeling of waste package corrosion, it is the minimal surface area of the outer container over which uniform corrosion occurs, as opposed to localized corrosion in pits.

pathway: A potential route by which radionuclides might reach the accessible environment and pose a threat to humans. For example, direct exposure is an external pathway, and inhalation and ingestion are internal pathways.

permeability: The ability of a material to transmit fluid through its pores when subjected to a difference in head (pressure gradient). Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they are interconnected.

phase: A physically homogeneous and distinct portion of a material system, such as the gaseous, liquid, and solid phases of a substance. In liquids and solids, single phases may coexist.

phase stability: A measure of the ability of a particular phase to remain without transformation.

pit: A small cavity formed in a solid as a result of localized dissolution.

pitting corrosion: Localized corrosion of a metal surface, confined to a small area, that takes the form of cavities named pits.

porosity: The ratio of openings, or voids, to the total volume of a soil or rock expressed as a decimal fraction or as a percentage. See also *effective porosity*.

pre-startup and startup testing: Activities to evaluate the readiness to receive, possess, process, store, and dispose of high-level radioactive waste.

probabilistic: (1) Based on or subject to probability. (2) Involving a variate, such as temperature or porosity. At each instance of time, the variate may take on any of the values of a specified set with a certain probability. Data from a probabilistic process are an ordered set of observations, each of which is one item from a probability distribution.

probabilistic risk assessment: (1) A systematic process of identifying and quantifying the consequences of scenarios that could cause a release of radioactive materials to the environment. (2) Using predictable behavior to define the performance of natural, geologic, human, and engineered systems for thousands of years into the future including probability distributions to account for uncertainty and variability.

probability: The chance that an outcome will occur from the set of possible outcomes. Statistical probability examines actual events and can be verified by observation or sampling. Knowing the exact probability of an event is usually limited by the inability to know, or compile, the complete set of possible outcomes over time or space.

probability distribution: The set of outcomes (values) and their corresponding probabilities for a random variable.

processes: Phenomena and activities that have gradual, continuous interactions with the system being modeled. For the purposes of screening features, events, and processes for the total system performance assessment, a process is defined as a natural or human-caused phenomenon that has a potential to affect disposal system performance and that operates during all or a significant part of the period of performance.

process model: A depiction or representation of a process, along with any hypotheses required to describe or to explain the process.

radioactive decay: The process in which one radionuclide spontaneously transforms into one or more different radionuclides, which are called daughter radionuclides.

radioactivity: The property possessed by some elements (i.e., uranium) of spontaneously emitting radiation (e.g., alpha particles, beta particles, or gamma rays) by the disintegration of atomic nuclei.

radiolysis: Chemical decomposition by the action of radiation.

radionuclide: Radioactive type of atom with an unstable nucleus that spontaneously decays, usually emitting ionizing radiation in the process. Radioactive elements are characterized by their atomic mass and atomic number.

range (statistics): The numerical difference between the highest and lowest value in any set.

receptor: An individual for whom radiological doses are calculated or measured.

relative permeability: The ability of a material to transmit fluid through its pores when subjected to a pressure gradient under unsaturated conditions. Relative permeability is a function of permeability (has a value between 0 and 1).

repository footprint: The areal extent of the underground repository facility.

retardation: Slowing or stopping radionuclide movement in ground water by mechanisms that include sorption of radionuclides, diffusion into rock matrix pores and microfractures, and trapping of large colloidal molecules in small pore spaces or dead ends of microfractures.

risk: The probability that an undesirable event will occur, multiplied by the consequences of the undesirable event.

risk assessment: An evaluation of potential consequences or hazards that might be the outcome of an action. This assessment focuses on potential negative impacts on human health or the environment.

rock matrix: See *matrix*.

runoff: Lateral movement of water at the ground surface, such as down steep hillslopes or along channels, that is not able to infiltrate at a specified location. See *runon*.

runon: Lateral movement of water along the ground surface from some upstream location that becomes available for infiltration. See *runoff*.

safety question: A question regarding the adequacy of structures, systems, and components important to safety and engineered or natural barriers important to waste isolation.

scenario: A well-defined, connected sequence of features, events, and processes that can be thought of as an outline of a possible future condition of the potential repository system. Scenarios can be undisturbed, in which case the performance would be the expected, or nominal, behavior for the system. Scenarios can also be disturbed, if altered by disruptive events such as human intrusion or natural phenomena such as volcanism or nuclear criticality.

scenario class: A set of related scenarios sharing sufficient similarities that they can usefully be aggregated for the purposes of screening or analysis. The number and breadth of scenario classes depend on the resolution at which scenarios have been defined. Coarsely defined scenarios result in fewer, broad scenario classes, whereas narrowly defined scenarios result in many narrow scenario classes. Scenario classes (and scenarios) should be aggregated at the coarsest level at which a technically sound argument can be made while still retaining adequate detail for the purposes of the analysis.

seepage: The inflow of ground water moving in fractures or pore spaces of permeable rock to an open space in the rock such as a drift. Seepage rate is the percolation flux that enters the drift. Seepage is an important factor in waste package degradation and mobilization and migration of radionuclides out of the potential repository.

seismic: Pertaining to, characteristic of, or produced by earthquakes or earth vibrations.

shallow infiltration: The amount of infiltration that escapes the root zone and percolates downward into the unsaturated zone. See *net infiltration*.

site recommendation: A recommendation by the Secretary of Energy to the President that the Yucca Mountain site is suitable for development as the Nation's first high-level radioactive waste repository.

sorb: To undergo a process of sorption.

sorption: The binding, on a microscopic scale, of one substance to another. A term that includes both adsorption and absorption. The sorption of dissolved radionuclides onto aquifer solids or waste package materials by means of close-range chemical or physical forces is potentially an important process in a repository. Sorption is a function of the chemistry of the radioisotopes, the fluid in which they are carried, and the mineral material they encounter along the flow path.

sorption coefficient (K_d): Coefficient for a term for the various processes by which one substance binds to another.

source term: Types and amounts of radionuclides that are the source of a potential release.

spatial variability: A measure of how a property, such as rock permeability, varies at different locations in an object such as a rock formation.

speciation: The existence of the elements, such as radionuclides, in different molecular forms in the aqueous phase.

spent nuclear fuel: Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. Spent fuel that has been burned (irradiated) in a reactor to the extent that it no longer makes an efficient contribution to a nuclear chain reaction. This fuel is more radioactive than it was before irradiation, and releases significant amounts of heat from the decay of its fission product radionuclides. See *burnup*.

stratigraphy: The science of rock strata. It is concerned with all characters and attributes of rocks as *strata* and their interpretation in terms of mode of origin and geologic history.

stress corrosion cracking: A cracking process that requires the simultaneous action of a corrodent and sustained (residual or applied) tensile stress. Stress corrosion cracking excludes both the fracture of already corroded sections and the localized corrosion processes that can disintegrate an alloy without the action of residual or applied stress.

structure: In geology, the arrangement of the parts of the geologic feature or area of interest such as folds or faults. This includes features such as fractures created by faulting and joints caused by the heating of rock.

tectonic: Pertaining to geologic forms or effects created by deformation of the earth's crust.

tephra: A collective term for all clastic materials ejected from a volcano and transported through the air. It includes volcanic dust, ash, cinders, lapilli, scoria, pumice, bombs, and blocks.

thermal-chemical: Of or pertaining to the effect of heat on chemical conditions and reactions.

thermal-hydrologic: Of or pertaining to changes in ground water movement due to the effects of changes in temperature.

thermal-hydrologic processes: Processes that are driven by a combination of thermal and hydrologic factors. These processes include evaporation of water near the potential repository when it is hot and subsequent redistribution of fluids by convection, condensation, and drainage.

thermal hydrology: The study of a system that has both thermal and hydrologic processes. A thermal-hydrologic condition, or system, is expected to occur if heat-generating waste packages are placed in the potential repository at Yucca Mountain.

thermal-mechanical: Of or pertaining to changes in mechanical properties of rocks from effects of changes in temperature.

thermodynamics: A branch of physics that deals with the relationship and transformations between work as a mechanical action and heat.

total system performance assessment: A risk assessment that quantitatively estimates how the potential Yucca Mountain repository system will perform in the future under the influence of specific features, events, and processes, incorporating uncertainty in the models and uncertainty and variability of the data.

transparency: The ease of understanding the process by which a study was carried out, which assumptions are driving the results, how they were arrived at, and the rigor of the analyses leading to the results. A logical structure ensures completeness and facilitates in-depth review of the relevant issues. Transparency is achieved when a reader or reviewer has a clear picture of what was done in the analysis, what the outcome was, and why.

transpiration: The removal of water from the ground by vegetation (roots).

transport: A process that allows substances to be carried in a fluid through (1) the physical mechanisms of convection, diffusion, and dispersion; and (2) the chemical mechanisms of sorption, leaching, precipitation, dissolution, and complexation. Types of transport include advective, diffusive, and colloidal.

tuff: A general term for all consolidated pyroclastic rocks. The most abundant type of rock at the Yucca Mountain site.

uncertainty: How much a calculated or measured value varies from the unknown true value.

uniform corrosion: A type of corrosion attack (deterioration) more or less uniformly distributed over a metal surface. Corrosion that proceeds at approximately the same rate over a metal surface. Also called general corrosion.

unsaturated zone flow: The movement of water in the unsaturated zone driven by capillary, viscous, gravitational, inertial, and evaporative forces.

variable: A non-unique property or attribute.

variability (statistical): A measure of how a quantity varies over time or space.

volcanism: Pertaining to volcanic activity.

watershed: The area drained by a river system including the adjacent ridges and hillslopes.

APPENDIX D

The following Risk Insights Baseline Report was issued in April 2004, and is reproduced here incorporating only minor editorial corrections.

RISK INSIGHTS BASELINE REPORT

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC–02–02–012

Prepared by

NRC and CNWRA Staffs

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

July 2004

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EXECUTIVE SUMMARY

As part of an ongoing effort to increase the use of risk information in its regulatory activities, the U.S. Nuclear Regulatory Commission (NRC) High-Level Waste Program is enhancing documentation of risk information and synthesizing the information to better support a risk-informed regulatory program. This effort is referred to as the Risk Insights Initiative. This report documents the results of the Risk Insights Initiative and provides the results in the form of the Risk Insights Baseline Report. The Risk Insights Baseline Report serves as a common reference for staff to use in risk-informing the NRC High-Level Waste Program, as it continues through prelicensing regulatory activities and prepares to review a license application that may be submitted by the U.S. Department of Energy (DOE) for a potential high-level waste repository at Yucca Mountain, Nevada.

The risk insights presented in this report address the staff current understanding of the repository system following cessation of repository operations and permanent closure of the repository through the 10,000-year compliance period (i.e., the postclosure period). The risk insights are drawn from the staff experience gained through the development and exercise of the Total-System Performance Assessment (TPA) computer code, technical analyses conducted by the staff to support prelicensing interactions with DOE, and analyses conducted by DOE and others. If DOE submits a license application for a potential repository at Yucca Mountain, staff will review the information provided by DOE and make its determinations based on information available at that time.

Background on Risk-Informed Regulation

In the Probabilistic Risk Assessment Policy Statement (60 FR 42622, August 16, 1995), NRC formalized its commitment to risk-informed regulation through the expanded use of probabilistic risk assessment in regulatory activities. In issuing the policy statement, NRC expected the implementation of probability risk assessment to improve the regulatory process in three ways: (i) incorporation of probabilistic risk assessment insights into regulatory decisions, (ii) efficient and effective utilization of agency resources, and (ii) reduction of unnecessary burden on licensees. The Probabilistic Risk Assessment Policy Statement in part says, "The use of probabilistic risk assessment technology should be increased in all regulatory matters to the extent supported by the state-of-the-art in Probabilistic Risk Assessment methods and data, and in a manner that complements the NRC deterministic approach and supports the NRC traditional defense-in-depth philosophy." In a white paper staff requirements memorandum, Risk-Informed and Performance-Based Regulation (SECY–98–144, March 1, 1999), NRC stated that a risk-informed approach should use risk insights to focus regulatory attention on issues, commensurate with their importance to public health and safety.

The definition for risk in the white paper takes the view that assessing risk involves three questions: What can go wrong?; How likely is it?; and, What are the consequences? These three questions are referred to as the risk triplet. The traditional definition of risk, that is, probability times consequences, is fully embraced by the triplet definition of risk. For the high-level waste postclosure repository system, the risk is usually expressed in terms of probability-weighted dose, for comparison to the dose-based individual protection standard.

In the high-level waste program, performance assessment is the methodology that is used to assess the risks associated with postclosure performance of a repository system. The high-level waste performance assessments include not only the system-level analyses performed to calculate probability-weighted dose, but also the supporting analyses performed to understand system-level results, the sensitivities and uncertainties in the system-level results, the capability of individual system components and processes, and interactions among the components and processes. Thus, risk insights may be expressed explicitly relative to system-level risk, such as probability-weighted dose, and also may be expressed in terms of surrogate measures (e.g., calculation of waste package failure rates, release rates of radionuclides from the waste package, and transport times of radionuclides to the compliance location), as long as the relationship between the surrogate measure and the system-level risk is understood. In the high-level waste program, risk insights are based on the quantitative results of performance assessments.

Developing the Risk Insights Baseline Report

Building on approximately 20 years of performance assessment activity, the high-level waste Risk Insights Initiative began in 2002. The early efforts of the Risk Insights Initiative were aimed at enhancing communication, among staff, of the more significant technical issues, and identifying and focusing staff attention on the more significant of the prelicensing agreements that had been established between NRC and DOE. Following these initial efforts, staff began development of its Risk Insights Baseline Report. The risk insights baseline provides a system-level perspective on the relative significance of system features, events, and processes by looking at how they might affect the waste isolation capabilities of the repository system during the postclosure period, and the potential effect on public health and safety.

To facilitate the application of the Risk Insights Baseline Report to its regulatory activities, staff organized the risk insights around the 14 postclosure performance assessment model abstractions, referred to as integrated subissues (Figure 1). Two other primary NRC documents related to the high-level waste program, NUREG–1762 (NRC, 2002) and NUREG–1804 (NRC, 2003), are also structured around these integrated subissues. Within each model abstraction, staff developed individual risk insights to address the important features, events, and processes, both natural and engineered, of the repository system, and to communicate how they relate to waste isolation capability and to estimates of risk. Staff did not attempt to develop risk insights to address all the components of a potential repository system at Yucca Mountain, but instead has focused on those components identified as most significant to waste isolation.

The risk insights are generally framed around the three aspects of the risk triplet. Risk insights are generally stated in terms of a scenario, essentially a statement of the feature, event, or process that might exist or occur in the postclosure repository system. The baseline provides context for understanding the likelihood that the feature, event, or process will exist or occur during the compliance period. For each risk insight, the baseline provides: (i) supporting quantitative analyses, and an interpretation of the analyses to the extent necessary to explain the relationship between the analyses and the risk insight; and (ii) a discussion of the uncertainties associated with the analyses and their interpretation.

To support the application of the Risk Insights Baseline Report, the staff grouped the risk insights into three categories of relative significance (high, medium, and low), based on

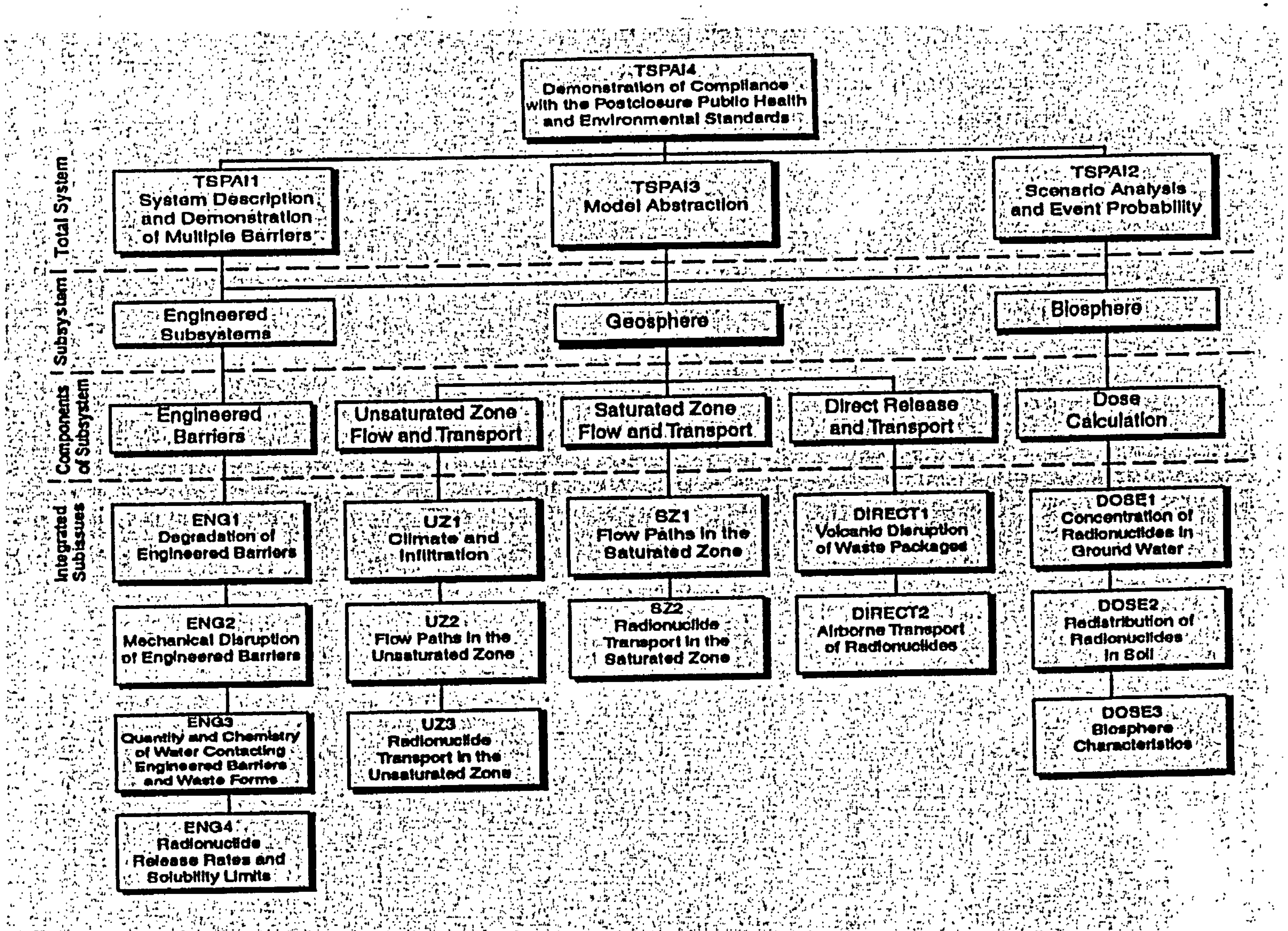


Figure 1. Components of Performance Assessment Review. (NRC, 2003, Figure A1-5)

contribution to, or effect on, the waste isolation capabilities of the repository system. Three criteria were considered in evaluating the significance of the risk insights:

- Effect on the integrity of waste packages
- Effect on the release of radionuclides from the waste form and waste package
- Effect on the transport of radionuclides through the geosphere and biosphere

In general, high significance is associated with features, events, and processes that could: (i) affect a large number of waste packages; (ii) significantly affect the release of radionuclides; or (iii) significantly affect the transport of radionuclides through the geosphere or biosphere. Medium significance is associated with a lesser effect on waste packages, radionuclide releases, or radionuclide transport, and low significance is associated with no or negligible effect.

General Risk Insights on Geologic Disposal

Geologic disposal has been internationally adopted as an appropriate method for ensuring protection of public health and safety for very long time periods (e.g., 10,000 years) because deep geologic disposal: (i) limits the potential for humans to come into direct contact with the waste; (ii) isolates the waste from a variety of natural, disruptive processes and events occurring on the surface of the earth; and (iii) limits the transport of radionuclides, after release to ground water, by the natural hydrological and chemical properties of geologic strata comprising a potential repository site. Additionally, it has been widely accepted that a geologic repository is to be comprised of multiple barriers as a means of providing defense-in-depth.

The inventory of high-level waste represents a significant risk if the inventory were quickly released to the biosphere. However, current performance assessments of a potential repository at Yucca Mountain indicate that the majority (i.e., greater than 99 percent) of the inventory is isolated from humans during the regulatory compliance period and beyond, because of the effectiveness of the engineered barriers and the attributes of the site (i.e., natural barriers). For example: (i) long-lived waste packages are expected to retain their integrity during the period of the highest thermal output of the waste, when the waste-form behavior is most uncertain; (ii) radionuclides are expected to be released slowly from the engineered barrier system once the waste packages degrade; and (iii) radionuclides are expected to travel slowly from the engineered barrier system to the area where potential exposures might occur because of the sorptive properties of the surrounding rock. Thus, multiple barriers, as a defense-in-depth approach, result in a robust repository system that is more tolerant of failures and external challenges.

Table 1 provides a general perspective on the capabilities and effectiveness of the site and design attributes for isolating the radionuclides considered in the ground water pathway. The site and design attributes are divided into three categories affecting waste isolation: (i) delay of the onset of initial release; (ii) release rates from the engineered barriers (principally the waste package and waste form); and (iii) transport in the geosphere. The effectiveness of each barrier is indicated by the letters D (for delay) or L (for limit), which are used to represent three levels of effectiveness, by the number of letters present.

Table 1. Representation of Effectiveness of the Attributes of Waste Isolation							
	Attributes of Waste Isolation						
	Onset of Release	Release Rate			Geosphere Transport		
Radionuclide	Waste Package	Waste Form	Solubility Limits	Solubility and Limited Water	Unsaturated Zone	Saturated Zone - Tuff	Saturated Zone - Alluvium
Am-241	DDD				DDD	DDD	DDD
Pu-240	DDD			L	DDD	DD	DDD
Pu-239	DDD			L	DDD	DD	DDD
Am-243	DDD			L	DDD	DD	DDD
Tc-99	DDD	LL			D	D	D
U-234	DDD			L	DDD	D	DDD
Ni-59	DDD	LLL	L	LL	DDD	D	DDD
C-14	DDD	LLL			D	D	D
Np-237	DDD			L	DDD	D	DDD
Nb-94	DDD	LL	LLL	LLL	D	DD	DDD
Cs-135	DDD	LL			DDD	DDD	DDD
Se-79	DDD	LL			DD	D	DD
U-238	DDD	L	LLL	LLL	DDD	D	DDD
Cm-246	DDD	L			D	DD	DDD
I-129	DDD	LL			D	D	D
Th-230	DDD	LL	L	LL	DDD	DD	DDD
Cl-36	DDD	LL			DDD	DDD	DDD
Ra-226	DDD	LL		L	DDD	DD	DDD
Pb-210	DDD	LL	L	LL	DDD	DD	DDD

Notes: D denotes delay time of at least 10,000 years (DDD); 1,000 years (DD); and 100 years (D)

L denotes limit on release of 10,000 (LLL), 1,000 (LL) and 100 (L) times less than 0.15 mSv (15 mrem)

Table 1 offers a general explanation for the risk currently estimated for the potential repository; namely, the variety and number of design and site attributes result in a very limited amount of the high-level waste inventory being transported by ground water to the compliance location. Additionally, from a defense-in-depth perspective, the importance of any one barrier is generally diminished as the number of relatively independent barriers increases. In other words, poor performance of one barrier does not cause a significant increase in the estimated risk; thus, confidence in the overall safety of the repository system is significantly enhanced when there are multiple and effective barriers.

Although the information presented in Table 1 provides a useful general overview of repository system capabilities for waste isolation, this approach does not address the uncertainties in estimating the behavior of the potential repository system. The technical details and uncertainties are the subject of the detailed risk insights provided for the 14 integrated subissues (Figure 1). Additionally, Table 1 addresses releases in the ground water pathway and does not address releases to the air pathway from a potential igneous event. Igneous activity has a potential for higher consequences than estimated for the ground water pathway. However, the risk is still estimated to be small from this scenario because the probability for igneous activity is orders of magnitude below the probability for ground water releases.

Detailed Risk Insights

NRC staff have identified, to date, detailed risk insights related to performance of the repository system during the postclosure regulatory period. The risk insights are organized by the 14 performance assessment model abstractions (i.e., the integrated subissues) (Figure 1). For each risk insight, NRC staff ranked the significance of the insight to waste isolation as a means of providing a transparent view of NRC current understanding of features, events, and processes associated with a potential repository at Yucca Mountain. Such a representation of the risk insights benefits the NRC high-level waste program by providing: (i) NRC staff with information to risk-inform prelicensing interactions and the review of a potential DOE license application; and (ii) other stakeholders and interested groups and individuals (e.g., State of Nevada, DOE, Advisory Committee on Nuclear Waste) with information regarding the focus of NRC interactions with DOE and its review of a potential license application. Table 2 summarizes the detailed risk insights, organized by the 14 integrated subissues (Figure 1), along with their significance rankings.

Table 2. Summary of Risk Insights Rankings: Significance to Waste Isolation

ENG1—Degradation of Engineered Barriers	
Persistence of a Passive Film	High Significance
Waste Package Failure	Medium Significance
Drip Shield Integrity	Medium Significance
Stress Corrosion Cracking	Medium Significance
Juvenile Failures of the Waste Package	Low Significance
ENG2—Mechanical Disruption of Engineered Barriers	
Effects of Accumulated Rockfall on Engineered Barriers	Medium Significance
Dynamic Effects of Rockfall on Engineered Barriers	Low Significance
Effects of Seismic Loading on Engineered Barriers	Medium Significance
Effects of Faulting on Engineered Barriers	Low Significance

Table 2. Summary of Risk Insights Rankings: Significance to Waste Isolation (continued)	
ENG3—Quantity and Chemistry of Water Contacting Engineered Barriers and Waste Forms	
Chemistry of Seepage Water	High Significance
ENG4—Radionuclide Release Rates and Solubility Limits	
Waste Form Degradation Rate	Medium Significance
Cladding Degradation	Medium Significance
Solubility limits	Medium Significance
Mode of Release from Waste Package	Low Significance
Effect of Colloids on Waste Package Releases	Medium Significance
Invert Flow and Transport	Low Significance
Criticality	Low Significance
UZ1—Climate and Infiltration	
Present-day Net Infiltration Rate	Medium Significance
Long-term Climatic Change	Medium Significance
UZ2—Flow Paths in the Unsaturated Zone	
Seepage	High Significance
Hydrologic Properties of the Unsaturated	Medium Significance
Transient Percolation	Low Significance
UZ3—Radionuclide Transport in the Unsaturated Zone	
Retardation in the Calico Hills Non-Welded Vitric Unit	Medium Significance
Matrix Diffusion in the Unsaturated Zone	Medium Significance
Effect of Colloids on Transport in the Unsaturated Zone	Medium Significance
SZ1—Flow Paths in the Saturated Zone	
Saturated Alluvium Transport Distance	Medium Significance
SZ2—Radionuclide Transport in the Saturated Zone	
Retardation in the Saturated Alluvium	High Significance
Matrix Diffusion in the Saturated Zone	Medium Significance
Effect of colloids on Transport in the Saturated Zone	Medium Significance
DIRECT1—Volcanic Disruption of Waste Packages	
Probability of Igneous Activity	High Significance
Number of Waste Packages Affected by Eruption	High Significance
Number of Waste Packages Damaged by Intrusion	Medium Significance
DIRECT2—Airborne Transport of Radionuclides	
Volume of Ash Produced by an Eruption	Medium Significance
Remobilization of Ash Deposits	Medium Significance
Inhalation of Resuspended Volcanic Ash	High Significance
Wind Vectors During an Eruption	Medium Significance
DOSE1—Concentration of Radionuclides in Ground Water	
Well-pumping Model	Low Significance
DOSE2—Redistribution of Radionuclides in Soil	
Redistribution of Radionuclides in Soil	Low Significance
DOSE3—Biosphere Characteristics	
Characterization of the Biosphere	Low Significance

METRIC TO ENGLISH SYSTEM CONVERSION FACTORS

The following table provides the appropriate conversion factors to allow the user to switch between the System Internationale or metric system and the English system of measure. Not all units or methods of conversions are shown. Unit abbreviations are shown in parentheses. All conversion factors are approximate. Multiply quantity in metric units by the appropriate conversion factor to obtain English unit equivalents. For additional unit conversions, refer to C.J. Pennycuick (1988).

Conversion Factors			
	To Convert	To	Multiply By
Length	Microns or micrometer (µm)	Inches (in)	3.94×10^{-5}
	Microns or micrometer (µm)	Feet (ft)	3.28×10^{-6}
	Millimeters (mm)*	Inches (in)*	0.0394
	Millimeters (mm)	Feet (ft)	0.0033
	Centimeters (cm)	Inches (in)	0.3937
	Centimeters (cm)	Feet (ft)	0.0328
	Meters (m)*	Inches (in)*	39.3701
	Meters (m)*	Feet (ft)*	3.2808
	Meters (m)	Yards (yd)	1.0936
	Kilometers (km)*	Miles (mi)*	0.6215
Area	Square centimeters (cm^2)	Square inches (in^2)	0.1550
	Square meters (m^2)*	Square feet (ft^2)*	10.7639104
	Square meters (m^2)	Square yards (yd^2)	1.1960
	Square meters/gram (m^2/g)	Square feet/pound mass (ft^2/lbm)	4882.4276
	Square kilometers (km^2)	Square miles (mi^2)	0.3861
Volume	Cubic centimeters (cm^3)	Cubic inches (in^3)	0.0610
	Cubic meters (m^3)*	Cubic feet (ft^3)*	35.3107
	Cubic meters/year (m^3/yr)	Cubic feet/year (ft^3/yr)	35.3107
	Cubic meters (m^3)	Cubic yards (yd^3)	1.3072
	Liters (L)	Pints (pt)	2.1142
	Liters (L)	Quarts (qt)	1.0571
	Liters (L)	Gallons (gal)	0.2642
Specific Volume	Milliliters/gram (ml/g)	Gallons/pound mass (gal/lbm)	0.1198
Velocity	Meters/second (m/s)*	Feet/second (ft/s)*	3.2808
	Centimeters/second (cm/s)	Inches/second (in/s)	0.3937
	Centimeters/second (cm/s)	Feet/second (ft/s)	0.0328
Acceleration	Meters/second (m/s^2)	Feet/second (ft/s^2)	3.2808
Mass	Milligrams (mg)	Pounds (lb)	2.205×10^{-6}
	Grams (g)	Ounces (oz)	0.0353
	Kilograms (kg)	Pounds (lb)	2.2046
	Metric ton (t)*	Tons (long)*	0.9843

Conversion Factors (continued)			
	To Convert	To	Multiply By
Density	Milligrams/cubic meter (mg/m^3)	Pounds/cubic foot (lbs/ft^3)	6.243×10^{-8}
	Grams/cubic centimeter (g/cm^3)	Pounds/cubic foot (lbs/ft^3)	6.243×10^{1}
	Grams/cubic meter (g/m^3)	Pounds/cubic foot (lbs/ft^3)	6.243×10^{-5}
	Kilograms/cubic meter (kg/m^3)	Pounds/cubic foot (lbs/ft^3)	0.0624
Force	Newton (N)	Pound-force (lbf)	0.2248
	Dyne (dyn)	Pound-force (lbf)	2.248×10^{-6}
Pressure	Grams per square centimeter (g/cm^2)	Pounds per square inch (psi)	0.0142
	Pascals (Pa)	Pounds per square inch (psi)	1.450×10^{-4}
	Kilopascals (kPa)	Pounds per square inch (psi)	0.1450
	Dyne/square centimeter (dyn/cm^2)	Pound-force/square foot (lbf/ft^2)	0.0021
	Kilopascals (kPa)	Atmosphere (atm)	0.0099
	Megapascals (MPa)	Kilo pounds per square inch (kpsi)	0.145037738
Power	Kilowatts (kW)	Hosepower (hp)	1.3405
Temperature	Celsius (°C)*	Fahrenheit (°F)*†	1.8000
	Kelvin (K)	Fahrenheit (°F)	1.8000
Δ Temperature	Celsius (°C)*	Fahrenheit (°F)*‡	1.8000
Thermal Conductivity	Watts/meter - K (W/m-K)	British Thermal Unit/hour/foot-Fahrenheit (BTU/hr/ft-°F)	0.5778
Activity	Becquerels (Bq)*	Curies (Ci)*	2.70×10^{-11}
Absorbed Dose	Gray (Gy)	Rad	100
Dose Equivalent	Sievert (Sv)	Rem	100
	Millisievert (mSv)*	Millirem (mrem)*	100
Permeability	Square meters (m^2)	Darcy	1.01325×10^{12}
	Square millimeters (mm^2)	Darcy	1013249.966

*Conversions with an asterisk are used in the current document.

†The formula for converting temperature in Celsius to Fahrenheit is $T_F = (1.8)T_c + 32$

‡The formula for converting relative temperature differences in Celsius to Fahrenheit is $T_F = (1.8)T_c$

REFERENCE:

Pennycuick, Colin J. "Conversion Factors: S.I. Units and Many Others." Vol. 48. p. 1974. Chicago, Illinois: University of Chicago Press. 1988.

1 INTRODUCTION

As part of an ongoing effort to increase the use of risk information in its regulatory activities, the U.S. Nuclear Regulatory Commission (NRC) High-Level Waste Program is enhancing documentation of risk information and synthesizing the information to better support a risk-informed regulatory program. This effort is referred to as the Risk Insights Initiative. This report documents the results of the Risk Insights Initiative and provides the results in the form of the Risk Insights Baseline Report. The Risk Insights Baseline Report serves as a common reference for the staff to use in risk-informing the NRC high-level waste program, as it continues through prelicensing regulatory activities and prepares to review a license application that may be submitted by the U.S. Department of Energy (DOE) for a potential high-level waste repository at Yucca Mountain, Nevada.

The system description and the risk insights presented in this report are intended to assist the staff in its prelicensing interactions with DOE and in reviewing any license application DOE may submit. Staff have not made any determinations regarding the technical conditions or the adequacy of a repository at Yucca Mountain at this time. If DOE submits a license application for a repository at Yucca Mountain, staff will review the information provided by DOE, and make its determinations based on information available at that time.

1.1 Background

In the Probabilistic Risk Assessment Policy Statement (60 FR 42622, August 16, 1995), NRC formalized its commitment to risk-informed regulation through the expanded use of probabilistic risk assessment in regulatory activities. In issuing the policy statement, NRC expected the implementation to improve the regulatory process in three ways: (i) incorporation of probabilistic risk assessment insights into regulatory decisions; (ii) conservation of Agency resources; and (iii) reduction of unnecessary burden on licensees. The Probabilistic Risk Assessment Policy Statement states, in part, "The use of probabilistic risk assessment technology should be increased in all regulatory matters to the extent supported by the state-of-the-art in Probabilistic Risk Assessment methods and data, and in a manner that complements NRC deterministic approach and supports NRC traditional defense-in-depth philosophy."

In its staff requirements memorandum for COMSECY–96–061 (April 15, 1997), the Commission envisioned a risk-graded approach where the staff would use risk information to focus on those licensee activities that pose the greatest risk to the public health and safety, thereby accomplishing the NRC principal mission in an efficient and cost-effective manner. In general, activities of higher risk should be the primary focus of the DOE efforts and resources.

NRC defined the terms and expectations for risk-informed and performance-based regulation in a white paper staff requirements memorandum, Risk-Informed and Performance-Based Regulation (Staff Requirements Memorandum for SECY–98–144; March 1, 1999). The guidance was intended to ensure consistent interpretation of the terms and implementation of NRC expectations with respect to their use in regulatory activities. NRC believes that a risk-informed approach should use risk insights to focus regulatory attention on issues, commensurate with their importance to public health and safety. NRC also stated in the white paper that risk insights can make the elements of defense-in-depth, a fundamental tenet of nuclear regulatory practice, clearer by quantifying them to the extent practicable.

Building on approximately 20 years of performance assessment activities, the high-level waste program staff began the Risk Insights Initiative, in 2002, to improve integration and communication of the issues considered important to the performance of the high-level waste repository, thereby enhancing its ability to conduct a focused, risk-informed review of both issue resolution activities and ultimately the license application that the DOE is anticipated to submit for the proposed geologic repository at Yucca Mountain.

In response to a request from the Commission, the staff provided an initial draft of the Risk Insights Baseline Report to the Commission on June 5, 2003, along with an initial ranking of the risk significance of the key technical issue agreements. This report provides the supporting quantitative analyses and discussion of uncertainties for the risk insights.

1.2 Purpose of the Risk Insights Baseline Report

The primary purpose of the Risk Insights Baseline Report is to summarize the staff current understanding of how a repository system at Yucca Mountain might function to isolate waste and, thus, protect public health and safety during the compliance period. The Risk Insights Baseline Report outlines the staff current thinking of how the principal features, events, and processes that might be present at Yucca Mountain following permanent closure of the repository could affect the estimated risks to an individual in the vicinity of Yucca Mountain. The staff perspective presented in the baseline is drawn from experience gained through its independent technical analyses, reviews, and performance assessment activities, as well as through the extensive technical interactions with the DOE and other groups external to the Agency, that have been completed to date. The Risk Insights Baseline Report provides a common basis for the staff as it conducts its prelicensing regulatory activities regarding postclosure repository performance in a risk-informed manner.

Risk insights are the results and findings drawn from risk assessments. In the high-level waste program, risk insights help to convey the significance of specific features, events, and processes to waste isolation capabilities and calculated estimates of system risk. The high-level waste risk insights have been integrated into a baseline and presented in a way that enhances their communication and understanding among the staff and others, both inside and outside NRC. Although the significance of the risk insights may be expressed in somewhat qualitative terms (i.e., high, medium, and low significance), individual insights are supported by quantitative risk information derived from risk assessments and other technical analyses. The Risk Insights Baseline Report summarizes these supporting analyses and discusses the associated uncertainties.

1.3 Objectives of the Risk Insights Baseline Report

The format of the Risk Insights Baseline Report is intended to clearly communicate staff current understanding of the repository system, as supported by quantitative risk analyses. The baseline also discusses the relative uncertainties associated with the staff understanding. Finally, the baseline organizes the risk insights into a structure that readily supports risk-informing staff high-level waste regulatory activities. To this end, the report:

- Clarifies the application of risk insights in the high-level waste program
- Documents the baseline set of risk insights for the postclosure repository system, identifying the significance of the insights relative to waste isolation
-
- Describes the quantitative analyses that support the risk insights
- Documents uncertainties associated with the baseline set of risk insights
- Discusses the application of the baseline set of risk insights to staff ongoing and future regulatory activities (e.g., issue resolution, license application review, etc.)

The individual risk insights were developed as concise statements to enhance their communication and comprehension. As stated, staff developed the risk insights by drawing on many years of technical analysis and risk assessment experience.

1.4 Scope of the Risk Insights Baseline Report

The Risk Insights Baseline Report presented in this report addresses staff current understanding of the repository system following cessation of repository operations and permanent closure of the repository through the 10,000-year compliance period (i.e., the postclosure period). This understanding is currently reflected, to a great extent, in the NRC Total-system Performance Assessment (TPA) computer code. The staff, together with the Center for Nuclear Waste Regulatory Analyses (CNWRA), have developed this computer code in support of prelicensing activities and potential review of a license application for a repository at Yucca Mountain. The Risk Insights Baseline Report presented in this report is drawn from staff experience gained through the development and exercise of the TPA code, technical analyses conducted by staff to support prelicensing interactions with DOE, and analyses conducted by DOE and others.

The Risk Insights Baseline Report presented in this report does not address staff current understanding of the risks associated with the operation of a repository before permanent closure (i.e., the preclosure period). The staff, together with CNWRA, are currently developing the Preclosure Safety Analysis Tool, a computer code that staff will use to support its review of preclosure safety issues. The Risk Insights Baseline Report is expected to be expanded at a later date, to make use of the Preclosure Safety Analysis Tool results.

This report directly addresses risk insights related to estimating potential dose to an individual during the postclosure period. Although risk insights related to ground water protection are not explicitly identified in this report, staff believe they would be adequately addressed by the insights provided in this report.

2 APPLICATION OF RISK TERMINOLOGY IN THE NRC HIGH-LEVEL WASTE PROGRAM

This chapter discusses the general application of risk terminology in the U.S. Nuclear Regulatory Commission (NRC) high-level waste regulatory program. The NRC white paper report, Risk-Informed and Performance-Based Regulation, is the basis for the risk terminology used in the high-level waste program. This section provides additional guidance on how the terms relate specifically to the Risk Insights Baseline Report.

On March 1, 1999, NRC approved issuing the Risk-Informed and Performance-Based Regulation white paper that outlines its expectations regarding the risk-informed and performance-based regulation of nuclear safety. The white paper defines these and other related terms in an effort to promote a more common understanding within NRC and its regulated community, as well as by the public, as to how risk-informed and performance-based concepts apply to various agency functions.

NRC advocates using risk-informed and performance-based approaches in developing and implementing regulations, and directs staff to increase its use of probabilistic risk assessment in all regulatory matters to the extent supported by the state-of-the-art in methods and data, and in a manner that complements NRC deterministic approach and supports NRC tradition of defense-in-depth. With respect to the high-level waste program, NRC promulgated its regulation at 10 CFR Part 63 after the issuance of the Probabilistic Risk Assessment Policy Statement. Consistent with this policy, the regulation at 10 CFR Part 63 is risk-informed. The regulation includes risk-based requirements, as well as deterministic and prescriptive requirements. The staff are currently focused on risk-informed implementation of the rule.

This section discusses the application of several of the terms from the white paper to the high-level waste Risk Insights Baseline Report. Much of the discussion has been taken directly from the white paper.

2.1 Risk

The definition for risk in the white paper takes the view that assessing risk involves three questions: What can go wrong?; How likely is it?; and What are the consequences? These three questions are referred to as the risk triplet. The traditional definition of risk, that is, probability times consequences, is fully embraced by the triplet definition of risk.

For the high-level waste postclosure repository system, the risk is usually expressed in terms of probability-weighted dose, for comparison to the dose-based individual protection standard.

2.2 Risk Assessment

The white paper defines risk assessment as a systematic method for addressing the risk triplet as it relates to the performance of a particular system (which may include a human component) to understand likely outcomes, sensitivities, areas of importance, system interactions, and areas of uncertainty. From this assessment, the important scenarios can be identified.

The method used to conduct a risk assessment depends on the particular system being evaluated. In the high-level waste program, performance assessment is used to assess the risks associated with postclosure performance of a repository system. Consistent with the white paper definition, the performance assessment methodology includes not only the system-level analyses performed to calculate probability-weighted dose, but also the supporting analyses performed to understand system-level results, the sensitivities and uncertainties in the system-level results, the capability of individual system components and processes, and interactions among the components and processes. These supporting analyses use intermediate results from system-level computer codes as well as results from auxiliary calculations.

2.3 Risk Insights

The white paper defines the term risk insights as the results and findings that come from risk assessments. Risk insights may be explicitly expressed relative to system-level risk, such as probability-weighted dose. Risk insights also may be expressed in terms of surrogate measures, as long as the relationship between the surrogate measure and the system-level risk is understood. The extent to which risk insights are explicitly factored into the activities and decisionmaking of a specific regulatory program depends on the maturity of risk assessment methodologies and data for that program. Incorporating risk insights into a regulatory program is intended to improve both efficiency and effectiveness of the regulatory program.

In the high-level waste program, risk insights are based on the quantitative results of performance assessments. As previously defined, performance assessments include the quantitative analyses of system-level performance (e.g., analyses using the TPA code or simplified models that result in a calculation of probability-weighted dose) as well as supporting analyses (e.g., calculation of waste package failure rates, release rates of radionuclides from the waste package, and transport times of radionuclides to the compliance location) that help the staff understand the system-level results. Risk insights include the interpretation of, and the conclusions drawn from, the quantitative risk assessment results, relative to system-level risk (e.g., probability-weighted dose). Uncertainties in the risk estimates are addressed through the use of parameter ranges and alternative approaches and models.

The risk assessment methodologies applicable to the high-level waste program are relatively mature. Therefore, it is expected that high-level waste regulatory activities and decisionmaking will be guided by risk insights to a great extent, to improve effectiveness and efficiency.

2.4 Risk-Based and Risk-Informed Approaches

According to the white paper, a risk-based approach to regulatory decisionmaking is one in which such decisionmaking is solely based on the numerical results of a risk assessment. However, uncertainties in risk assessment methodologies and results limit the practicality and acceptability of purely risk-based regulatory decisionmaking. Because NRC does not endorse risk-based regulatory decisionmaking, regulatory decisionmaking in the high-level waste program will not be based solely on the quantitative results of risk assessments.

NRC endorses a risk-informed approach to regulatory decisionmaking, a philosophy whereby risk insights are considered, together with other factors, to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety. According to the white paper, a risk-informed approach enhances the deterministic approach, which requires safety systems capable of mitigating consequences of adverse conditions which are assumed to exist, by:

- Allowing explicit consideration of a broader set of potential challenges to safety;
- Providing a logical means for prioritizing these challenges, based on risk significance, operating experience, and/or engineering judgment;
- Facilitating consideration of a broader set of resources to defend against these challenges;
- Explicitly identifying and quantifying sources of uncertainty in the analysis (although such analyses do not necessarily reflect all important sources of uncertainty); and
- Leading to better decisionmaking by providing a means to test the sensitivity of the results to key assumptions.

Where appropriate, a risk-informed regulatory approach also can be used to reduce unnecessary conservatism in purely deterministic approaches, or can be used to identify areas with insufficient conservatism in deterministic analyses and provide the bases for additional requirements or regulatory actions. Risk-informed approaches lie somewhere on the spectrum between the risk-based and purely deterministic approaches, depending on the regulatory issue under consideration.

Risk insights make the elements of defense-in-depth more clear by quantifying them to the extent practicable. Risk insights related to the individual performance of each defense system, in relation to overall performance, support decisionmaking on the adequacy of, or the necessity for, elements of defense (see Section 2.5).

The high-level waste program will follow a risk-informed approach to support regulatory activities and decisionmaking with respect to the requirements of the regulation at 10 CFR Part 63. This approach will focus resources on issues commensurate with their importance to risk. This approach will take into account the quantitative risk insights, together with uncertainties and sensitivities, engineering judgment, and other relevant factors.

2.5 Risk-Informed Approach and Defense-in-Depth

The concept of defense-in-depth has always been, and will continue to be, a fundamental tenet of regulating nuclear facilities. Defense-in-depth is an element of NRC safety philosophy that employs successive compensatory measures to prevent accidents or mitigate damage if a malfunction, accident, or naturally caused event occurs at a nuclear facility. For the postclosure repository system, the regulation at 10 CFR Part 63 incorporates the defense-in-depth concept through the multiple barriers requirements. The defense-in-depth philosophy ensures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of a nuclear facility. The net effect of incorporating defense-in-depth into design, construction, maintenance, and operation is that the facility or system in question tends to be more tolerant of failures and external challenges. Risk insights can make the elements of defense-in-depth more clear by quantifying their significance to waste isolation to the extent practicable. Although the uncertainties associated with the importance of some elements of defense may be substantial, the fact that these elements and uncertainties have been quantified can assist and support regulatory decisionmaking. Decisions on the adequacy of, or the necessity for, elements of defense-in-depth, should reflect risk insights gained through identification of the individual performance of each safety system in relation to overall performance.

3 DEVELOPMENT OF THE RISK INSIGHTS BASELINE REPORT

3.1 Background

The Risk Insights Initiative began in January 2002. The early efforts of the Risk Insights Initiative were aimed at enhancing communication, among the staff, of the more significant technical issues, and identifying and focusing the staff attention on the more significant of the prelicensing agreements that had been established between the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC). A facilitated approach was used during a series of meetings to develop a consensus, among the staff, of the significance of the 293 prelicensing agreements relative to the calculated system-level risk estimates. During these initial activities, consideration of risk was not limited to a quantitative, dose-based definition. Instead, the staff considered more subjective measures of risk as part of the enhanced communication effort.

The preliminary results of the initial Risk Insights Initiative exercise were presented to the Advisory Committee on Nuclear Waste in April 2002. The committee commented that the effort was successful as a communication exercise among the staff. However, the committee agreed with the staff plan for repeating the exercise, but emphasized that the staff should focus on quantitative health and safety risks.

Following these initial efforts, the staff adopted a more integrated and quantitative systems approach to evaluating the significance of the key technical issue agreements. The staff began to develop the Risk Insights Baseline Report, a concise description of how a potential repository system at Yucca Mountain might function during the postclosure period. The Risk Insights Baseline Report provided a system-level perspective on the relative significance of system features, events, and processes, by looking at how they might affect the waste isolation capabilities of the repository system during the postclosure period, and the potential effect on public health and safety. The staff could then relate the agreements to this integrated system-evel baseline to assess the relative significance of individual key technical issue agreements.

3.2 Development of the Current Baseline

The Risk Insights Baseline Report has been developed by synthesizing available information drawn from quantitative risk assessments. The insights are based on many years of experience with conducting total-system performance assessments, subsystems analyses, and auxiliary calculations. The insights are also based on the staff review and interpretation of the performance assessments and supporting analyses conducted by others. Generally, the staff are relying on their own analyses to develop the risk insights, however, the analyses of others are useful for identifying alternative approaches and models that differ from those used by the staff in its performance assessment analyses. Understanding the analyses of others (e.g., DOE) is especially useful in specific areas where the staff approach in its total-system performance assessment computer code differ significantly from the approach of others (e.g., matrix diffusion in the unsaturated zone, representation of climate change). An understanding of the analyses of others provides additional information to evaluate the strengths and limitations of the risk insights.

The staff started with a system-level perspective and worked down to levels of greater detail and specificity. To coordinate the development of the set of insights, and to facilitate application of the Risk Insights Baseline Report to the staff regulatory activities, the staff organized the risk insights around the postclosure performance assessment model abstractions, referred to as integrated subissues. These integrated subissues are identified in two other primary NRC documents related to the high-level waste program, NUREG–1762 (NRC, 2002) and NUREG–1804 (NRC, 2003).

Within each model abstraction, the staff developed individual risk insights to address the important components (i.e., features, events, and processes, both natural and engineered) of the repository system and to communicate how these components relate to waste isolation capability and to estimates of risk. Thus, the risk insights discussed in this report for the high-level waste program tie the system components to some potential effect on health and safety, in terms of dose. The staff did not attempt to develop risk insights to address all the components of a potential repository system at Yucca Mountain, but has, instead, focused on those the staff have identified as most important.

The risk insights are generally framed around the three aspects of the risk triplet. Each risk insight is stated in terms of a scenario, essentially as a statement of the feature, event, or process that might exist or occur. The baseline also provides context for understanding the likelihood that the scenario will exist or occur during the regulatory period of interest. The baseline also includes a discussion of the consequence of the scenario, in terms of its beneficial or adverse effect on the waste isolation capabilities of the repository system. An effect on waste isolation capability subsequently affects the estimated dose, or risk, to an individual.

Quantitative results for waste isolation capability (e.g., release rates from waste package, transport times for radionuclides) provide further insight to understand the effect on risk. Additionally, certain analyses were conducted beyond the regulatory period of 10,000 years to understand the sensitivity of repository performance to the timing of a process or event (i.e., when it occurs) that is currently estimated to occur beyond the compliance period (e.g., corrosion of the waste package, certain climate changes).

The baseline also provides an interpretation of the analyses to the extent necessary to explain the relationship between the analyses and the risk insight. These analyses generally have been excerpted from existing technical reports, papers, and presentations. The analyses address the likelihood of the condition described in the insight occurring at the site during the period of regulatory interest, or the consequence if the condition were to occur. Although development of the risk insights was based primarily on quantitative, system-level risk analyses, such as performance assessment calculations, the analyses include all of the supporting evidence that is used to build confidence in the calculations and the safety attributes of the repository system. Such evidence may include information from laboratory and field experiments, natural or human-induced analogs, sensitivity analyses, and other specialized analyses at a subsystem level.

For each risk insight, the baseline also provides a discussion of the uncertainties associated with the analyses and their interpretation. Uncertainties are inherent in any attempt to characterize, understand, and model the future behavior of a natural or engineered system. Therefore, it is important that a discussion of the staff current state of knowledge and understanding of the functioning of the repository system considers uncertainties. This includes data and model uncertainties, as well as uncertainties associated with the combined effects of scenarios. Generally, important uncertainties for estimating repository performance are addressed in the current analyses through a variety of approaches such as use of parameter ranges (e.g., range of retardation factors of radionuclides in alluvium) and conservative modeling approaches (e.g., assume southerly blowing wind direction for igneous activity). The discussion of uncertainties primarily provides insight where increased realism would reduce uncertainty in performance estimates. Because the approaches in the staff TPA computer code tend to be conservative when the uncertainty is large, improved realism is generally expected to reduce the current estimate of risks.

The staff plan to use the Risk Insights Baseline Report to help prioritize its prelicensing activities, focus staff resources, and support risk-informed project management and decisionmaking in the high-level waste program, during prelicensing activities and during the review of a potential license application for a Yucca Mountain repository. To support this intended application of the Risk Insights Baseline Report, the staff grouped the risk insights into three categories of relative significance (high, medium, and low) based on contribution to, or effect on, the waste isolation capabilities of the repository system.

Although individual risk insights are supported by quantitative analyses, classifying the risk insights by relative significance to waste isolation is more qualitative. Staff judgment was used, as needed, when combining information from different analyses. Significance is evaluated relative to the waste isolation capabilities of the repository system. Three criteria were considered in evaluating the significance of the risk insights:

- Effect on the integrity of waste packages;
- Effect on the release of radionuclides from the waste form and waste package; and
- Effect on the transport of radionuclides through the geosphere and biosphere.

In general, high significance is associated with features, events, and processes that could: (i) affect a large number of waste packages, (ii) significantly affect the release of radionuclides, or (iii) significantly affect the transport of radionuclides through the geosphere or biosphere. Medium significance is associated with a lesser effect on waste packages, radionuclide releases, or radionuclide transport, and low significance is associated with no or negligible effect.

3.3 Multiple Barriers

Integral to developing the risk insights is the concept of multiple barriers (i.e., both engineered and natural barriers) in geologic disposal of high-level waste. For example, the safety of geologic disposal is enhanced if the system includes: (i) a long-lived waste package that retains its integrity during the period of the highest thermal output of the waste when the waste-form behavior is most uncertain because of potentially high temperatures, (ii) slow release rates of radionuclides from the engineered barrier system once the waste packages are breached, and (iii) slow travel of released radionuclides from the engineered barrier system to the area where potential exposures might occur. Multiple barriers, as an element of a defense-in-depth approach, result in a robust repository system that is more tolerant of failures and external challenges (e.g., poor or highly degraded performance is necessary in multiple areas to have a significant effect on risk). The risk insights are developed within the multiple barrier context (i.e., understanding the significance to waste isolation of the long-lived waste package, release rates of radionuclides, and transport of radionuclides in the context of the effect on risk estimates).

4 RISK INSIGHTS RELATED TO POSTCLOSURE PERFORMANCE ASSESSMENT MODEL ABSTRACTIONS

The system description and the risk insights presented in this report are intended to assist the staff in their prelicensing interactions with the U.S. Department of Energy (DOE) and in reviewing any license application DOE may submit. The staff have not made any determinations regarding the technical conditions or the adequacy of a potential repository at Yucca Mountain at this time. If DOE submits a license application for a repository at Yucca Mountain, the staff will review the information provided by DOE, and make its determinations based on information available at that time.

4.1 Risk Insights on Geological Disposal

Geologic disposal has been internationally adopted as an appropriate method for ensuring protection of public health and safety for very long time periods (e.g., 10,000 years) because deep geologic disposal: (i) limits the potential for humans to come into direct contact with the waste; (ii) isolates the waste from a variety of natural, disruptive processes and events occurring on the surface of the earth; and (iii) limits the transport of radionuclides, after release to ground water, by the natural hydrological and chemical properties of geologic strata comprising a potential repository site. Additionally, it has been widely accepted that a geologic repository is to be comprised of multiple barriers as a means of providing defense-in-depth. The multiple barrier approach includes consideration of both natural barriers (e.g., hydrological properties of rock and soil units, geochemical retardation) and engineered, or human-induced, barriers (e.g., waste package, waste form) as a means to contain and isolate waste.

Understanding the potential risk of high-level waste begins by considering the radionuclides that comprise high-level waste, radionuclides that vary significantly with respect to inventory, radioactive half-life, and radiotoxicity. Table 4-1 provides information on the radionuclides relevant for evaluating releases in the ground water pathway (i.e., radionuclides or daughters of radionuclides with radioactive half-lives of at least 100 years, and sufficient inventory, such that a portion of these radionuclides might be transported to the compliance location via ground water). As shown in Table 4-1, the overall radionuclide activity at 1,000 years is dominated by relatively few radionuclides (i.e., Am-241, Pu-240, Pu-239, Am-243, and Tc-99). The potential risk of the overall radionuclide inventory is determined by weighting the inventory of each radionuclide by its dose conversion factor, a measure of a radionuclide radiotoxicity. The potential risk of the inventory is similarly dominated by the same radionuclides, with the exception of Tc-99, which is not as significant because of its low radiotoxicity (i.e., low dose conversion factor).

Although the entire inventory of high-level waste represents a significant risk, if the inventory were quickly released to the biosphere, current performance assessments of a potential repository at Yucca Mountain indicate that the majority (i.e., greater than 99 percent) of the inventory is isolated from humans during the regulatory period and beyond, because of the effectiveness of the engineered barriers and the attributes of the site (i.e., natural barriers). Evaluating the effectiveness of the multiple barriers requires an understanding of both the potential risk of the high-level waste inventory as well as the attributes of the design and site that affect the release and transport of each radionuclide. For example: (i) long-lived waste

Table 4-1. Inventory (Based on the Activity Present at 1,000 Years) and Weighted Inventory (Based on the Activity Present at 1,000 Years Weighted by the Dose Conversion Factor) of Radionuclides Evaluated in Ground Water Releases				
Radionuclide	Half-Life, Years	Inventory at 1,000 Years, Percent of Total	Ground Water Dose Conversion Factor, mrem/yr/pCi/l	Weighted Inventory at 1,000 years, Percent of Total
Am-241	430	54	4.9	56
Pu-240	6,500	25	4.7	25
Pu-239	24,000	18	4.7	18
Am-243	7,400	1.2	4.9	1.2
Tc-99	210,000	0.73	0.0022	0.00033
U-234	240,000	0.13	0.38	0.010
Ni-59	76,000	0.12	0.00032	0.0000083
C-14	5,700	0.065	0.0035	0.000048
Np-237	2,100,000	0.064	6.0	0.080
Nb-94	20,000	0.042	0.0096	0.000052
Cs-135	2,300,000	0.027	0.012	0.000065
Se-79	65,000	0.023	0.013	0.000063
U-238	4,500,000,000	0.016	0.35	0.0012
Cm-246	4,700	0.0032	4.9	0.0033
I-129	16,000,000	0.0018	0.43	0.00016
Th-230	77,000	0.0011	0.74	0.00017
Cl-36	300,000	0.00058	0.0061	0.00000075
Ra-226	1,600	0.00019	1.8	0.000074
Pb-210	22	0.00019	7.3	0.00030

packages are expected to retain their integrity during the period of the highest thermal output of the waste, when the waste-form behavior is most uncertain; (ii) radionuclides are expected to be released slowly from the engineered barrier system once the waste packages are breached; and (iii) radionuclides are expected to travel slowly from the engineered barrier system to the area where potential exposures might occur because of the sorptive properties of the surrounding rock. Thus, multiple barriers, as a defense-in-depth approach, result in a robust repository system that is more tolerant of failures and external challenges.

The risk insights for geologic disposal are developed by understanding the significance to waste isolation of the long-lived waste package, release rates of radionuclides, and transport of radionuclides, in the context of the effect on risk estimates. One approach for understanding and communicating the waste isolation capability of attributes of geologic disposal is to evaluate the releases of radionuclides at certain well-defined locations, such as from the waste package and geologic setting (the potential receptor location or compliance location). This helps characterize the behavior of specific barriers or subsystems of the overall repository. Figures 4-1 and 4-2 represent the effective activity released from the waste package and geologic setting, respectively. Effective activity is determined by weighting the activity for each radionuclide by its dose conversion factor, which allows the releases of radionuclides to be compared on a similar radiotoxicity basis. For the radionuclides shown in Figures 4-1 and 4-2, the majority of radionuclides that exit the waste package are not released from the geologic setting (i.e., at the compliance location) before 10,000 years. The radionuclides that tend to chemically sorb onto rock surfaces (e.g., plutonium, americium, and neptunium) are not estimated to arrive at the compliance location, whereas, radionuclides such as iodine and technetium, which are less likely to chemically sorb, do arrive at the compliance location. The releases of iodine and technetium are barely discernable in Figure 4-2; however, the release rates from the geologic setting are approximately three times smaller than the release rates from the waste package. These figures provide quantitative risk information regarding the magnitude of releases from the waste package, and the attenuation of these releases by the attributes of the geosphere, before they reach the compliance location.

Although the presentation of radionuclide release rates from specific subsystems is useful for understanding specific processes, this type of information does not readily convey the behavior of the spectrum of barriers of the repository system and the collective effectiveness for isolating waste. The staff have developed an approach for representing the waste isolation capabilities of specific attributes of the repository system in the context of the overall system, as a means to enhance understanding and risk insights. This approach represents the following three primary attributes for achieving waste isolation: (i) long-lived waste packages, (ii) slow release of radionuclides from the engineered barriers, and (iii) slow migration of radionuclides in the geosphere. These attributes promote waste isolation by delaying and/or reducing releases of radionuclides to the compliance location. Performance assessment calculations are used to evaluate the effectiveness of individual barriers to isolate waste. For example, delay times are calculated for barriers that principally act to delay the onset of releases or the movement of radionuclides (e.g., waste package lifetime, transport time to move through the geosphere), whereas release rates are calculated for barriers that limit, rather than delay, releases (e.g., solubility limits, limited water contact with waste, spent nuclear fuel degradation rates).

Table 4-2 provides this type of general perspective on the capabilities of the site and design attributes for isolating the radionuclides considered in the ground water pathway. The site and design attributes are divided into three categories affecting waste isolation: (i) delay for the

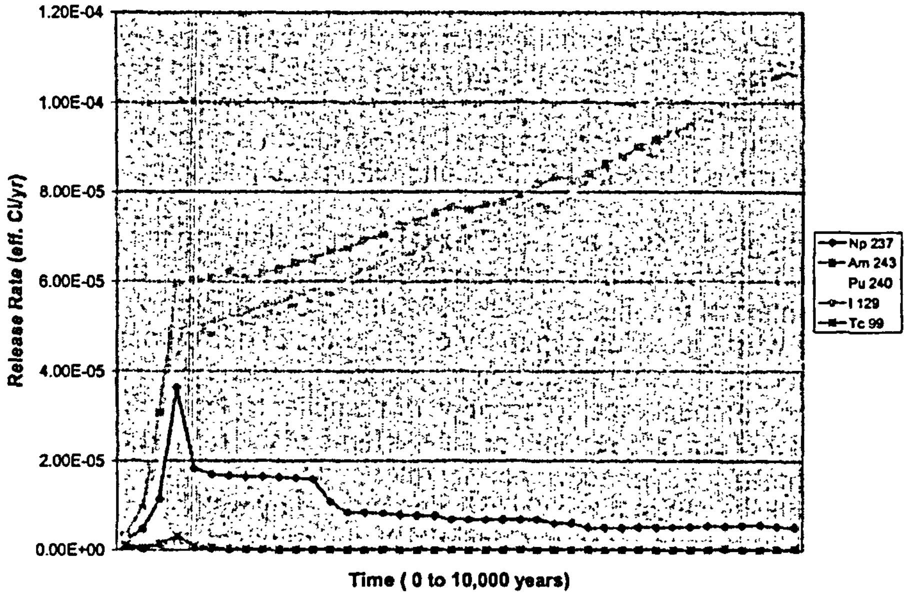


Figure 4-1. Effective Activity Released from the Waste Package.
(1 Ci/yr = 3.7 × 10^{10}Bq/yr)

Note: Effective Activity Determined by Weighting Release for Each Radionuclide by its Dose Conversion Factor.

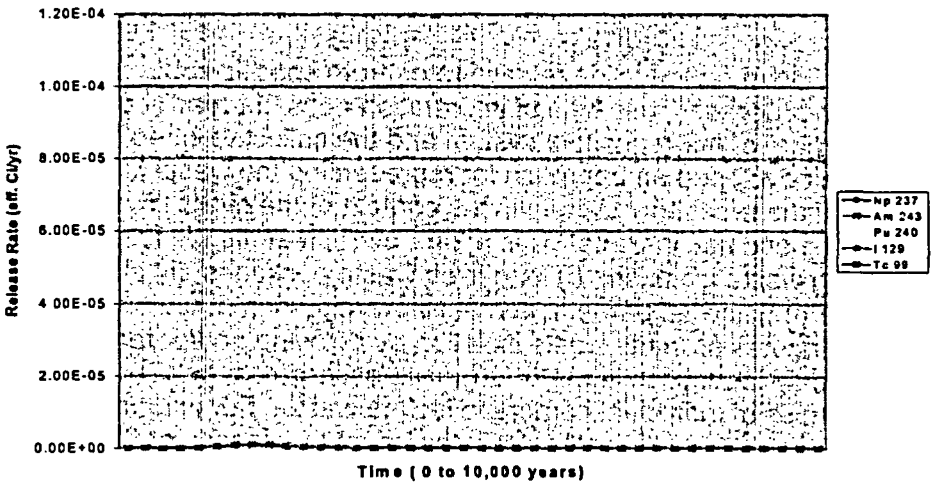


Figure 4-2. Effective Activity Released from the Geologic Setting.
(1 Ci/yr = 3.7 × 10^{10}Bq/yr)

Note: Effective Activity Determined by Weighting Release for Each Radionuclide by its Dose Conversion Factor.

Table 4-2. Representation of Effectiveness of the Attributes of Waste Isolation							
	Attributes of Waste Isolation						
	Onset of Release	Release Rate			Geosphere Transport		
Radionuclide	Waste Package	Waste Form	Solubility Limits	Solubility and Limited Water	Unsaturated Zone	Saturated Zone - Tuff	Saturated Zone - Alluvium
Am-241	DDD				DDD	DDD	DDD
Pu-240	DDD			L	DDD	DD	DDD
Pu-239	DDD			L	DDD	DD	DDD
Am-243	DDD			L	DDD	DD	DDD
Tc-99	DDD	LL			D	D	D
U-234	DDD			L	DDD	D	DDD
Ni-59)	DDD	LLL	L	LL	DDD	D	DDD
C-14	DDD	LLL			D	D	D
Np-237	DDD			L	DDD	D	DDD
Nb-94	DDD	LL	LLL	LLL	D	DD	DDD
Cs-135	DDD	LL			DDD	DDD	DDD
Se-79	DDD	LL			DD	D	DD
U-238	DDD	L	LLL	LLL	DDD	D	DDD
Cm-246	DDD	L			D	DD	DDD
I-129	DDD	LL			D	D	D
Th-230	DDD	LL	L	LL	DDD	DD	DDD
Cl-36	D	LL			D	D	D
Ra-226	DDD	LL		L	DDD	DD	DDD
Pb-210	DDD	LL	L	LL	DDD	DD	DDD

Notes: D denotes delay time of at least 10,000 years (DDD); 1,000 years (DD); and 100 years (D).

L denotes limit on release of 10,000 (LLL), 1,000 (LL) and 100 (L) times less than 0.15 mSv (15 mrem).

onset of initial release, (ii) release rates from the engineered barrier system (principally the waste package and waste form), and (iii) transport in the geosphere. The effectiveness of each barrier associated with the attributes of waste isolation is indicated by the letter D or L, which is used to represent three levels of effectiveness by the number of letters present.

When the design or site attribute delays the onset of release or transport in the geosphere, the level of effectiveness was determined according to delays of no less than 10,000 years (DDD), 1,000 years (DD), or 100 years (D). For the release rate, where the attribute of a barrier is not a delay but rather a limitation on the magnitude of the release, the level of effectiveness was determined by whether the magnitude of release, if instantly released to the biosphere, would result in a potential dose of 10,000 (LLL), 1,000 (LL), or 100 (L) times less than 0.15 mSv [15 mrem].

Table 4-2 offers a general explanation for the risk currently estimated for the proposed repository; namely, the variety and number of design and site attributes result in a very limited amount of the high-level waste inventory being transported by ground water to the compliance location. Additionally, from a defense-in-depth perspective, the importance of any one barrier is generally diminished as the number of relatively independent barriers increases. In other words, poor performance of one barrier does not cause a significant increase in the estimated risk; thus, confidence in the overall safety of the repository system is significantly enhanced when there are multiple and effective barriers.

The results presented in Table 4-2 are based primarily on the average behavior of the repository system and provide a useful general overview. However, this approach does not readily lend itself to addressing the uncertainties in estimating the behavior of the repository system. For example, there are uncertainties with mechanical damage of the waste package, and the effect of colloidal transport of radionuclides, that are not directly represented in Table 4 2. The technical details and uncertainties are the subject of the detailed risk insights provided in the remainder of this section.

Additionally, Table 4-2 addresses releases in the ground water pathway and does not address releases to the air pathway from a potential igneous event. Igneous activity has a potential for higher consequences than estimated for the ground water pathway. However, the risk is still estimated to be small from this scenario, because the probability for igneous activity is orders-of-magnitude below the probability for ground water releases. (Sections 4.3.10 and 4.3.11 provide more discussion on igneous activity.)

4.2 Current Understanding of the Postclosure Repository System

This section provides a summary of the staff current understanding of a postclosure repository system at Yucca Mountain. This understanding is based on the process-level and system-level technical information and performance assessment results that are currently available. The staff understanding continues to evolve as information becomes available through the prelicensing activities and interactions.

The system description provided in this section is presented in seven sections:

- Infiltration, percolation, and seepage into the repository
- Degradation of the engineered barrier system, including the waste form

- Radionuclide release from the engineered barrier system
- Flow and transport of radionuclides in the unsaturated zone below the repository
- Flow and transport of radionuclides in the saturated zone
- Biosphere and reasonably maximally exposed individual
- Igneous activity

4.2.1 Infiltration, Percolation, and Seepage

Yucca Mountain has a semiarid climate and currently receives an average of approximately 190 mm [7.5 in] of precipitation per year. Future climate is expected to evolve according to anticipated glacial cycles. Evidence suggests at the last full glacial maximum, average, annual precipitation may have been 1.5 to 2.5 times larger than current climatic conditions, whereas average annual temperatures may have been 5 to 10 °C [9 to 18 °F] cooler. Approximately 95 percent of the precipitation currently falling onto Yucca Mountain is estimated to be removed by runoff, evaporation, and plant transpiration. The remainder infiltrates through the near-surface environment in a heterogeneous spatial pattern and generally percolates vertically downward through the unsaturated tuff toward the proposed repository horizon. However, large-scale features (e.g., fault zones, hydraulic conductivity contrasts at the interfaces between tuff layers) and small-scale features (e.g., variability of hydraulic conductivity within a tuff layer) may complicate the flow paths and cause deep percolation to redistribute spatially. Although surface infiltration is highly episodic, unsaturated flow reaching the repository is generally assumed to be steady and continuous as a result of the damping effect of the permeable and porous rock matrix of the overlying Paintbrush tuff nonwelded horizons.

Deep percolation rates above the repository directly influence water seepage into the drifts and the amount of water entering breached waste packages, which, in turn, facilitates the release of radionuclides from the engineered barrier system into the underlying the repository horizon. The ambient seepage model suggests that only a small fraction of the percolating water will enter the drift by way of dripping from the drift ceiling because of capillary diversion. The effect of the repository thermal pulse also affects seepage into drifts. When ventilation is stopped at the time of closure, the temperature of the wallrock will quickly rise. The quantity of percolating water that will reach the engineered barrier system will be significantly reduced as decaying radioactive waste heats surrounding rock above boiling temperature during the first few thousand years, thereby driving liquid water away. Water evaporated by repository heat will move toward cooler areas where it will condense and may flow back as liquid water toward the drifts (refluxing). A combination of ambient percolating and refluxed water may penetrate back along preferential flow paths, into the thermally perturbed rock that has temperatures above boiling, and seep into the drifts. Not all areas of the drifts will experience above-boiling conditions. Edge-cooling effects allow water to be present in the wallrock throughout the performance period in drift areas near the periphery of the repository.

At early times following repository closure, the drifts likely will remain open and could be effective at diverting water (if water is present) around the drifts by capillary retention in the rock matrix and fracture networks. The drifts, however, may degrade over time and fill with rockfall rubble from the tunnel walls. As a result, an increased fraction of the percolating water may contact engineered barrier components by way of seepage through rock rubble. Drift ceiling irregularities, such as small asperities and lithophysae, may give way to larger irregularities as drift degradation occurs, potentially reducing the amount of water diversion caused by capillary retention.

Film flow along open drift walls is another mechanism for diverting water away from the drip shield and waste package. The formation of a rubble pile in contact with waste packages or shields could provide an additional mechanism for percolating water to come into contact with engineered barriers. During the reflux period, or as the thermal pulse is dissipating, water seepage into the drifts (including along-wall seepage) contributes to the vapor pressure in the drifts and, thus, elevates the relative humidity of air surrounding the engineered components. Movement of water vapor into cooler areas of drifts could produce condensation that results in additional or focused dripping. Water dripping onto engineered components during the thermal period would evaporate and leave a residue, which, along with any dust present, may affect the chemistry of any liquid water that is later present on those engineered components.

The chemistry of water contacting engineered components can strongly affect degradation of those components through aqueous corrosion processes. Estimating the evolution of the near-field environment is complex because of coupled thermal-hydrological-mechanical-chemical processes and changes in the emplacement drift configuration caused by the collapse and rubbling of overlying rocks. Water and gas compositions will be influenced by chemical reactions within the unsaturated fractured rock. Local changes in water and gas chemistry may result from interactions with engineered materials, corrosion products, or both. The presence of rubbled rock will cause higher temperatures within the near-field environment and engineered barrier components. Major processes affecting the evolution of the near-field environment include evaporative processes and mineral dissolution and precipitation, as well as aqueous- and gaseous-phase transport and chemical reactions.

Deep percolation rate also directly influences the transport of radionuclides through the unsaturated zone to the saturated zone. Transport of radionuclides through the unsaturated zone mainly occurs in fractures within the welded units and in the matrix within the nonwelded units. Sorption during matrix flow through vitric and devitrified nonwelded tuff horizons can significantly delay transport of radionuclides to the water table.

4.2.2 Degradation of the Engineered Barrier System

The current DOE design for the engineered components calls for 63,000 metric tons [69,450 tons] of commercial spent nuclear fuel, as well as 7,000 metric tons [7,720 tons] of DOE spent nuclear fuel and solidified high-level waste, to be loaded into waste packages before placement in tunnels cut into the unsaturated tuff approximately 350 m [1,150 ft] below the surface. The commercial spent nuclear fuel generally is in the form of ceramic-like pellets of irradiated uranium-dioxide (UO_2) clad in corrosion-resistant Zircaloy tubes, approximately 0.6 to 0.9 mm [0.024 to 0.035 in] thick. The current waste package design for commercial spent nuclear fuel consists of a 20-mm [0.8-in]-thick Alloy 22 outer container surrounding a 50-mm [2.0-in]-thick Type 316 nuclear-grade stainless steel inner container, to provide structural strength during preclosure operations. The staff understanding is that after the spent nuclear fuel or other high-level waste is loaded, lids will be welded onto the waste packages before they are placed them in the repository; and before permanent closure of the repository, an inverted U-shaped metal drip shield, approximately 15 mm [0.6 in] thick, fabricated from Titanium Grade 7, will be installed over the emplaced waste packages. The bulk of the 7,000 metric tons [7,720 tons] of DOE waste will be in the form of borosilicate glass, poured into stainless steel canisters, and encased in waste packages of similar design to that used for commercial spent nuclear fuel.

The drip shield and waste package can protect the waste form from dripping water while they remain intact, thereby limiting both the timing and magnitude of radionuclide release. The drip shield may also limit the exposure of the waste package to aggressive chemical environments resulting from thermal-hydrological-chemical processes, as well as mitigate mechanical damage to the waste package from falling rocks. These engineered barriers may be compromised by various degradation processes, including corrosion and mechanical damage. The lifetime of the engineered barriers can be influenced by the environmental conditions to which they are exposed; rockfall from drift degradation or seismicity; faulting; or ascending magma from volcanic activity.

The flow of water into a breached waste package will depend on the location and cross-sectional area of the breaches through the waste package. Four simplified categories of failure can facilitate understanding of the performance of the waste package in limiting radiological releases: (i) a limited number of waste packages with small cracks or perforations, (ii) a small number of waste packages with large breaches, (iii) a large number of waste packages with small cracks or perforations, and (iv) a large number of waste packages with large breaches. A limited number of waste package breaches, either large or small, may result from aggressive and highly localized environments, isolated rockfall from drift degradation or seismic events, faulting, and manufacturing defects. Stress corrosion cracking is the main process by which frequent but small cracking of waste packages could occur. The likelihood of stress corrosion cracking can be promoted by aggressive environmental conditions combined with residual stresses resulting from fabrication and closure operations or applied stresses as a consequence of extensive rockfall from widespread drift degradation or seismicity, as well as accidental internal overpressure. Large widespread failures of the waste packages may result from accelerated, localized corrosion because of pervasive aggressive environments or extensive rockfall from large-scale drift degradation or very large seismic events. In this context, the fabrication and closure processes may result in microstructural changes of the container material that can affect significantly the resistance to localized corrosion and mechanical damage, as well as the mode and extent of the resulting failure.

4.2.3 Radionuclide Release from the Engineered Barrier System

The engineered barrier system consists of the waste form, cladding (for spent nuclear fuel) pour container (for vitrified waste), waste package, invert, and drift. Once radionuclides released from the waste package leave the boundary of the drift, they are considered to be in the unsaturated zone, although components of the engineered barrier system, such as the invert, can also be considered to be unsaturated.

The waste form may begin to degrade once the waste package integrity is breached so that air, water vapor, and liquid water can come into contact with it. Although the waste form can degrade in the presence of air and water vapor, the release of most radionuclides of concern from the waste package and through the invert will only occur when liquid water is present to facilitate transport by means of advection (i.e., transport with the flow of water) and diffusion (i.e., transport from areas of high concentration to low concentration by random motion at the molecular level).

Spent nuclear fuel would be the main contributor to the radioactive inventory of the repository. This waste will be in the form of small UO_2 pellets placed in long tubes known as cladding. Most fuel will be clad in zirconium alloy (e.g., Zircaloy), which is highly corrosion-resistant, and will prevent the spent nuclear fuel from coming into contact with air and water as long as it remains intact. A small fraction of cladding will already be failed on placement in the waste packages. In addition, some reactor fuel was clad with aluminum or stainless steel, which has inferior or less predictable corrosion resistance than zirconium. Factors affecting the long-term integrity of the Zircaloy cladding include: (i) localized corrosion and stress corrosion cracking of cladding that is exposed to in-package water; (ii) hydride reorientation and cracking; (iii) creep failure; and (iv) mechanical stresses caused by seismic shaking, rockfall, faulting, and handling during shipment and loading. Under some conditions, small failures of the clad fuel-tubes will allow water and air to cause swelling of the exposed fuel pellets, which can lead to rapid unzipping of the cladding in that tube. Swelling of fuel pellets as well as hydride cracking and creep failure are processes that are likely to have a more pronounced effect on high burnup fuel.

In the case of fuel reprocessing, vitrified glass-like waste will be encased in stainless steel pour canisters before placement in the waste packages. The pour canisters, like cladding, will provide protection beyond what is available from the waste packages alone.

As the waste forms degrade and come into contact with liquid water, radionuclides will be released in the form of dissolved species, particulates, and colloids. The process of radionuclide release from the waste form to liquid water is generally known as dissolution, although it does not necessarily involve dissolved materials only. The water-borne radionuclides may then escape the waste package by advection and diffusion. Dissolution of radionuclides; formation of, or attachment to, mobile colloids; and incorporation into secondary minerals, formed from the degradation products of UO_2, may influence the transport rates and the amounts of radionuclides that are available for transport from the waste package. A small percentage of the waste consists of radionuclides that are very soluble and are expected to be released to the water quickly. The bulk of the radionuclide inventory consists of radionuclides that will be released from the waste form no faster than their solubility limit would allow. Therefore they will not be released from the waste package any faster than the flow of water at the solubility limit would allow. Some solubility-limited radionuclides (e.g., plutonium), particularly those associated with the vitrified high-level waste forms, can form colloids or attach themselves to naturally occurring or human-induced, nonradioactive colloids (e.g., iron oxyhydroxides from corrosion of steel). Association of radionuclides with colloids can increase the effective concentration of the water above the solubility limit of the radionuclide itself. However, colloids behave differently from dissolved constituents, and may be inhibited from transport from the waste package by attaching to internal surfaces (Wilson and Bruton, 1989). In addition, diffusion of colloids is significantly lower than truly dissolved materials because of their much greater size.

Once radionuclides exit the waste package, they must migrate from the waste package through the underlying invert to be released to the unsaturated zone. The current DOE design for the invert consists of a carbon steel support frame backfilled with compacted crushed tuff, up to about 0.5 m [20 in] in thickness, through which the radionuclides must migrate by advection and diffusion to the unsaturated zone. The porous nature of the invert material may delay transport of radionuclides; however, it is necessary to assess the porous flow and sorption properties of the invert material to determine the effectiveness of this barrier.

4.2.4 Flow and Transport of Radionuclides in the Unsaturated Zone below the Repository

The potential repository at Yucca Mountain will be underlain by approximately 300 m [1,000 ft] of unsaturated volcanic rock layers above the water table. The series of unsaturated layers below the repository is comprised of tuffaceous rock exhibiting varying degrees of welding, which affect both the fracture density and matrix conductivity. Densely welded tuffs are brittle and typically develop interconnected fractures, which may allow water to divert around areas of lower conductivity, whereas nonwelded tuffs exhibit low fracture density and higher matrix conductivity.

Dissolved and suspended radionuclides released from the engineered components would be transported by water flowing through the unsaturated tuffs to the water table. Water typically moves vertically downward through the unsaturated tuffs below the repository through a combination of fracture and matrix flow. However, large-scale (e.g., fault zones or hydraulic conductivity contrasts at the interfaces between tuff layers) and small-scale (e.g., the variability of hydraulic conductivity within a tuff layer) features may add complexity to the flow paths. Water tends to move slowly {e.g., currently estimated at 1 m/yr [3.3 ft/yr] and slower} through unsaturated tuff layers when flow occurs predominantly within the rock matrix. As the water flux exceeds the matrix saturated hydraulic conductivity, water will flow through fractures. Water tends to flow more swiftly (e.g., an estimated tens of meters per year and faster) through tuff layers when flow is predominantly through fractures. Current understanding suggests the Calico Hills nonwelded vitric layer is the only unsaturated tuff layer below the repository with sufficient matrix saturated hydraulic conductivity to allow water to flow predominantly within the rock matrix. The thickness of the Calico Hills nonwelded vitric unit layer is spatially uncertain and may pinch-out, resulting in no Calico Hills nonwelded vitric unit layer beneath portions of the repository.

In addition to the advective transport process described above, transport of radionuclides in the unsaturated zone would be affected by molecular diffusion between fractures and the rock matrix, mechanical dispersion, and physico-chemical processes such as sorption and precipitation. Sorption of radionuclides onto mineral surfaces can be a significant retardation mechanism when radionuclides move through the rock matrix because of the large surface area associated with the rock pores; conversely, fracture pathways have relatively limited surface area and thus exhibit limited if any sorption effects. Dissolved radionuclides transported by water within fractures may diffuse from the water within the fractures into the slow-moving water within the rock matrix, thereby limiting the transport of radionuclides in fractures. However, radionuclides transported by fracture flow could have limited time to diffuse from the fractures into the rock matrix because of the high velocity of water in the fractures (i.e., tens of meters per year).

Transport of radionuclides in colloidal form can limit the effectiveness of sorption processes; however, it can be expected that many colloids will be filtered out over long transport paths in geologic systems.

4.2.5 Flow and Transport of Radionuclides in the Saturated Zone

The saturated zone in the vicinity of Yucca Mountain consists of a series of alternating volcanic aquifers and confining units above the regional carbonate aquifer. The volcanic rocks generally thin toward the south and become interspersed with valley fill aquifers to the south and southeast of Yucca Mountain. The valley fill aquifer is composed of alluvium derived from Fortymile Wash, and colluvium from the adjacent highlands to the east and west, as well as lacustrine deposits formed near the southern end of Jackass Flats. The effective porosities of the fractured rock are expected to be lower than the valley fill alluvium, resulting in higher ground water velocities in the fractured tuffaceous rocks.

Dissolved or suspended radionuclides released from the engineered components would be transported by water generally moving vertically downward through the unsaturated tuffs to the saturated zone. Ground water flow, in the saturated zone immediately below the repository, is driven by a small hydraulic gradient, approximately 0.0001, and is directed to the east-southeast through the eastward dipping upper volcanic confining unit and upper volcanic aquifer. Approximately 2 to 4 km [1.2 to 2.5 mi] east-southeast of Yucca Mountain, the hydraulic gradient is larger, approximately 0.001, and ground water is reoriented south through the tuff aquifer. South of Yucca Mountain, approximately 10 to 20 km [6 to 12 mi], radionuclides would enter the highly porous valley fill aquifer.

The transport of radionuclides in the saturated zone would be affected by molecular diffusion between fractures and the rock matrix, mechanical dispersion, as well as physico-chemical processes associated with sorption of radionuclides onto mineral surfaces. Many radionuclides are retarded when moving through the porous alluvium, because of the large surface area associated with porous media. Certain radionuclides, however, such as I-129 and Tc-99, are generally not retarded in geologic systems. Conversely, the fracture paths in the volcanic rock of the saturated zone are characterized by relatively limited surface areas and thus exhibit limited if any sorption effects within the fractures. However, dissolved radionuclides transported by water within fractures may diffuse from the water within the fractures into the slow-moving water within the rock matrix, thereby limiting the transport of radionuclides in fractures. The flow path in the saturated zone is more than 10 times longer than the flow path in the unsaturated zone (i.e., kilometers versus hundreds of meters). Therefore, significantly more time is available for radionuclides to diffuse from the fractures into the rock matrix of the saturated zone.

Transport of radionuclides in colloidal form or attached to colloids can limit the effectiveness of sorption processes; however, it can be expected that many colloids will be filtered out over long transport paths in geologic systems.

4.2.6 The Biosphere and the Reasonably Maximally Exposed Individual

Radionuclides reaching the accessible environment enter the biosphere. The biosphere is the environment that the reasonably maximally exposed individual inhabits. Characteristics of the biosphere and the reasonably maximally exposed individual are based on current human behavior and environmental conditions in the Yucca Mountain region.

Ground water transporting released radionuclides to the biosphere may be used for drinking and agricultural purposes typical of current Amargosa Valley practices. Radionuclides entering the biosphere via ground water may reach the reasonably maximally exposed individual through some combination of three likely pathways: direct exposure from surface or suspended contamination; inhalation of suspended dust that has been contaminated; or ingestion of contaminated water, plants, or animal products. In the igneous activity release scenario, radionuclides are assumed to transport through the air and over the land surface by remobilization processes to the reasonably maximally exposed individual location. Radionuclides entering the biosphere from an igneous event may reach the reasonably maximally exposed individual through pathways such as direct exposure from surface or suspended contamination, inhalation of suspended dust that has been contaminated, or ingestion of contaminated plants or animal products. Dose conversion factors from Federal guidance are used to convert exposures from contaminated materials to doses for the reasonably maximally exposed individual.

4.2.7 Igneous Activity

Basaltic igneous activity has occurred for over 10 million years throughout the Yucca Mountain region. The probability of future igneous activity occurring directly at the proposed repository site is presently estimated at between 10^{-7} and 10^{-8} per year; however, the discovery of additional buried anomalies thought to represent basalt could change this value. Igneous activity can affect the repository through direct release or indirect release of radionuclides during extrusive or intrusive events, respectively. Although the likelihood of future igneous activity is very small, the potential radiological doses are large enough to make a significant contribution to postclosure risk in current performance calculations.

If rising magma intersects repository drifts, the magma could flow into drift openings (intrusive event) and possibly continue an upward ascent to the surface (extrusive event). During the extrusive phase of an igneous event, magma reaches the surface and forms a volcanic eruption. Generally, a magma conduit to the surface gradually widens during an eruption. If this were to occur at Yucca Mountain, waste packages intersected by flowing magma in the conduit could be expected to break apart and allow the erupting magma to entrain radionuclides. These radionuclides would be transported downwind in the volcanic plume and deposited on the ground surface. Through time, wind and water could erode and redeposit this possibly contaminated ash. Potential radiological dose from extrusive igneous events results primarily from inhalation of contaminated ash.

During the intrusive phase of an igneous event, rising magma could flow into open or partially backfilled drifts in response to the pressure gradient between the confined magma and drift voids. The thermal, mechanical, and chemical environment in magma would likely damage the waste packages and may alter the high-level waste form. After the magma cools, radionuclides would then be available for potential release from damaged waste packages through the ground water pathway.

4.3 Baseline of Risk Insights

This section discusses the risk insights that have been identified to date by the U.S. Nuclear Regulatory Commission (NRC) staff, related to performance of the potential repository system during the postclosure regulatory period.

The risk insights presented in this section are organized by 14 performance assessment model abstractions, also referred to as integrated subissues (Figure 4-3). This organizational format has also been used in two other primary NRC documents related to the high-level waste program, NUREG–1804 (NRC, 2003) and NUREG–1762 (NRC, 2002).

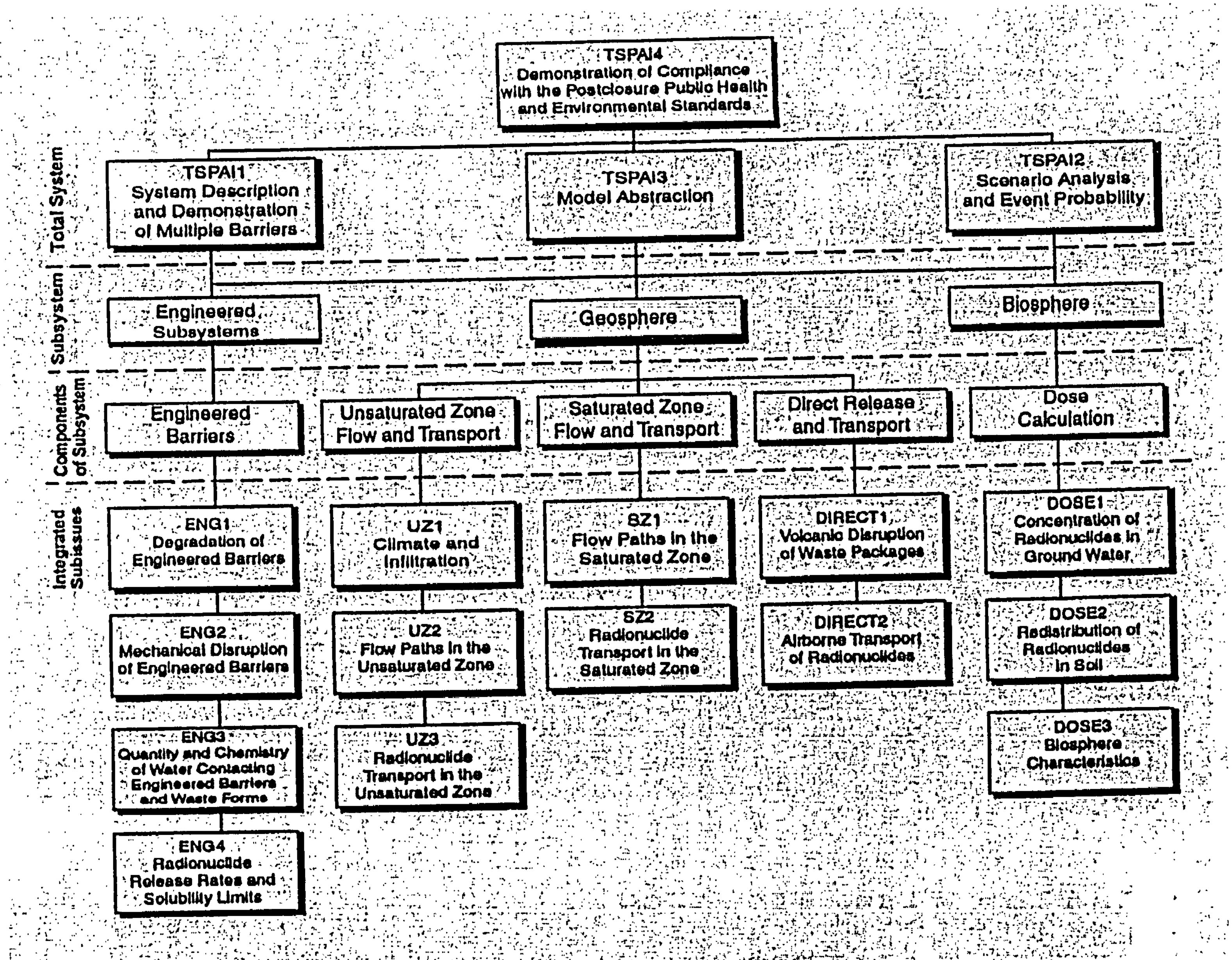


Figure 4-3. Components of Performance Assessment Review (NRC, 2003, Figure A1-5)

For each risk insight, this section provides a short title for the insight as well as a longer, more descriptive statement of the technical issue addressed by the insight. A ranking of the significance of the insight to waste isolation is provided. These rankings, which are based on risk insights, provide a transparent view of the NRC current understanding of features, events, and processes associated with a potential repository at Yucca Mountain. Such a representation of the risk insights benefits the NRC high-level waste program by providing: (i) NRC staff with information to risk-inform its review of a potential DOE license application, and (ii) other stakeholders (e.g., State of Nevada, DOE, Advisory Committee on Nuclear Waste) with information about the focus of the NRC interactions with DOE and review of a potential license application. For each risk insight, this section also provides a discussion of the technical basis for the insight, focusing as much as possible on supporting quantitative analyses as well as associated uncertainties.

Table 4-3 provides a summary of the risk insights, organized by the 14 integrated subissues, along with their significance rankings. They are presented in the table in the order in which they are presented in the following sections.

4.3.1 Degradation of Engineered Barriers (ENG1)

Risk Insights:	
Persistence of a Passive Film	High Significance
Waste Package Failure Mode	Medium Significance
Drip Shield Integrity	Medium Significance
Stress Corrosion Cracking	Medium Significance
Juvenile Failures of the Waste Package	Low Significance

4.3.1.1 Discussion of the Risk Insights

Persistence of a Passive Film: High Significance to Waste Isolation

The persistence of a passive film on the surface of the waste package is anticipated to result in very low corrosion rates of the waste package. High temperatures and aggressive water chemistry conditions have a potentially detrimental effect on the stability of the passive film and may accelerate corrosion over extended surface areas.

Discussion

Under environmental conditions where a stable oxide film is maintained, corrosion is uniform and occurs at a slow rate. Typical values for the passive corrosion rate of Titanium Grade 7 and Alloy 22 are in the range of 10^{-5} to 10^{-3} mm/yr [10^{-7} to 10^{-5} in/yr] (Brossia, et al., 2001; Pensado, et al., 2002). Passive corrosion rates are generally independent of pH, redox potential, and solution composition, but exhibit an Arrhenius dependence on temperature (e.g., faster corrosion rates at higher temperatures).

Table 4-3. Summary of Risk Insights Rankings: Significance to Waste Isolation	
ENG1 - Degradation of Engineered Barriers	
Persistence of a Passive Film	High Significance
Waste Package Failure	Medium Significance
Drip Shield	Medium Significance
Stress Corrosion	Medium Significance
Juvenile Failures of the Waste	Low Significance
ENG2 - Mechanical Disruption of Engineered Barriers	
Effects of Accumulated Rockfall on Engineered Barriers	Medium Significance
Dynamic Effects of Rockfall on Engineered Barriers	Low Significance
Effects of Seismic Loading on Engineered Barriers	Medium Significance
Effects of Faulting on Engineered Barriers	Low Significance
ENG3 - Quantity and Chemistry of Water Contacting Engineered Barriers and Waste Forms	
Chemistry of Seepage Water	High Significance
ENG4 - Radionuclide Release Rates and Solubility Limits	
Waste Form Degradation Rate	Medium Significance
Cladding Degradation	Medium Significance
Solubility limits	Medium Significance
Mode of Release from Waste Package	Low Significance
Effect of Colloids on Waste Package Releases	Medium Significance
Invert Flow and Transport	Low Significance
Criticality	Low Significance
UZ1 - Climate and Infiltration	
Present-day Net Infiltration Rate	Medium Significance
Long-term Climatic Change	Medium Significance
UZ2 - Flow Paths in the Unsaturated Zone	
Seepage	High Significance
Hydrologic Properties of the Unsaturated	Medium Significance
Transient Percolation	Low Significance
UZ3 - Radionuclide Transport in the Unsaturated Zone	
Retardation in the Calico Hills non-welded vitric unit	Medium Significance
Matrix Diffusion in the Unsaturated	Medium Significance
Effect of Colloids on Transport in the Unsaturated Zone	Medium Significance
SZ1 - Flow Paths in the Saturated Zone	
Saturated Alluvium Transport Distance	Medium Significance
SZ2 - Radionuclide Transport in the Saturated Zone	
Retardation in the Saturated Alluvium	High Significance
Matrix Diffusion in the Saturated Zone	Medium Significance
Effect of colloids on Transport in the Saturated Zone	Medium Significance
DIRECT1 - Volcanic Disruption of Waste Packages	
Probability of Igneous Activity	High Significance
Number of Waste Packages Affected by Eruption	High Significance
Number of Waste Packages Damaged by Intrusion	Medium Significance
DIRECT2 - Airborne Transport of Radionuclides	
Volume of Ash Produced by an Eruption	Medium Significance
Remobilization of Ash Deposits	Medium Significance
Inhalation of Resuspended Volcanic Ash	High Significance
Wind Vectors During an Eruption	Medium Significance

Table 4-3. Summary of Risk Insights Rankings: Significance to Waste Isolation (continued)	
DOSE1 - Concentration of Radionuclides in Ground Water Well-pumping Model	Low Significance
DOSE2 - Redistribution of Radionuclides in Soil Redistribution of Radionuclides in Soil	Low Significance
DOSE3 - Biosphere Characteristics Characterization of the Biosphere	Low Significance

Figure 4-4 shows the calculated dose assuming that: (i) in the basecase, passive conditions prevail for all waste packages; and (ii) passive conditions are not maintained for 25 percent of the waste packages. In this latter case, the expected dose approaches 0.01 mSv/yr [1 mrem/yr] after 10,000 years. As a result of the low corrosion rates under passive conditions (basecase), the first waste package failure from uniform corrosion is estimated to occur after the 10,000-year performance period. Doses that occur before 10,000 years in the basecase estimate are the result of juvenile waste package failure. Assuming a uniform corrosion rate in the range from 5.0×10^{-5} to 5.4×10^{-4} mm/yr [2.0×10^{-6} to 2.1×10^{-5} in/yr], initial waste package failures from corrosion occur after 37,000 years and all waste packages fail after 403,000 years. The absence of passivity is assumed to result in uniform corrosion rates ranging from 5.0×10^{-3} to 5.4×10^{-2} mm/yr [2.0×10^{-4} to 2.1×10^{-3} in/yr]. Failure times for waste packages in the absence of a protective, stable passive film are estimated to range from approximately 400 to 4,000 years.

Uncertainties

The corrosion rate of the alloys proposed for the engineered barrier system, such as Alloy 22 and titanium alloys, are controlled by the presence of a thin, protective oxide film that restricts metal dissolution. The stability of oxide films on passive alloys is dependent on the material and exposure conditions. Loss of passivity can lead to corrosion rates that are orders of magnitude greater than those measured under passive conditions. For chromium-containing alloys such as Alloy 22, loss of passivity (depassivation) can occur in aggressive solutions characterized by low pH and high chloride concentrations, especially at high temperatures. See Section 4.3.3 for a discussion of the likelihood of such conditions. Chromium-containing alloys exhibit transpassive dissolution at high anodic potentials, also resulting in high corrosion rates. Other processes, such as anodic segregation of sulfur or preferential dissolution of alloying elements, may also disrupt passivity. Passive films on titanium alloys are very stable in chloride solutions, but are strongly affected by the presence of fluoride, which significantly enhances the uniform corrosion rate (Brossia, et al., 2001). As discussed in Section 4.3.3, there are uncertainties associated with the amount and concentration of fluoride in the water seeping into the drift.

Minor increases in fluoride concentration in pore water may have a significant effect on corrosion rate.

Waste Package Failure Mode: Medium Significance to Waste Isolation

The failure mode of the waste package (uniform corrosion, localized corrosion, or stress corrosion cracking) and its morphology (e.g., pits, cracks, or large corrosion holes or patches) is important for determining the amount of water that can enter the waste package.

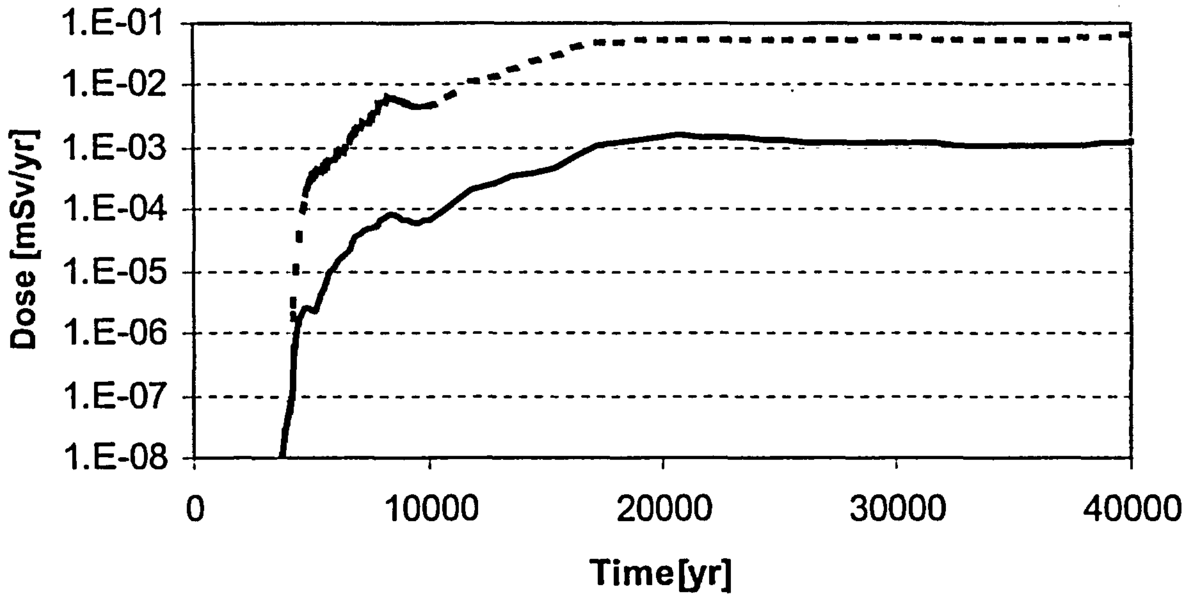


Figure 4-4. Dose Calculations as a Function of Waste Package Corrosion Rate. In the Basecase (TPA Version 4.1j Code) (Continuous Line), all Waste Packages Are Assumed to Undergo Passive Dissolution. Assuming Enhanced General Corrosion Rate for 25 Percent of the Waste Packages (Broken Line) Results in an Increase in the Calculated Dose.

Discussion

Different corrosion mechanisms create different types of failures (openings) in the surfaces of the engineered system. The amount of water that will enter a waste package and the amount of waste that will be transported out of a waste package will be influenced by the size of the openings. Intact surfaces will divert water away from the waste. The failure modes and morphology only have significant influence on the risk estimate when the openings are of limited surface area and frequency or when the waterflow rates are very small. The degree of pessimism introduced into the analyses can reduce the effectiveness of geometrical considerations to limit the release of radionuclides. For diffusional releases, the size of the openings at which there is no longer a significant limitation on mass transport will be influenced by assumptions for boundary conditions and flow paths before radionuclides arrive at the opening and after they exit the opening. Current understanding indicates that stress corrosion cracks and pits that would form from localized corrosion will likely be small in cross-sectional area such that capillary forces may strongly limit the advective transport of water and radionuclides through such openings.

Alloy 22 was selected as the waste package outer container material to mitigate degradation and failure that can result from stress corrosion cracking, hydrogen embrittlement, localized corrosion, and accelerated uniform corrosion as a consequence of loss of passivity (CRWMS M&O, 2000a). Under conditions where the passive film can be maintained, failure of the waste package by corrosion-only processes is unlikely within the 10,000-year compliance period. Although highly resistant to various modes of corrosion, Alloy 22 is susceptible to localized corrosion, stress corrosion cracking, and hydrogen embrittlement.

Crevice corrosion of Alloy 22 can occur if aggressive solutions are in contact with the waste package and the corrosion potential exceeds the critical potential (i.e., the repassivation potential) for localized corrosion (Brossia, et al., 2001; Dunn, et al., 2003). In addition to the nature of the metal or alloy, the corrosion potential is mainly dependent on temperature and solution pH, whereas the repassivation potential for localized corrosion is dependent on temperature, the concentrations of aggressive and inhibiting species, and the microstructure of the material. Figure 4-5 shows the repassivation potential for Alloy 22 as a function of material condition and chloride concentration and the corrosion potential as a function of pH (Dunn, et al., 2003). In concentrated chloride solutions with a low pH, localized corrosion can be initiated when the corrosion potential exceeds the repassivation potential for localized corrosion. Localized corrosion is not expected in solutions with low chloride concentrations at neutral or alkaline pH, because the corrosion potential is below the repassivation potential. The localized corrosion susceptibility is also dependent on the relative concentrations of inhibiting and aggressive species. No localized corrosion will occur if a sufficient concentration of inhibiting species is present in the water contacting the waste package.

Figure 4-6 shows the expected dose for the basecase and conditions where 10 percent of the waste packages are exposed to aggressive environmental conditions that promote localized corrosion. In the latter case, the peak expected dose is on the order of 0.001 mSv/yr [0.1 mrem/yr] during the first 10,000 years. The calculations shown in Figure 4-6 assume a limited amount of water can enter the waste package after corrosion penetrates the Alloy 22 outer container, which accounts for failure of the waste package from all corrosion processes.

Failure of the engineered barrier system components by uniform corrosion may result in large openings in the waste package. In contrast, pitting and crevice corrosion will likely result in small localized penetrations of the waste package. Stress corrosion cracks may also have a small aperture that will limit radionuclide release. The effects of localized penetrations of the waste package may be influenced by the combined effects of mechanical loads that are likely to occur as a consequence of rockfall, drift degradation, and seismic events. Mechanical loading of waste packages that are degraded as a consequence of uniform or localized corrosion, stress corrosion cracking, or hydrogen embrittlement may increase the size of the failure openings detrimentally affecting overall system performance.

<u>Uncertainties</u>

The amount of water that will enter a waste package and the amount of waste that will be transported out of a waste package will be influenced by the size of the openings. Release of radionuclides, in particular via diffusive mechanisms, will correlate with the failed surface area. Degradation modes that may lead to failure of the engineered barrier system and allow release of radionuclides include corrosion processes such as uniform and localized corrosion, stress corrosion cracking, and hydrogen embrittlement and mechanical interactions as a result of disruptive events. The location, size, and orientation of failure openings will be influenced by

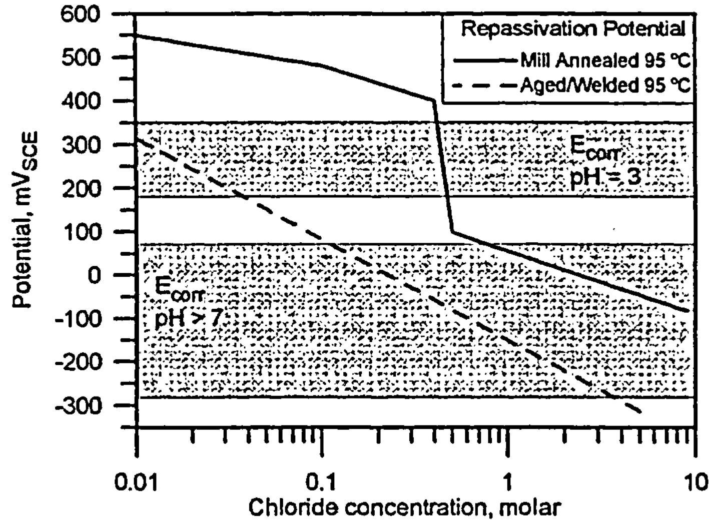


Figure 4-5. Repassivation Potential for Crevice Corrosion for Mill-Annealed and Thermally Aged or Welded Alloy 22 as a Function of Chloride Concentration at 95 °C [203 °F]. Range of Corrosion Potentials as a Function of pH are Shown as Shaded Banks. (Dunn, et al., 2003)

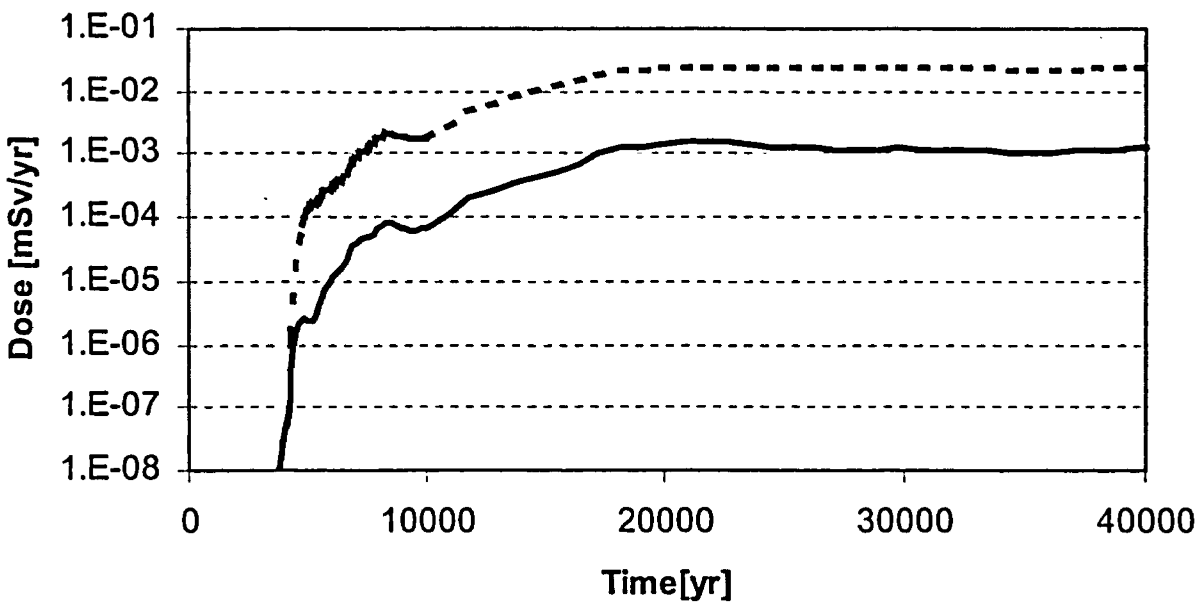


Figure 4-6. Effect of Waste Package Corrosion Mode on Calculated Dose. All Waste Packages are Assumed to Undergo Passive Dissolution in the Basecase (Cotninuous Line). Assuming 10 Percent of the Waste Packages Are Exposed to Aggressive Sol.utions that Promote Localized Corrosion Increases the Calculated Dose (Broken Line).

corrosion processes and mechanical interactions. However, there are uncertainties related to the specific characteristics of these openings, depending on the area of contact with water, the presence of deposits on the waste package surface, and the action and nature of the applied loads.

Drip-Shield Integrity: Medium Significance to Waste Isolation

The integrity of the drip shield will influence the quantity and chemistry of the water that can develop on the waste package and the potential effects on corrosion modes and rates.

<u>Discussion</u>

The quantity and chemistry of the water contacting the waste package and the drip shield is addressed in Section 4.3.3 of this report. Analyses performed by DOE for the total system performance assessment for site recommendation (Figure 4-7) show the drip shield has little effect on repository performance (CRWMS M&O, 2000b). However, the role of the drip shield to control the formation of aggressive environments on the waste package surface was not included in the DOE model. Figure 4-8 shows the effect of drip-shield integrity on the estimated dose, assuming 10 percent of the waste packages are exposed to environments that promote localized corrosion. Higher doses observed with accelerated drip-shield failure are attributed to water seepage, which is not diverted by the drip shield, and hence contacts the breached waste packages.

Depending on the timing and extent of rockfall, the drip-shield design may be important for limiting damage to the waste package (see Section 4.3.2.1).

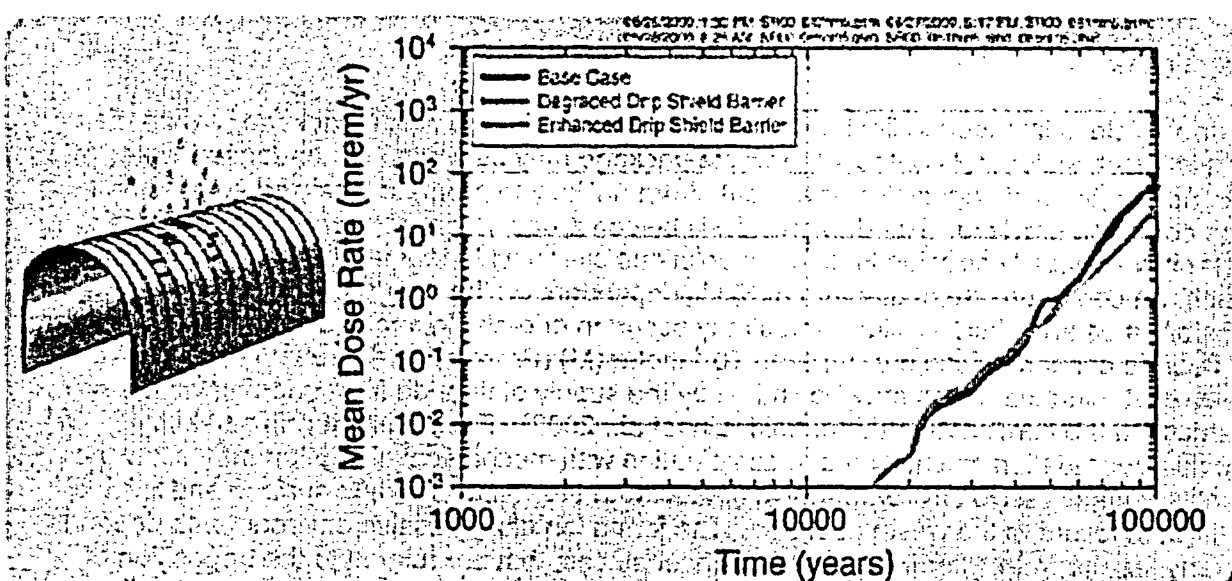


Figure 4-7. Drip-Shield Sensitivity Analysis Using the Total System Performance Assessment for Site Recommendation (CRWMS M&O, 2000b, Figure 5.3-3) (1 mrem/yr = 0.01 mSv/yr)

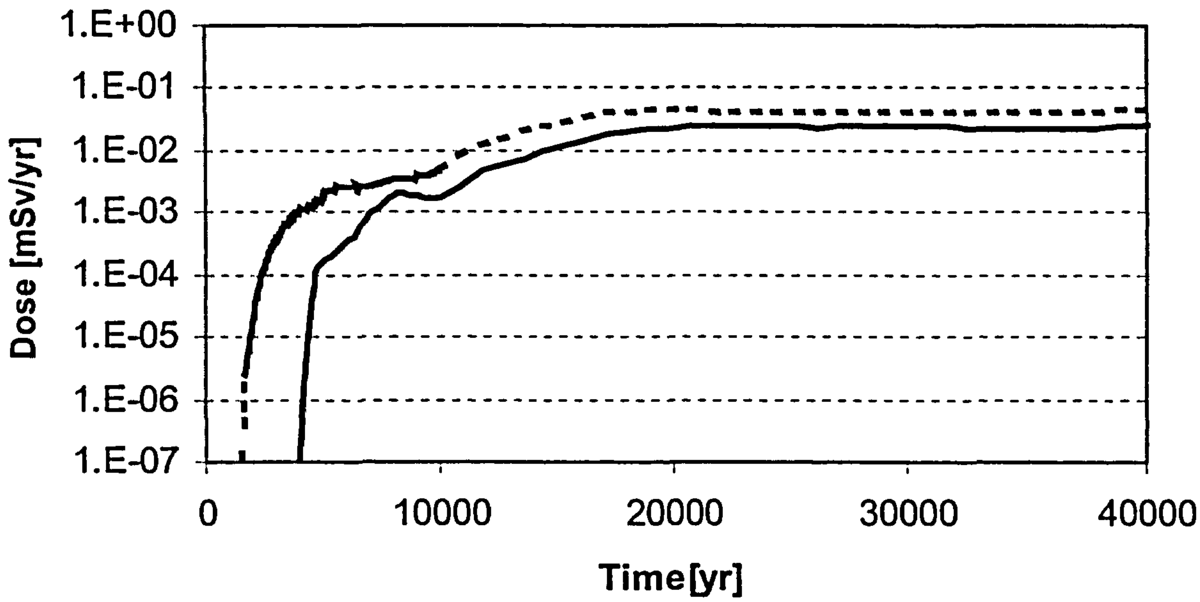


Figure 4-8. Effect of Drip-Shield Failure on Calculated Dose. In the Reference Case (10 Percent of Waste Packages are Assumed to Display Localized Corrosion), Drip-Shield Failures Are Assumed to Have a Lognormal Distribution with 0.1 Percent of Drip Shields Failing at 2,700 Years and 99.9-Percent Failing at 20,400 Years (Continuous Line). Enhanced Failures of Drip Shields Assume a Uniform Distribution with 10 Percent of the Drip Shields Failing Between 1,000 and 5,000 Years (Broken Line).

Uncertainties

The drip shield is intended to limit ground water contact with the waste package. While the drip shield is intact, water that contacts the waste package may be limited to condensed water with low concentrations of aggressive species that are unlikely to promote localized corrosion or stress corrosion cracking. The drip shield will be constructed from titanium alloys that are resistant to localized corrosion in chloride solutions over a wide temperature range. However, the uniform corrosion rate of titanium alloys is dependent on the fluoride concentration. Faster corrosion rates and shorter failure times may occur on drip-shield sections exposed to solutions with fluoride concentrations greater than 10^{-4} molar (M) (Brossia, et al., 2001; Lin, et al., 2003). However, titanium corrosion may be limited by the supply of fluoride from dripping water, and not strictly to the concentration threshold (Lin, et al., 2003). Failure of the drip shield by corrosion degradation mechanisms in combination with mechanical disruption may allow the formation of aggressive environments in contact with the waste package surface and lead to accelerated failure of the waste package. The formation of aggressive environments depends on many factors, with different degrees of uncertainties, that are related to the deposition of deliquescent salts, the rate of evaporation, and the composition of the seepage water. These aspects are discussed in Section 4.3.3.

Stress Corrosion Cracking: Medium Significance to Waste Isolation

Stress corrosion cracking of the drip shield or waste package affects a limited area and, thus, this corrosion process is not expected to allow substantial amounts of water to enter the waste package. However, applied loads arising from accidental internal overpressure, rockfall, or seismic events may increase the failure area and facilitate the ingress of water through the extended opening of stress corrosion cracks.

Discussion

The stress corrosion cracking susceptibility of Alloy 22 is dependent on material condition, corrosion potential, and stress intensity (Andresen, et al., 2003). Crack propagation rates for mill-annealed, cold-worked, and thermally aged Alloy 22 in basic saturated water are shown in Table 4-4. Under constant loading conditions, the crack propagation rates of the mill-annealed alloy decrease with time. However, sustained crack propagation under constant loading conditions has been observed for Alloy 22 in the cold-worked and thermally aged conditions. Recent results reported by General Electric and Lawrence Livermore National Laboratory and results obtained in independent tests conducted at the Center for Nuclear Waste Regulatory Analyses (CNWRA) show that Alloy 22 is susceptible to stress corrosion cracking in simulated concentrated water at temperatures below boiling, provided sufficient stress intensity is present.

The effect of stress corrosion cracking on the estimated dose is likely to be low because of the limited area of the cracks. In Figure 4-9, mean values (from 100 realizations) of radionuclide release rates (I-129, Tc-99, and Np-237) from the waste package are compared to estimates of diffusive release. Case 1 (continuous lines) is the reference case which assumes 90 percent of the waste packages are breached by general corrosion and 10 percent by localized corrosion. Case 2 (lines with circles) considers that radionuclides are released from the waste package

Table 4-4. Crack Propagation Rates for Alloy 22 in Basic Saturated Water

Material Condition	Stress Intensity, $MPa{\cdot}m^{1/2}$	Crack propagation Rate, mm/s
Mill-annealed	30	0
	45	4×10^{-10} — 1.3×10^{-9}
Mill-annealed plus 20% cold work	30	2×10^{-10} — 5×10^{-10}
Thermally aged 175 hours at 700 °C (1292°F)	16.5	—
	24.2	8×10^{-10} — 1.3×10^{-9}

(From Andresen, et al., 2003)

NOTES: English equivalents for $MPa{\cdot}m^{1/2}$ and mm/s are as follows: $MPa{\cdot}m^{1/2} \times 0.9091 = ksi\ in^{1/2}$ and mm/s × 0.039 = in/s.

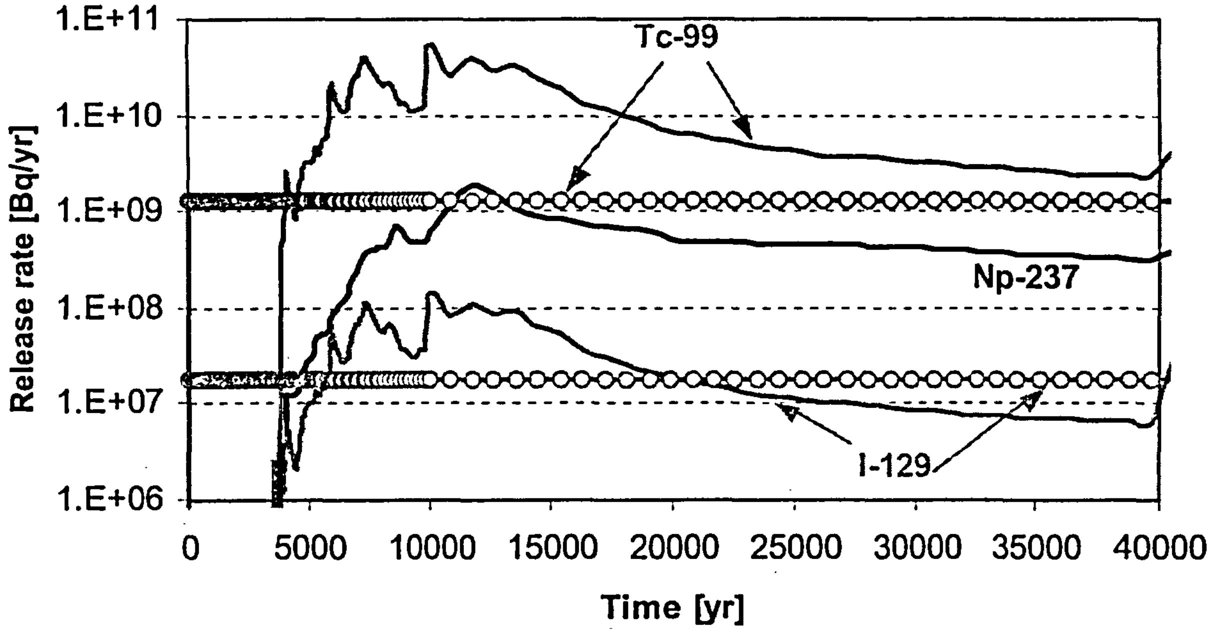


Figure 4-9. Radionuclide Release Rates from the Waste Package for Two Cases. Case 1 (Continuous Lines) Is a Reference Case Accounting for 90 Percent of the Waste Packages Breached by General Corrosion and 10 Percent by Localized Corrosion. Case 2 (Lines with Circles) Shows Diffusive Release Rates (I-129 and Tc-99) Assuming Saturation at the End of the Water Film in Contact with the Spent Nuclear Fuel, and Zero Concentration at the Other End. (Tc-99; I-129; Np-237).

only through stress corrosion cracks by a diffusive mechanism. In deriving these release rates (lines with circles), the following assumptions were made: (i) all the waste packages are breached by stress corrosion cracking at the time of emplacement; (ii) a thin film of water connects the spent nuclear fuel with the exterior of the waste package; (iii) the radionuclide concentration in the film, at the point of contact with the spent nuclear fuel, is determined by the saturation of radionuclide-bearing solids; (iv) the concentration at the end of the diffusive path is zero; (v) the problem is one-dimensional with a path length equal to 0.3 m [1.0 ft] and film cross section of 10^{-8} m^2 [10^{-7} ft^2]; and (vi) no credit is taken for cladding protection. As seen in Figure 4-9, diffusive releases, as modeled, are dominant during the first 4,000 years; however, they are at least one order of magnitude below the maximum release rates of Case 1 (I-129 and Tc-99), occurring at around 10,000 years. The estimated diffusive releases of Np-237 are less than 10^5 becquerels/yr [10^{-5} curies/yr] and are not displayed in Figure 4-9. After approximately 4,000 years, the radionuclide release rates associated with Case 1 exceed the diffusive release rates.

Advective release through stress corrosion cracks could occur if cracks were opened by mechanical loading (e.g., mechanical interactions of the waste package with other components of the engineer barrier system during seismic events or as a result of static loading). Figure 4-10 shows the estimated effects of advective release of Np-237, I-129, and

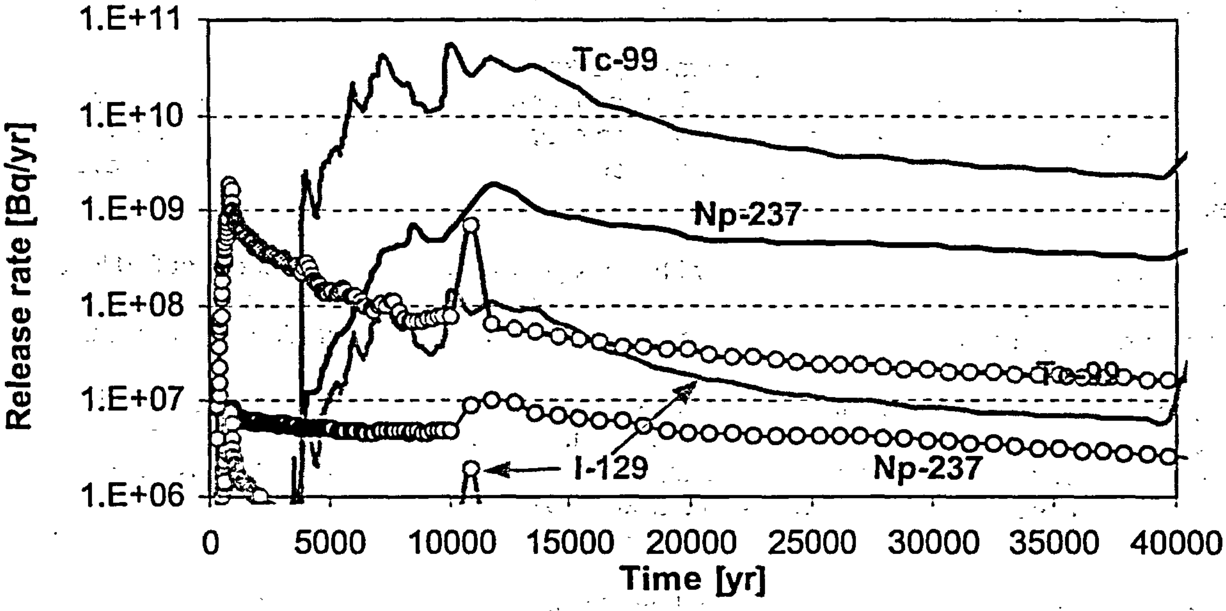


Figure 4-10. Radionuclide Release Rates from the Waste Package for Cases 1 and 3. Case 1 (Continuous Lines) Is a Reference Case Accounting for 90 Percent of the Waste Packages Breached by General Corrosion and 10 Percent by Localized Corrosion. Case 3 (Lines with Circles) Shows Advective Release Rates Estimated by Multiplying the Waste Package Release Rates in the Flow-Through Scenario by a Factor of 1/1,000 (Factor to Account for Protection Against Seepage Offered by Unbreached Waste Package Surface). Both Curves Correspond to Mean Values from 100 Realizations (TC-99, I-129, and Np-237).

Tc-99 through cracks. To facilitate comparison, Figure 4-10 includes radionuclide release rates of Case 1 from Figure 4-9. Stress corrosion cracks were assumed to develop during a period of temperatures above the boiling point of water and relative humidity above a deliquescence point of salt formation. Radionuclide release rates from the waste package were estimated for the flow-through scenario, and decreased by a factor of 1/1000 to account for protection against seepage offered by the unbreached area of the waste package. Protection by the drip shield or cladding was disregarded. Under these assumptions, it was estimated that advective release through stress corrosion cracks was largest during early years of repository operation, up to 4,000 years (Case 3, lines with circles in Figure 4-10). However, maximum release rates of Np-237, Tc-99, and I-129 are one order of magnitude lower than those derived for Case 1 (continuous lines).

<u>Uncertainties</u>

Stress corrosion cracking requires the combination of a susceptible material or microstructure, an aggressive environment, and an applied or residual tensile stress. Although nickel-base alloys are known to be resistant to environmentally assisted cracking in hot chloride solutions, stress corrosion cracking of Alloy 22 has been reported in simulated ground water solutions that may contact the waste packages (Andresen, et al., 2003; King, et al., 2002; Estill, et al., 2002).

Stress corrosion cracks that penetrate the waste package may be tight and may restrict the transport of water into the waste package. Cracks that remain tight may allow only diffusive release of radionuclides. Stress corrosion cracking coupled with mechanical loading from disruptive events may propagate existing cracks or enlarge existing failures and allow advective release of radionuclides.

There is significant uncertainty associated with crack geometry and the effect of applied loads arising from accidental internal overpressure, rockfall, or seismic events that may propagate existing stress corrosion cracks, or lead to mechanical failure of the degraded waste package.

Release rates associated with stress corrosion cracking may be influenced by: (i) limited cross section of stress corrosion cracks, (ii) frequency of nucleation sites for stress corrosion cracks, (iii) frequency of chemical solutions necessary for stress corrosion cracking, (iv) levels of material stress needed for stress corrosion cracking, (v) stress corrosion cracking propagation rate, and (vi) crack location on the waste package geometry.

Juvenile Failures of the Waste Package: Low Significance to Waste Isolation

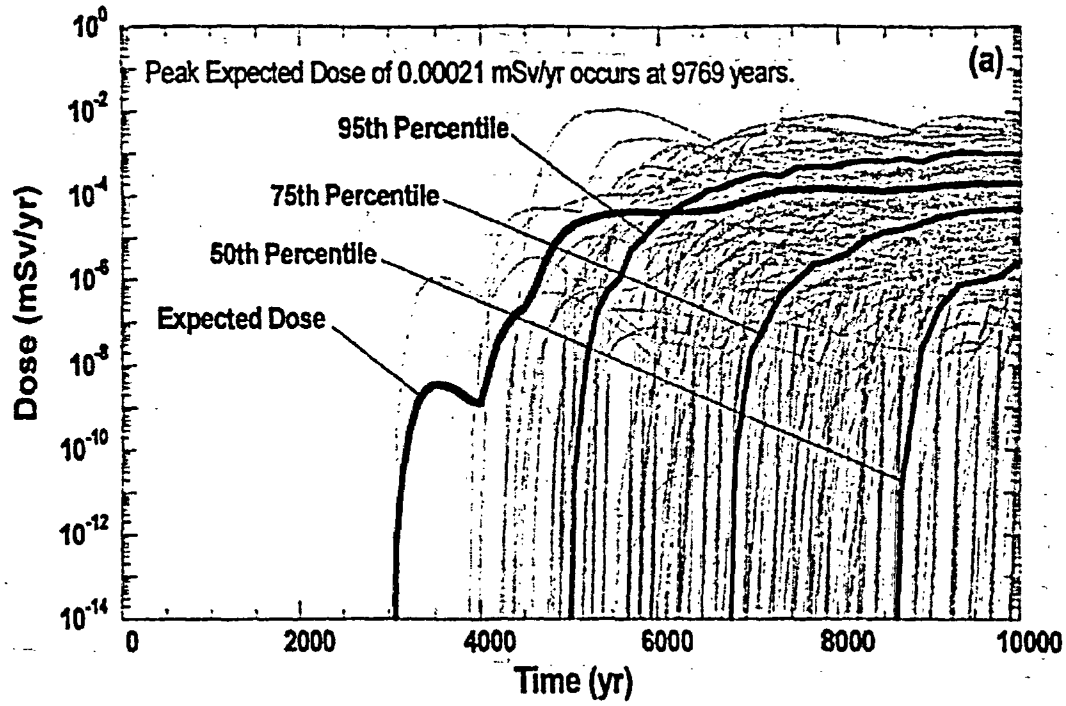
Juvenile or early failures of the waste package (e.g., closure welding defects, such as flaws, which can promote other degradation processes) are expected to be limited to a small fraction of waste packages and not have a significant effect on waste package performance and hence on radionuclide release.

Discussion

The basecase results from the TPA code, and the results from the DOE total system performance assessment for the supplemental science and performance analyses model, quantitatively support that juvenile or early failures of the waste package are of low significance to waste isolation (Figures 4-11 and 4-12). For the TPA Version 4.1 basecase, the risk from the nominal scenario (on average 44 juvenile failures, or 0.63 percent) is 0.00021 mSv/yr (0.021 mrem/yr) at 10,000 years. The DOE total system performance assessment for the supplemental science and performance analyses model had on average less than one package failure per stochastic realization, and the resultant doses were very small at 10,000 years [e.g., less than 10^{-6} mSv/yr (10^{-4} mrem/yr)]. Quality assurance procedures for fabrication, characterization, handling, and emplacement of waste packages should reduce the likelihood of significant defects and, therefore, juvenile failures. Quantitative analyses to date demonstrate the repository system is likely to tolerate limited waste package failures. Processes such as loss of passivity or occurrence of localized corrosion are not considered to be part of juvenile failures and are modeled separately.

Uncertainties

Initial defects coupled with waste package degradation processes and mechanical loading as a result of disruptive events may lead to early failures of waste packages. The number of waste packages that are susceptible to early failure processes will be dependent on the frequency, type, size, and orientation of the initial defects.



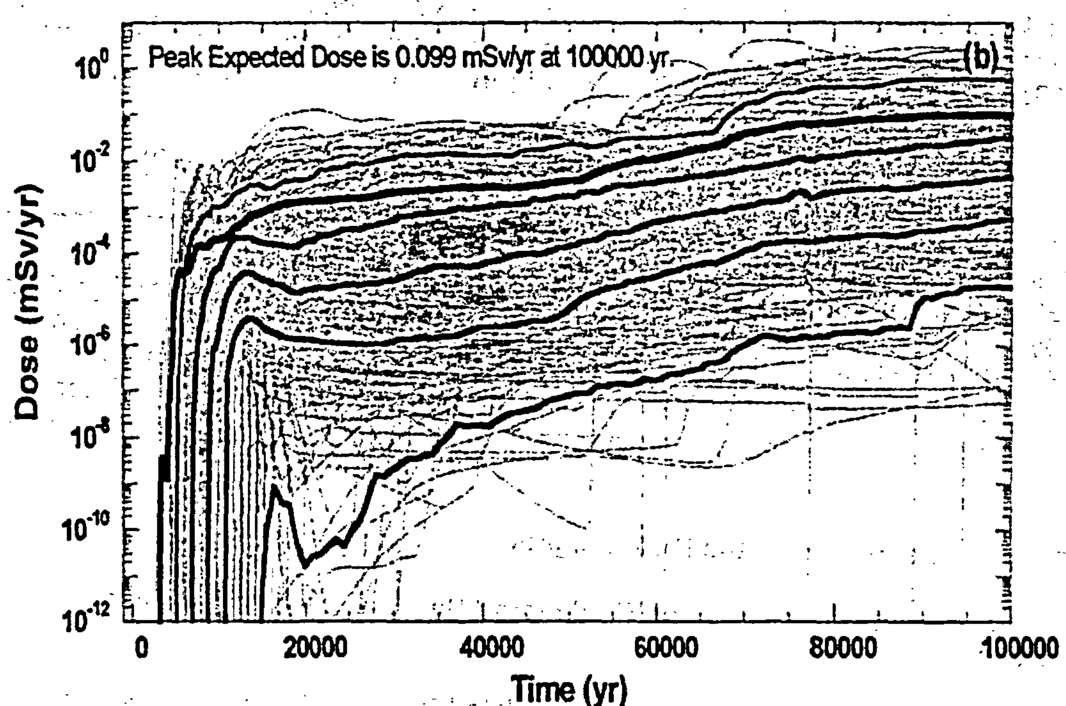


Figure 4-11. Ground Water Dose in (a) 10,000 Years, and (b) 100,000 Years, Including the Average Dose for 150 Realizations (Mohanty, et al., 2002, Figure 3-20)

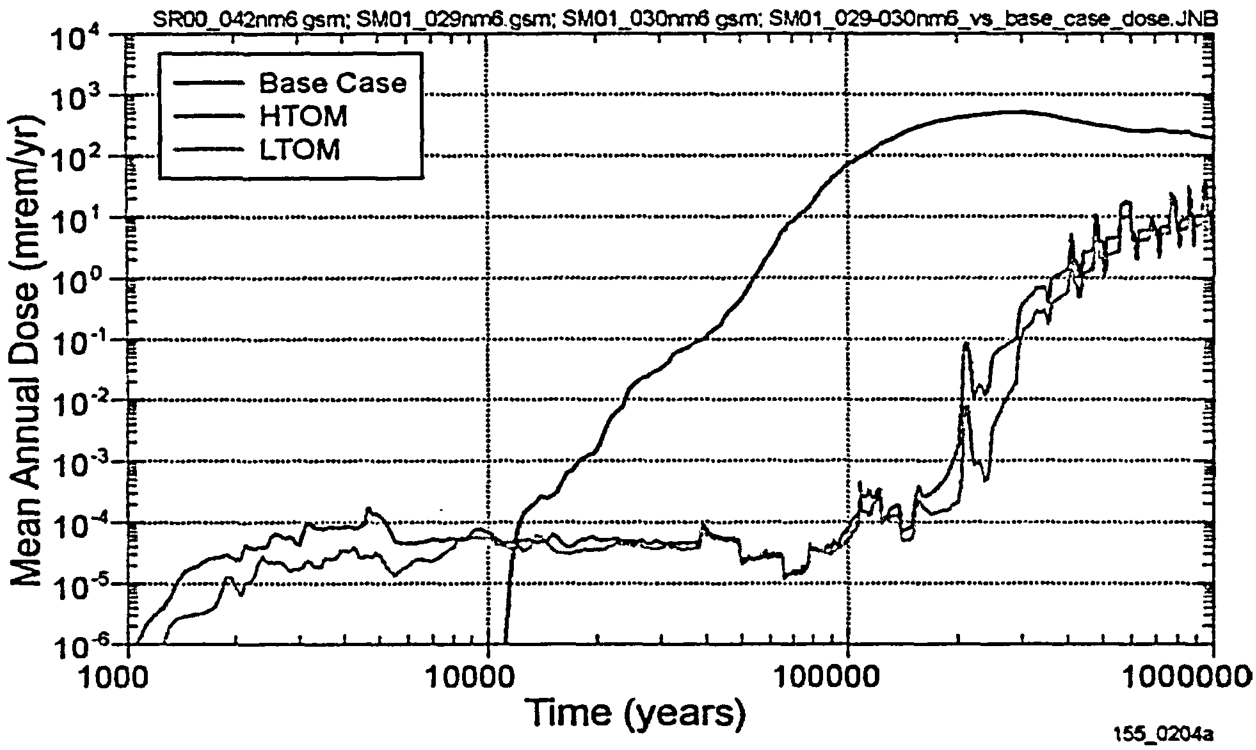


Figure 4-12. Summary of Peak Dose Performance Results (HTOM: High-Temperature Operating Mode; LTOM: Low-Temperature Operating Mode; Basecase: TSPA-SR) (Bechtel SAIC Company, LLC, 2001, Figure 4.1-1) (1 mrem/yr = 0.01 mSv/yr)

4.3.2 Mechanical Disruption of Engineered Barriers (ENG2)

Risk Insights:

Effects of Accumulated Rockfall on Engineered Barriers	Medium Significance
Dynamic Effects of Rockfall on Engineered Barriers	Low Significance
Effects of Seismic Loading on Engineered Barriers	Medium Significance
Effects of Faulting on Engineered Barriers	Low Significance

4.3.2.1 Discussion of the Risk Insights

Effects of Accumulated Rockfall on Engineered Barriers: Medium Significance to Waste Isolation

Mechanical loading from rockfall rubble accumulated from drift degradation over time may lead to failure of the drip shields and waste packages. The failure of the drip shields and waste packages will depend on the rate of accumulation of rockfall rubble in the drift (building static load on the drip shield) and the threshold load-bearing capacity of the drip shields and the waste packages. The accumulation of rock rubble in the drift outside the drip shield will also increase the waste package and drip-shield temperatures.

Discussion

Current understanding of the degradation of mined openings indicates that all of the drip shields could experience static loads from rockfall rubble that can accumulate after repository closure. These loads are expected to damage the drip shields. A total system performance assessment calculation (Figure 4-13) indicates that if all drip shields fail from rockfall without any associated waste package failure, the dose consequence will be low. A calculation in which all drip shields are assumed to fail simultaneously at the beginning of the postclosure period increased the peak expected dose by less than 75 percent relative to the nominal scenario, which is still at least two orders of magnitude below the regulatory limit. The higher temperature associated with rockfall and the potential increase in the amount of water entering the drift are not expected to significantly increase this result.

Sustained rockfall rubble loads may cause some of the drip shields and waste packages to fail. At the present time, however, the TPA code does not have a model to compute mechanical failure of the waste package if the drip shield is no longer capable of isolating it from rockfall loads. To address this interim limitation, another total system performance assessment calculation was performed to bound the potential effects of both the drip shields and waste packages failing at the time of repository closure. The results of this analysis (Figure 4-13) indicate that a simultaneous failure of all drip shields and waste packages increases dose significantly above the nominal scenario dose, which has a limited number of waste packages (i.e., 40 on average) failing before 10,000 years. However, the dose is below the regulatory dose limit, and the timing and extent of drift collapse is highly uncertain. This uncertainty has

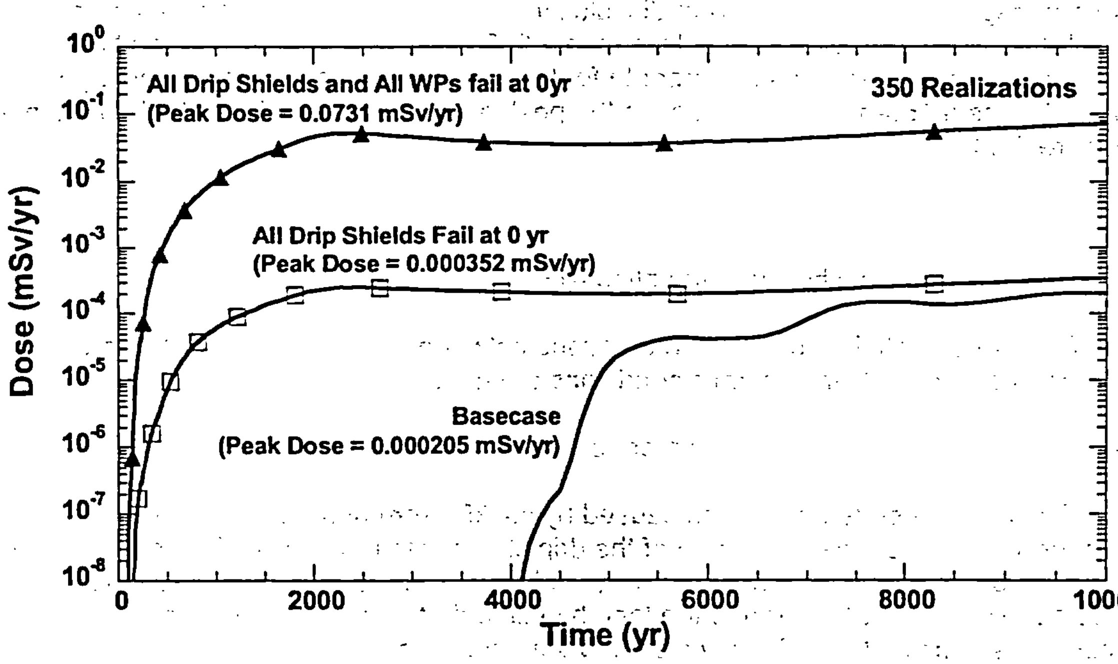


Figure 4-13. Conditional Peak Expected Doses Corresponding to (i) the Basecase, (ii) a Hypothetical Case in which all Drip Shields Have Failed at Postclosure, and (iii) a Hypothetical Case in which all Drip Shields and Waste Packages Have Failed at the Time of Postclosure (Doses Have Not Been Weighted by the Probability of Scenario Occurrence

implications that the significance associated with the process could range from minimal to high, but is expected to be less than the estimates of this bounding analysis. Additionally, a drip-shield design that limits damage to waste packages would limit the significance of drift collapse.

The insulating effects of the rockfall rubble will increase drip-shield, waste-package, and waste-form temperatures. High temperatures will adversely affect the load-bearing capacity of the drip shield and the waste package, thus increasing their failure potential during the duration of high temperatures. The increased temperature also may accelerate drip-shield and waste-package corrosion and waste-form dissolution.

DOE calculations with engineered backfill, which can be viewed as an upperbound for natural backfilling with rockfall rubble, indicate that the peak waste package temperature could increase nearly two fold to 315 °C [600 °F] , compared to the no-backfill scenario (DOE, 2000; p. 90). However, backfill from drift degradation is anticipated to contain more void space during times relevant to the repository thermal pulse than engineered backfill, thereby, limiting peak waste package temperature. The temperature of other components of the engineered system could be affected correspondingly. It is unlikely that liquid water will be present within the drift at temperatures above 160 °C [320 °F]. The NRC temperature estimates for the unbackfilled condition and the DOE temperature estimates for engineered backfill bound the time for which temperatures are elevated. The analyses estimate that drift degradation is not expected to substantially increase the length of time that engineered barrier system components remain above the critical temperature threshold for the occurrence of localized corrosion. Therefore, the effect on corrosion may not be substantially different from the nominal no-backfill scenario. NRC performed an analyses to determine the effect of increased temperature as a result of backfill from drift degradation on waste-form dissolution. The use of a higher-dissolution rate model in which the waste form dissolves in less than 1,000 years (e.g., Model 1 in the NRC TPA code) (Mohanty, et al., 2002) as a surrogate for the effect of increased waste package temperature indicates a 150-percent increase in the peak expected dose relative to the nominal scenario (Figure 4-14).

Uncertainties

The following are key areas in which uncertainties exist:

- The effects of potential mechanical interactions between the drip-shield and waste package under rockfall and seismic conditions are uncertain.

- The effects of drift degradation on water seepage into the drifts are uncertain.

- The effect of elevated temperatures caused by backfill from drift degradation may have an important effect on the creep rate of the drip shield titanium alloys. The impact of the effects are uncertain at this time, however, analyses estimate that drift degradation is not expected to substantially increase the length of time that engineered barrier system components remain at significantly elevated temperatures.

- In the case of low-probability intrusive igneous activity event, magma would flow into the drifts because of the pressure gradient between the magma conduit and the drift opening (Woods, et al., 2002). An extensive blockage of the drifts by

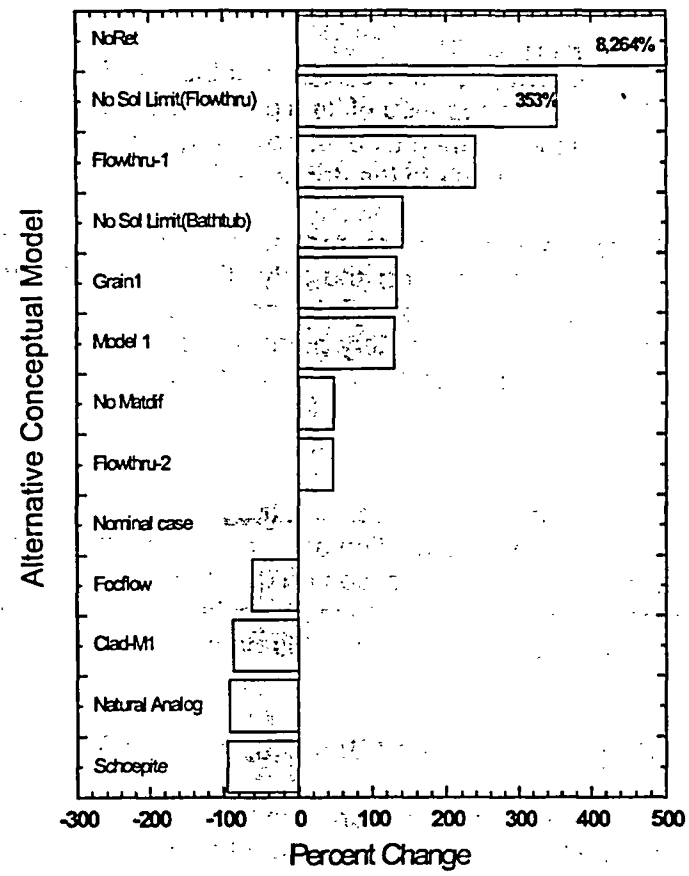


Figure 4-14. Effects of Alternative Conceptual Models at 10,000 Years (Mohanty, et al., 2002, Figure 4-15)

rockfall rubble may create a barrier against potential magma flow down the drifts, based on analogy with channelized flow of lavas. The extent of blockage necessary to halt a pressure-driven flow is uncertain at this time. In addition, partial backfill of waste packages and drip shields by rubble may create a buffer zone between possible magma and engineered materials, changing potential thermo-mechanical effects from conductive to convective. The possible rubble zone, however, may have elevated temperatures and advect corrosive gasses evolving from the potential magmas (Connor, et al., 1997). Effects on long-term barrier materials from these processes remain uncertain at this time. See Section 4.3.10.1 for more detailed discussion on the impacts of these uncertainties on magma intrusion into the drifts.

Dynamic Effects of Rockfall on Engineered Barriers: Low Significance to Waste Isolation

The mechanical response of the engineered barrier system to discrete dynamic rock-block impacts is dependent upon the formation of discrete rock blocks of sufficient size within rock units of the repository horizon. Rock blocks of sufficient size to damage engineered barrier system components are only expected for a small portion of the repository.

Discussion

It has been determined that the formation of discrete rock blocks of significant size within the lower lithophysal rock unit is unlikely because of its highly fractured nature (Gute, et al., 2003). The analysis of the middle nonlithophysal rock unit, however, indicated that there are rock blocks of sufficient size to cause damage to the drip shield.

Because the middle nonlithophysal rock unit represents a relatively small percentage of the repository footprint (i.e., less than 30 percent) and only 40 percent of the rock blocks in this unit will have a mass greater than 2.25 metric tons [2.48 tons], the potential effect of discrete dynamic rock block impacts on overall repository performance has been determined to be a low-risk scenario for mechanical disruption (Gute, et al., 2003).

Uncertainties

The primary uncertainties associated with assessing the potential effects of dynamic rockfall on the drip shield are the rock-block impact location and impact-velocity distributions. Assuming the rock-block impacts occur at the same location on the drip shield (i.e., the drip-shield crown) with varying impact velocities (corresponding to the calculated fall heights), it was determined that the damage incurred by the drip shields from this potential disruptive event is negligible (Gute, et al., 2003).

Effects of Seismic Loading on Engineered Barriers: Medium Significance to Waste Isolation

The mechanical response of the engineered barrier system and waste form to seismic loading is strongly affected by the extent of accumulated rock fall rubble and associated elevated temperatures.

Discussion

The drip shield and waste package may be breached by the accumulation of damage caused by multiple seismic loading events (in addition to other mechanically disruptive events). It is expected that seismic events will increase the effective static load because of rockfall on the drip shield and waste packages.

Uncertainties

At the present time, there is a great deal of uncertainty associated with the seismic threshold loads needed to generate appreciable drip-shield and waste package mechanical damage. These threshold loads are strongly affected by the anticipated in-drift conditions (i.e., the presence of accumulated rockfall rubble and the concomitant elevated temperatures) and the different levels of material and structural degradation that are caused by various corrosion processes, fabrication effects (residual stresses and loss of ductility from welding and quenching), and hydrogen embrittlement.

Effects of Faulting on Engineered Barriers: Low Significance to Waste Isolation

Mechanical disruption of the engineered barrier system caused by faulting is dependent upon the mechanical loads placed on the engineered barrier system components by fault displacements. Analyses considering patterns of surface-faulting displacements from historical earthquakes in the Basin and Range physiographic province indicate the potential effect of direct fault rupture of engineered barrier system components is expected to be small.

Discussion

Analysis of the potential effect of direct fault rupture on the engineered barrier estimates the risk is small [on the order of tenths of microsieverts (tens of microrems) or less]. The significance of faulting has been evaluated by using the FAULTO module in the TPA Version 4.1j code and by considering the patterns of surface-faulting displacements from historical earthquakes in the Basin and Range physiographic province (Stamatakos, et al., 2003). Both analyses relied on conservative, and in some cases, upperbound assumptions. For example, no credit was taken for the mechanical strength of the waste packages because of limited data and analyses on the mechanical behavior of waste packages during a faulting event. All waste packages intersected by faults were assumed to fail. Similarly, because of limited data on the amount of distributed and secondary fault displacements anticipated in the repository during an earthquake at Yucca Mountain, the faulting analyses conservatively assumed that all secondary or distributed faults were capable of failing waste packages, independent of the amount of fault displacement that might occur on the secondary or distributed faults. Nonetheless, risk estimates by both methods are similar and very small as shown in Figure 4-15. These analyses show that faulting does not contribute significantly to overall repository risk, even with the conservative and upperbound assumptions.

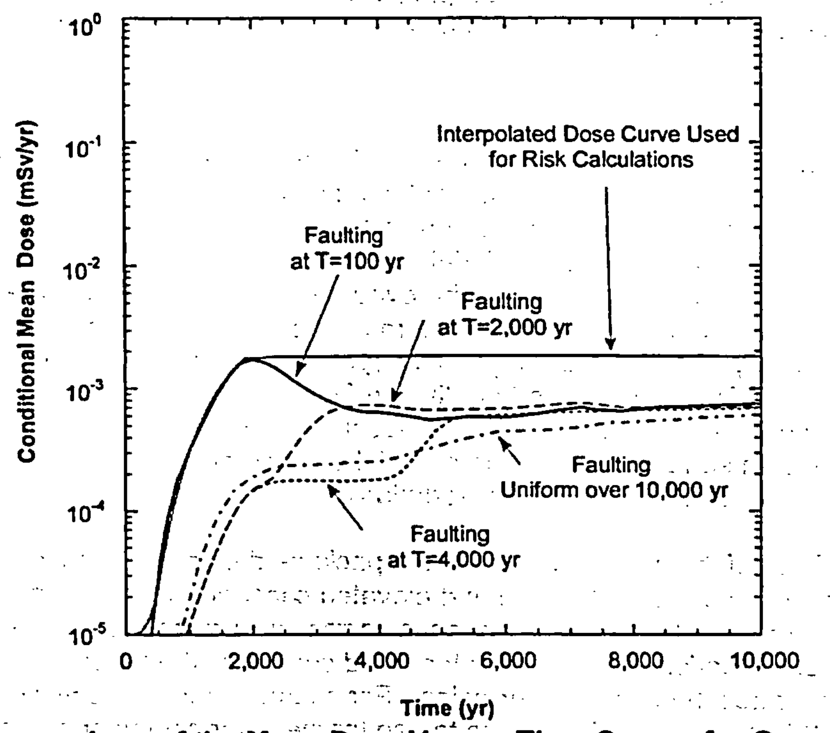


Figure 4-15. Comparison of the Mean Dose Versus Time Curves for Cases in which the Faulting Events on the Solitario Canyon Fault Were Forced to Occur in All 500 Realizations at a Specified Year (100, 2,000, and 4,000) and for a Case in Which the Faulting Events Occurred Uniformly over the Entire 10,000-Year Postclosure Period

Uncertainties

There are large uncertainties in both the amount and likelihood of fault displacements, and the associated mechanical loads placed on the waste packages and drip shields by these displacements. However, the bounding assumptions employed in the analyses discussed above provide confidence that these uncertainties are still not expected to result in faulting significantly contributing to overall repository risk.

4.3.3 Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms (ENG3)

Risk Insights:	
Chemistry of Seepage Water	High Significance

4.3.3.1 Discussion of the Risk Insights

Chemistry of Seepage Water: High Significance to Waste Isolation

Evaluating the range in chemistry of water seeping into the drift and contacting the drip shield and waste package is important for determining corrosion rates of the engineered materials.

Discussion

The quantity and chemistry of water that drips onto drip-shield and waste-package surfaces largely determine the composition of the salts that can precipitate on those surfaces. The composition of a salt determines the composition of its associated brine, and the relative humidity conditions under which that salt will deliquesce to form a brine. The composition of the salt is largely determined by the chemistry of the evaporating water, whereas the timing and extent of salt formation/evaporation is largely determined by thermal-hydrological conditions in and above the repository over time. Changes in seepage rate and the conditions appropriate for evaporation and salt formation depend on diverse factors, such as climate, flow pathways in the unsaturated zone, heat load, drift design, and local controls on flow pathways (i.e., roughness of drift crown surface, the location of rock bolts and other engineered materials, and the timing and extent of rock fall and drift degradation).

The expected lifetimes of the drip shield and waste package depend strongly on the chemistry of water contacting their surfaces. Low pH and elevated concentrations of certain dissolved anionic species are expected to enhance aqueous corrosion—promoting specific corrosion modes, either uniform corrosion, or localized corrosion, the latter of which has orders of magnitude higher rates than uniform corrosion. For example, the susceptibility to localized corrosion of Alloy 22, the material DOE plans to use for the outer container of the waste package is strongly dependent on pH and on chloride ion concentration (Dunn, et al., 2003). Titanium Grade 7, the material planned to be used for drip shields that would cover the waste packages, has been shown to be susceptible to generalized corrosion from fluoride ions (Brossia, et al., 2001), and other data indicate that titanium is susceptible to localized corrosion in the presence of bromide ions (Beck, 1971). On the other hand, other anionic species can inhibit localized corrosion if present in sufficient concentration. For example, nitrate ions have been shown to inhibit localized corrosion of Alloy 22 in chloride solutions (Dunn, et al., 2003). However, titanium corrosion may be limited by the supply of fluoride from dripping water and not strictly to the concentration threshold (Lin, et al., 2003).

High concentrations of these anionic species could result from the evaporation of seepage waters, even if those waters initially were dilute (Brossia, et al., 2001). Evaporation experiments (Rosenberg, et al., 2001) and some limited thermodynamic analyses (Pabalan, et al., 2002a,b) show that waters of widely varying initial composition evolve by evaporation toward three types of brines: (i) calcium-chloride (Ca-Cl), (ii) neutral, and (iii) alkaline brines. The results of thermodynamic simulations of evaporation of Yucca Mountain ground waters indicate that Ca-Cl brines tend to have chloride-to-nitrate ratios sufficiently high to make the corrosion-inhibiting property of nitrate ions ineffective (Pabalan, et al., 2002a,b). The thermodynamic calculations also show that alkaline brines tend to have fluoride ion concentrations that exceed 0.0005 moles/kg H_2O, a threshold fluoride concentration at whichTitanium Grade 7 has been observed to undergo accelerated general corrosion in deareated 1-M sodium chloride solutions (pH 6.4 to 8.2) at 95 °C [203 °F] (Brossia, et al., 2001). The thermodynamic analyses indicate that the three brine types have elevated bromide concentrations, but the potential effect of the elevated bromide concentrations is uncertain because of the limited data on corrosion of titanium in bromide solutions.

In addition to elevated concentrations of anionic species, evaporation of seepage waters possibly could lead to acidic condensates that could enhance the degradation of engineered materials. For example, experiments by Pulvirenti, et al. (2003) demonstrated a high corrosion rate for Alloy 22 that was reacted at 130 °C [266 °F] with acidic condensate formed by evaporation of simulated Yucca Mountain brines. The fast corrosion rate was interpreted as resulting from the formation of hydrochloric acid and nitric acid during evaporation of the highly concentrated brines. The formation of hydrochloric and nitric acid was supported by chemical tests of vapor samples in a closed system. While comparable temperatures are expected for the repository, the open nature of the Yucca Mountain system (i.e., the movement of air in the unsaturated zone), and the buffering effect due to minerals in the host rock, significantly limit the concentration of hydrochloric and nitric acid.

Additional salts, such as soluble chlorides, nitrates, and sulfates of sodium, potassium, calcium, and magnesium, that are present as aerosols in atmospheric air (Ge, et al., 1998) and entrained in ventilation air introduced into the repository drift also may be deposited on the drip-shield and waste-package surfaces (Bechtel SAIC Company, LLC, 2001). Inorganic salts are generally hygroscopic and will absorb moisture from humid air, generating small volumes of potentially corrosive brines. A phase change from a solid particle to a saturated aqueous phase usually occurs spontaneously when the relative humidity in the surrounding atmosphere increases to a level known as the deliquescence point or deliquescence relative humidity (Tang and Munkelwitz, 1993). The deliquescence relative humidity of salt mixtures depends on the mixture composition and temperature. Experimental data and thermodynamic analyses (Pabalan, et al., 2002a,b) show that mixtures containing magnesium and calcium have much lower deliquescence relative humidity than those containing sodium and potassium. If magnesium and calcium salts are deposited on waste package and drip-shield surfaces, deliquescence and rine formation could occur when the repository temperature is above 100 °C [212 °F] and could lead to early initiation of aqueous corrosion of the drip shield and waste package engineered barrier.

Uncertainties

Some uncertainty arises from the uncertainty in the quantity of water entering the drift, and the timing of and the temperature during which seepage occurs. Published experimental and modeling studies of evaporation have implicitly assumed that seepage water is present and that the temperature is sufficiently high to cause evaporation. However, the flux of seepage water over time depends on diverse factors, such as climate, flow pathways in the unsaturated zone, heat load, drift design, and local controls on flow pathways (i.e., roughness of drift crown surface, the location of rock bolts and other engineered materials, and the timing and extent of rockfall and drift degradation).

The most significant source of uncertainty in determining the chemical environment for corrosion is the range of in-drift water compositions that may result from spatial and temporal variations in seepage water composition, the composition and amount of condensed water formed by cold-trap processes, and the extent of chemical interactions between these waters and engineered and natural materials. Coupled thermal-hydrological-chemical processes occurring in the rocks that overlie the proposed repository will largely determine the quantity and chemistry of water seeping into the drifts. Explicit and comprehensive evaluation of these coupled processes, however, generally requires the construction of reactive transport models (CRWMS M&O, 2001).

Reactive transport predictions have two substantial sources of uncertainty that are difficult to quantify (Browning, et al., 2003a,b): (i) code limitations, especially algorithms that reflect a representation of coupled thermal-hydrological-chemical processes; and (ii) uncertain parameter values. A comprehensive evaluation of the uncertainties associated with conceptual models and code limitations requires an assessment of how omitted processes and components affect model results. It is generally not feasible to quantify precisely the uncertainties associated with the myriad individual input parameters and constraints typically associated with reactive transport models, limiting assessments to analyzing the effects for a range of potential chemistries. Nevertheless, these uncertainties are constrained by the system characteristics (e.g., relatively homogeneous rock chemistry) and by the well-understood dynamics of evaporation (i.e., the chemical divide phenomenon results in a diversity of water compositions evolving to a few brines).

The composition of in-drift water is a significant factor in determining the types of salts that can form and the corrosiveness of the associated brine. Bounding the range of in-drift water compositions requires characterization of diverse in-drift features, events, and processes that may alter the chemical composition of seepage waters. As noted above, these features, events and processes include cold-trap processes that control the timing, locations, and compositions of condensed waters; the development of preferential flow pathways that may focus flow over drip-shield and waste-package surfaces; the chemical consequences of degradation of the engineered drifts; and the chemical evolution of in-drift waters that have interacted chemically with engineered materials. The impact of these features, events, and processes on the quantity and chemistry of in-drift water is believed to be of less importance.

Some uncertainty also remains with respect to the composition of dust that may be deposited on the drip-shield and waste-package surfaces, and the extent to which chemical interactions between dust and in-drift waters may alter the chemical environment for corrosion. Chemical analyses by the U.S. Geological Survey (Peterman, et al., 2003) on a limited set of dust samples from the exploratory shaft facility indicate that a large proportion of the dust in the Exploratory Studies Facility comes from communication of the rock during tunnel construction and autogenous grinding of muck during haulage on the conveyor belt. However, the U.S. Geologic Survey data also indicate that salts of evaporated construction and native pore water are minor components of the dust. There are limited data to support extrapolation of the composition of dust sampled from the Exploratory Studies Facility to that of dust that may be encountered in the repository drift. There is also uncertainty with respect to the deliquescence behavior of salts mixed with rock dusts.

4.3.4 Radionuclide Release Rates and Solubility Limits (ENG4)

Risk Insights:	
Waste-Form Degradation Rate	Medium Significance
Cladding Degradation	Medium Significance
Solubility Limits	Medium Significance
Mode of Release from Waste Package	Low Significance
Effect of Colloids on Waste Package Releases	Medium Significance
Invert Flow and Transport	Low Significance
Criticality	Low Significance

4.3.4.1 Discussion of the Risk Insights

Waste-Form Degradation Rate: Medium Significance to Waste Isolation

The dissolution rate of the waste form in an aqueous environment is important for all radionuclides. Uncertainty in the dissolution rate is large such that the time required to release radionuclides from the spent nuclear fuel matrix or vitrified-waste forms can vary from hundreds of years to hundreds of thousands of years. Water chemistry and temperature within the waste package could affect the degradation rate of the spent nuclear fuel and vitrified wastes. Corrosion of the internal metallic components of the waste package (e.g., fuel assembly baskets) could reduce pH, leading to higher dissolution rates from spent nuclear fuel and vitrified wastes.

<u>Discussion</u>

Several studies point to the sensitivity of dose to the dissolution rate of the spent nuclear fuel source material. The preexponential coefficient for the basecase spent nuclear fuel dissolution model (exponential dissolution Model 2) in the TPA code is one of the most sensitive parameters (Table 4-5) (Mohanty, et al., 2002). Furthermore, among the four alternative models for spent nuclear fuel degradation in TPA Version 4.1 (which have markedly different release rates), there is a clear correlation between release rate and dose (Figure 4-16). Dissolution rate

Table 4-5. Influential Parameters for the 10,000-Year Simulation Period from Sensitivity Analysis Studies		
No.	Parameter Name	Score
1	Areal average mean annual infiltration at start	7/7
2	Drip-shield failure time	7/7
3	Preexponential term for spent nuclear fuel dissolution (Model 2)	6/7
4	Subarea wet fraction	6/7
5	Waste package flow multiplication factor	6/7
6	Well pumping rate at 20-km [12.4-mi] receptor group	6/7
7	Fraction of condensate toward repository	4/7
8	Alluvium retardation coefficient for Ne-237	3/7
9	Distance to tuff-alluvium interface	3/7
10	Waste package initially defective fraction	3/7

is a relatively important determinant of repository performance, but the overall peak dose is not directly proportional to it, because other mechanisms like diffusion, advection, and solubility attenuate ultimate release rates from the engineered barrier. The previous DOE total system performance assessment models use fuel dissolution rates considerably larger than those used by NRC (CRWMS M&O, 2000b). Using more aggressive chemical conditions (Model 1) in place of the basecase (Model 2) leads to a 2-order of magnitude increase in release rate, yet, as shown in Figure 4-16, the increase in peak expected dose is only a factor of approximately 2.5. NRC staff expect the basecase (Model 2) to represent chemical conditions to which spent nuclear fuel could be exposed under anticipated repository conditions.

Uncertainties

The dissolution rate of spent nuclear fuel depends on temperature, the presence of oxygen, and the chemistry of in-package water. There are similar controls on the dissolution of vitrified waste, although it is not significantly affected by oxidation potential. Furthermore, the rate at which radionuclides can leave the waste package may be restricted not strictly by the dissolution rate of the fuel but by: (i) the amount of water coming into contact with the waste form and escaping the waste package, (ii) diffusion processes inside and outside the waste package, and (iii) solubility. Model 4 (schoepite dissolution model) recognizes that the spent nuclear fuel can degrade relatively quickly in the presence of water and oxygen, but that some radionuclides may be incorporated into secondary minerals formed during spent nuclear fuel degradation and released at a slower rate by subsequent dissolution of these less-soluble phases.

Cladding Degradation: Medium Significance to Waste Isolation

Zircaloy cladding exhibits extremely low uniform corrosion rates in aqueous environments and could delay substantially the release of radionuclides from commercial spent nuclear fuel if it remains intact. Performance assessments estimate a high correlation between dose and fraction of failed cladding. However, cladding is thin and not physically strong. Cladding failure can occur as a result of localized corrosion, stress corrosion cracking, and hydride reorientation, under a combination of adverse environmental and stress conditions. Cladding may also fail

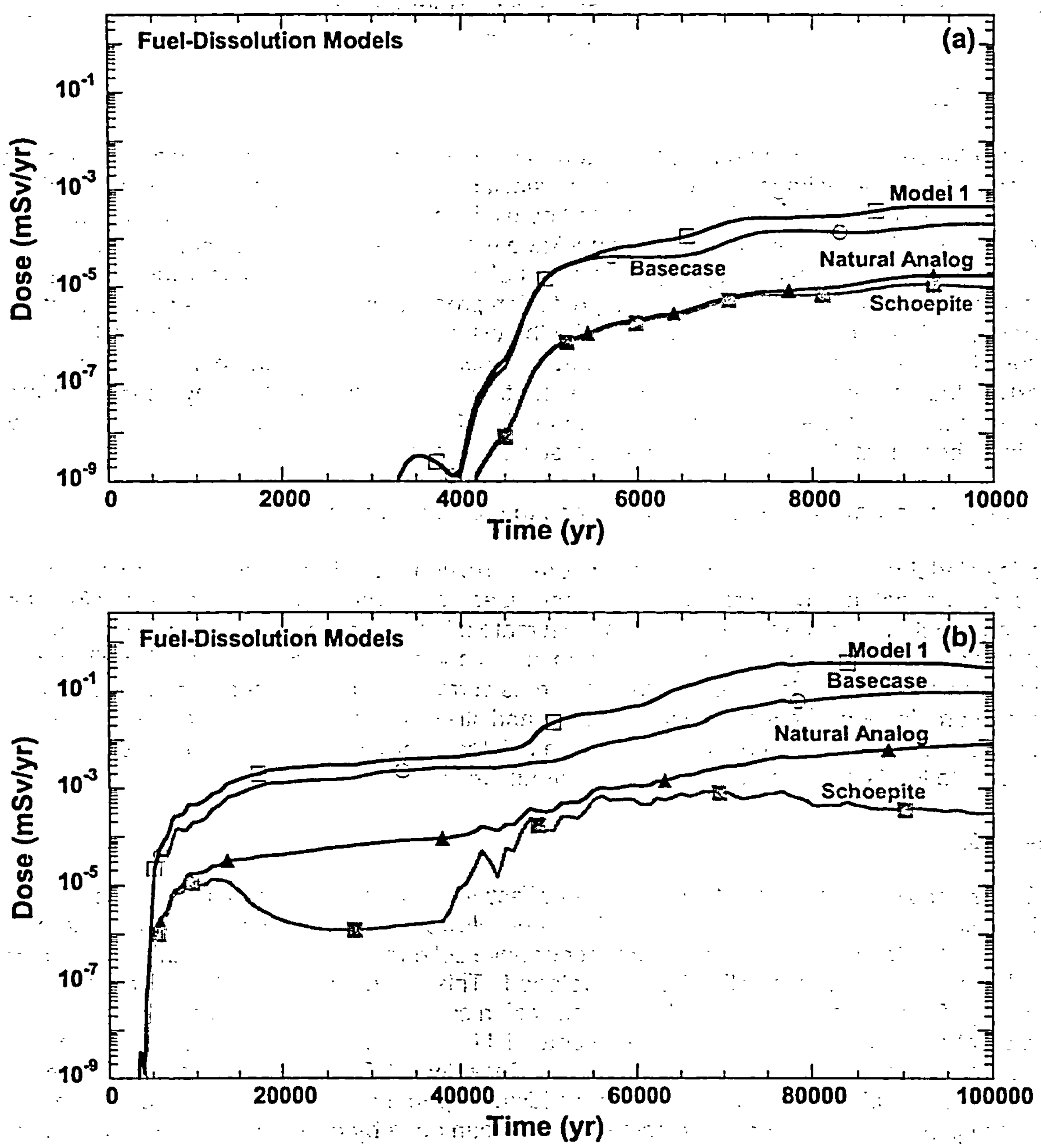


Figure 4-16. Ground Water Dose from the Basecase and the Fuel-Dissolution Alternative Conceptual Models for (a) 10,000 Years and (b) 100,000 Years, For 350 Realizations (Mohanty, et al., 2002, Figure 3-36)

as a result of creep caused by hoop stresses due to internal pressure, or mechanically, when subjected to loads associated with seismic events and rockfall.

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Discussion

DOE has considered that cladding can be an effective metallic barrier against the release of radionuclides from commercial spent nuclear fuel. However, little experimental evidence has been provided to support such assessment nor have solid technical bases for the assumptions included in the model abstraction been developed. This is the case, in particular, for the modeling of localized corrosion and stress corrosion cracking, as well as for the lack of consideration of hydride reorientation as a potential failure process that may be faster and, hence, more detrimental than unzipping alone. Recently, DOE has provided performance assessment calculations showing that the cladding degradation rate at the 95th percentile, or even complete neutralization, only increases the mean dose by one order of magnitude, and the dose is more than four orders of magnitude lower than that specified in the regulations at 10 CFR Part 63 for the reasonably maximally exposed individual (Figure 4-17). However, in their nominal case, DOE assumes that the fraction of failed cladding perforated before unzipping remains constant at 0.08 during the 10,000-year compliance period, reaching only 0.2 after 100,000 years (CRWMS M&O, 2000b). Also, these estimates of cladding protection do not consider the full range of possible failure mechanisms or their probabilities, and therefore, may overestimate the effectiveness of cladding as a barrier. In other international programs (e.g., France, Canada, Sweden, Finland), no credit is given to the cladding as a metallic barrier as a result of the uncertainties related to its integrity under repository conditions.

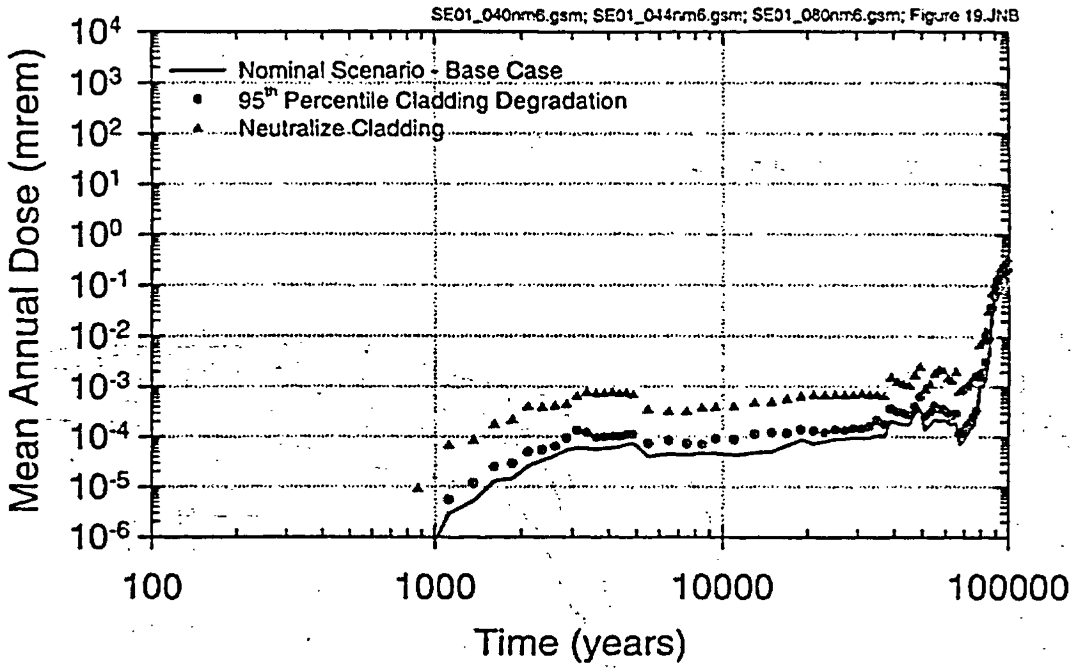


Figure 4-17. Sensitivity of Mean Annual Dose to the Commercial Spent Nuclear Fuel Cladding Degradation Rate (Bechtel SAIC Company, LLC, 2002. Note that Dose Estimates for Variations from the Basecase Do Not Represent Variations in Expected Risk because the Probability of the Variation Is Not Considered) (1.0 mrem = 0.01 mSv)

It is apparent in the TPA Version 4.1 Sensitivity Report (Figure 4-18) (Mohanty, et al., 2002) that the introduction of cladding protection decreases the dose at 10,000 years with respect to that for the basecase from 2×10^{-4} to 3×10^{-6} mSv/yr (2×10^{-2} to 3×10^{-4} mrem/yr). Release rates of highly soluble and mobile radionuclides like Tc-99 and I-129 account for most of the 10,000-year predicted dose, and are approximately proportional to the amount of spent nuclear fuel exposed. Other hazardous but less mobile radionuclides like plutonium and americium may not be as affected by the amount of spent nuclear fuel exposed, because their release is likely to be controlled by solubility limits.

Uncertainties

Cladding perforations may expose increasing areas of the spent nuclear fuel matrix to the in-package environment as a result of splitting (unzipping) caused by the oxidation of UO_2 pellets, either by air and water vapor or by liquid water. Perforations could exist in the cladding before waste emplacement and can develop by the corrosion and mechanical processes described above. Considerable uncertainties exist regarding the initial stage of cladding failure during which perforations occur, particularly in the case of corrosion processes. These uncertainties are mostly associated with uncertainties in the in-package environment and the initial condition of the spent nuclear fuel. A more significant range of uncertainties can be expected for high burnup fuel. Another concern is the potential for cladding failure under seismic conditions, rockfall, and drift collapse, with their associated uncertainties.

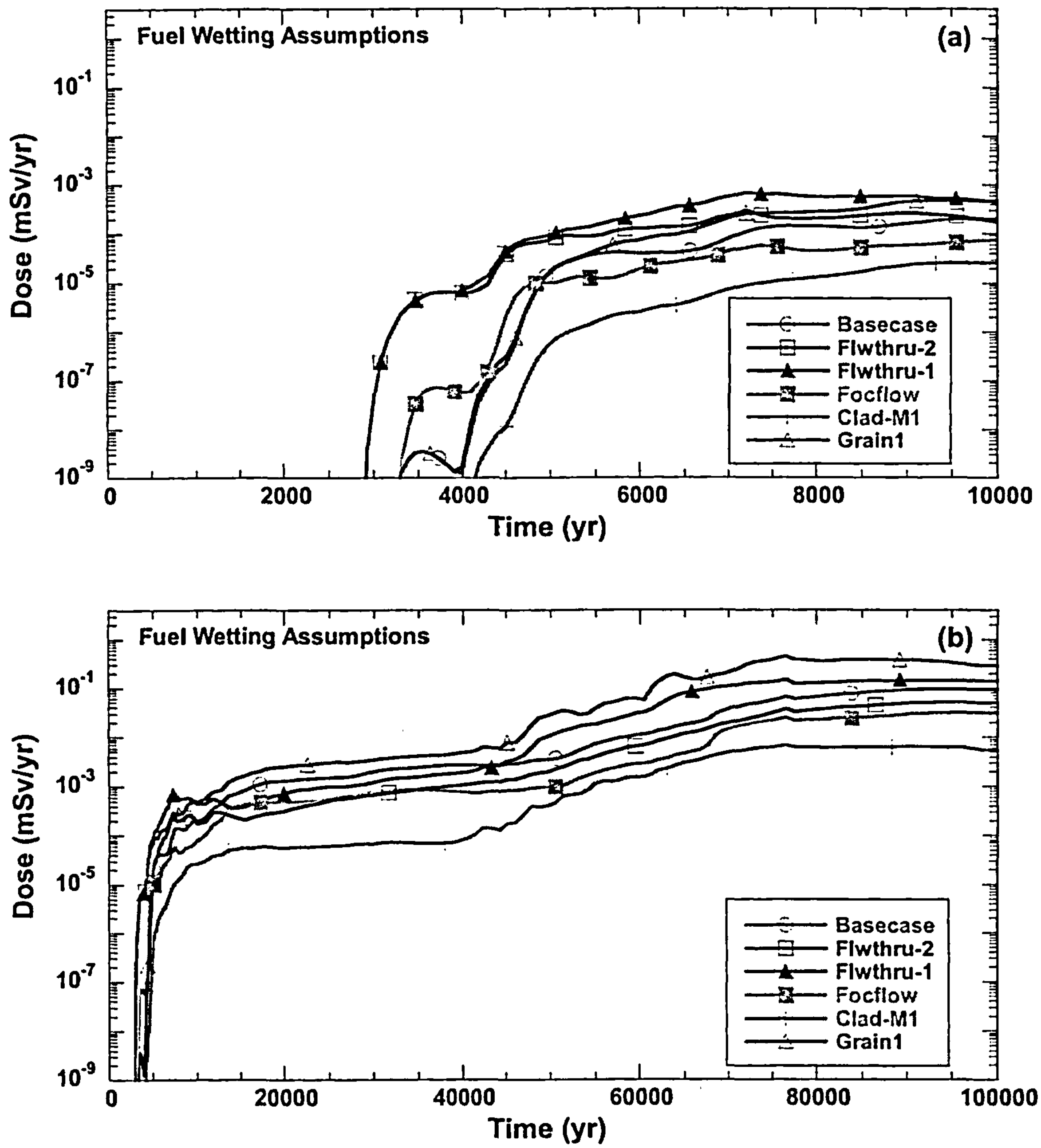


Figure 4-18. Effects of Cladding Credit: Ground Water Dose from the Basecase and the Fuel-Wetting Alternative Conceptual Models for (a) 10,000 Years and (b) 100,000 Years, Using the Mean Value Data Set (Mohanty, et al., 2002, Figure 3-37)

Solubility Limits: Medium Significance to Waste Isolation

Solubility limits effectively limit the release of many radionuclides.

Discussion

Solubility limits can be important factors in the release of radionuclides from the engineered barrier and ultimately to dose. Figure 4-19 shows the sensitivity of the DOE calculated doses to neptunium solubility. The degree to which radionuclide release to the environment is solubility-limited depends on the intricate interaction among the waste-form leaching rate, the degree of waste-form exposure to water, radionuclide half-life, radionuclide inventory, and the position of the radionuclide in the decay chain. Of the three radionuclides estimated to be major contributors to dose in a recent numerical study (i.e., Tc-99, I-129, and Np-237), only the release of Np-237 would be significantly decreased by its solubility limit (Mohanty, et al., 2003). However, 13 out of 20 radionuclides considered in this study exhibited solubility-limited behavior. Figure 4-20 plots the difference in cumulative release for each radionuclide from the waste packages between the basecase and a modified case in which the solubility limits for all radionuclides were set to an artificially high value. This figure shows that radionuclides such as americium and plutonium exhibit increased release when solubility limits are increased. Under the expected performance of other barriers, releases of radionuclides like plutonium and americium would not normally be seen because they are relatively immobile in the geosphere.

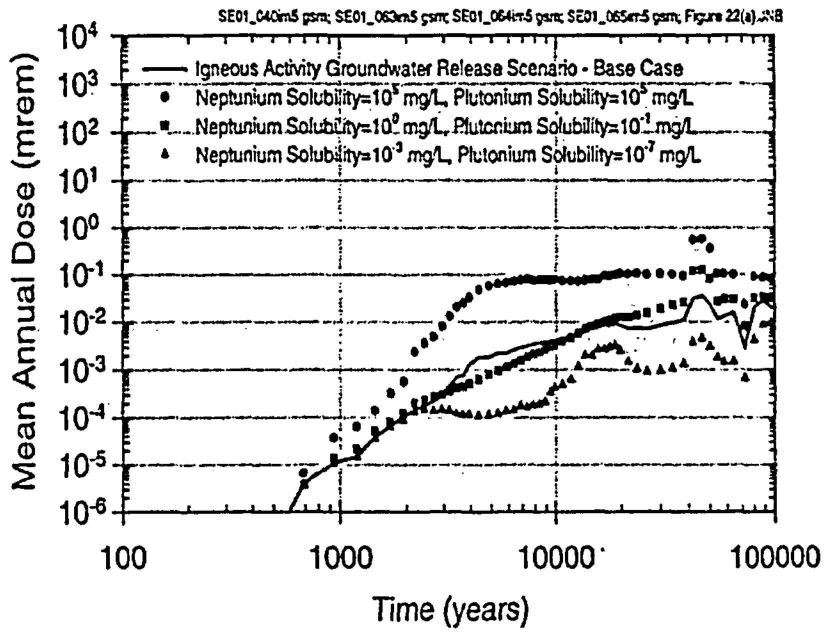
Uncertainties

The solubility value for particular radionuclides used in performance assessment calculations will depend on assumptions regarding the solubility controlling solid phase for the radionuclides of concern. The assumed solid phase may differ in its solubilities by several orders of magnitude. For some radionuclides, such as neptunium, incorporation into a low-solubility secondary phase is possible, but the evidence for this mechanism can be tenuous (Fortner, et al., 2003).

A necessary assumption in assigning solubility values pertains to the physical-chemical conditions of the system. The solubility of a radionuclide will depend on the composition of the aqueous phase as well as on its temperature and oxidation state. Inorganic and organic ligands that can form aqueous complexes with the radionuclide may be present. Complexation increases the amount of the radionuclide in the solution for elements such as uranium, neptunium, plutonium, and americium. Actinide solution chemistry in environmental waters would be dominated by hydroxide and carbonate complexation; thus, the solubility of actinide solids would be highly dependent on pH, aqueous carbonate concentration, and partial pressure of carbon dioxide gas. The solubility of some radionuclides depends strongly on their oxidation states.

In some cases, radionuclides released from the waste form may become sorbed to solid materials. This sorption could either hinder or enhance transport from the engineered barrier, depending on whether the substrates were immobile or mobile. In the former case, experiments with degrading spent nuclear fuel show a large fraction of plutonium and americium releases became attached to the container walls (Wilson, 1989). In the latter case, radionuclides that

(a) Igneous Activity Groundwater Release Scenario



(b) Nominal Scenario

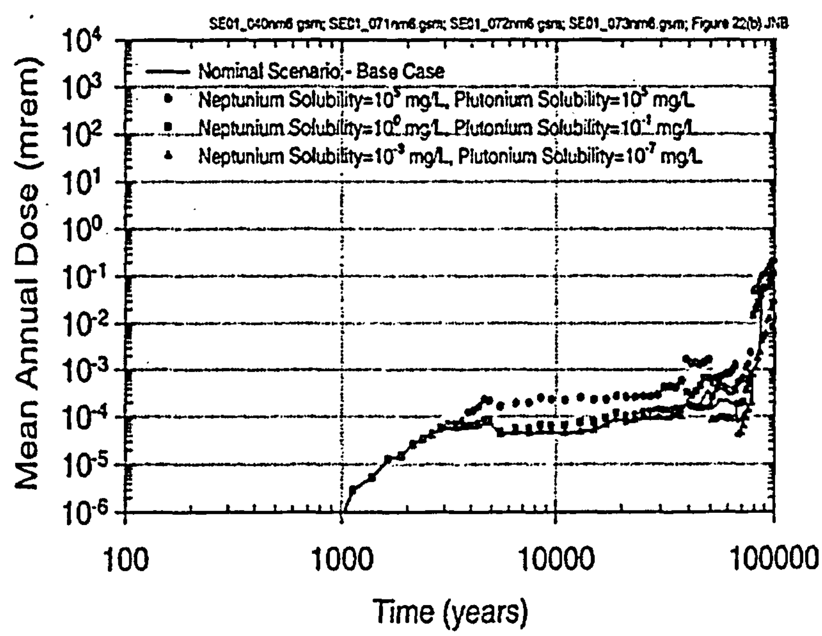


Figure 4-19. Sensitivity of Mean Annual Dose to Concentration Limits for Neptunium and Plutonium (Bechtel SAIC Company, LLC, 2002. Note that Dose Estimates for Variations from the Basecase Do Not Represent Variations in Expected Risk Because the Probability of the Variation Is Not Considered) (1.0 mrem = 0.01 mSv)

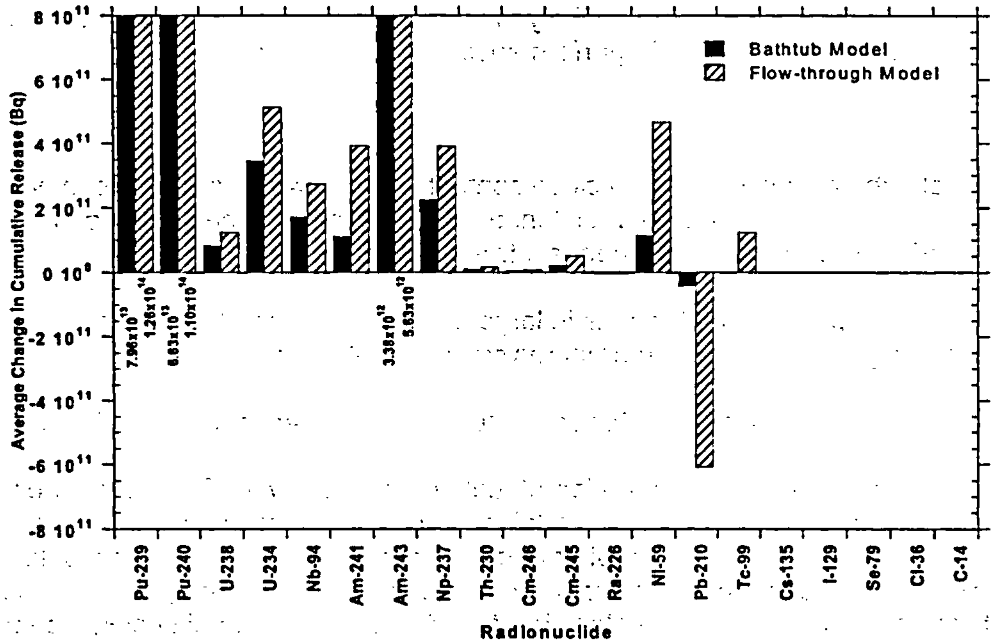


Figure 4-20. Average Change to the Nominal Scenario Cumulative Radionuclide Release in 10,000 Years When the Solubility Limit Is Specified as Ineffectivie in TPA Version 4.1 Code Simulations (i.e., Set to an Artificially High Value) (Mohanty, submitted)

become attached to colloids (e.g., hydrous ferric oxides generated by the corrosion of steel in the waste packages and ground support) might allow release of radionuclides in amounts greater than estimates based on solubility limits alone.

Mode of Release from Waste Package: Low Significance to Waste Isolation

The significance of diffusional release will depend on a number of assumptions such as water-film thicknesses, diffusion distances inside and outside the waste packages, unclogged openings, and a mechanism to sweep away contaminants, to keep the concentration gradients high. Advective releases rely on the quantity of water entering and leaving the waste package, and could be more significant than diffusion after degradation processes cause openings in the waste package that are sufficiently large to allow dripping water to come into direct contact with the waste. Processes leading to openings in the waste packages include localized corrosion, stress corrosion cracking coupled with mechanical loading events from dynamic and static rockfall loads, and intrusive igneous activity disruptive events.

<u>Discussion</u>

Scenarios capable of allowing diffusion in amounts that would be sufficient to cause significant releases are highly unlikely. There would have to be a continuous and substantial water pathway for diffusion and a mechanism to keep the concentration gradient high. Water films are likely to be thin or discontinuous. Under conditions where only water vapor is present in the drift, water films inside the waste package would be limited to layer thicknesses measured in tens of molecules or less. Mechanisms for flushing diffused radionuclides away from the waste package (i.e., to keep the concentration gradient high) are unlikely, requiring liquid water to drip onto cracks or holes in the waste package. Calculations of diffusion under any likely condition show that releases by this mechanism are unlikely to cause doses anywhere approaching the dose limits, even under the failure or underperformance of other barriers.

Uncertainties

Mechanisms whereby the rock is forced into close contact with the waste packages may enhance diffusion by lowering the external resistance. Such processes may include engineered backfill, infilling of drifts by collapse, and igneous intrusion.

Degradation of the waste package that results in large openings and short diffusion pathways inside the waste package would reduce internal resistance to diffusion.

Effect of Colloids on Waste Package Releases: Medium Significance to Waste Isolation

Colloids can form from the aqueous degradation of fuel and especially vitrified waste. For the degradation of fuel, dissolved radionuclides, in addition to colloids directly resulting from waste-form degradation, can attach to natural or anthropogenic (human-caused) colloids, especially iron oxyhydroxides formed from corrosion of the steel in the waste package and ground-support materials. Degradation of glass in vitrified waste can form clay colloids such as smectite and illite, which can also be the substrate for radionuclide attachment. Colloids can be transported out of the waste package primarily by advection in flowing water. However, colloids may be easily filtered once in a porous medium such as the invert, the Calico Hills vitric unit, and the alluvium.

Discussion

Colloids may be important to repository performance if sufficient experimental evidence indicates they will form in large amounts and not be removed in substantially the subsurface through coagulation and filtration. Figure 4-21 shows the results of a bounding approximation of colloid effects by eliminating all retardation of plutonium, americium, and thorium isotopes. These results led to significant increases in dose, although still below the 0.15-mSv/yr [15-mrem/yr] regulatory criterion (Contardi, et al., 1999; Mohanty, et al., 2003). However, these results were highly conservative because they assumed that all releases from the waste form would leave the waste package and not be removed by filtration or straining. Experimental results on plutonium and americium releases from spent nuclear fuel suggest that colloidal radionuclides easily become attached to surfaces such as the interior of the waste package, and may not be released easily (Wilson, 1989).

DOE has performed analyses to evaluate the sensitivity of colloids where plutonium and americium are irreversibly sorbed to waste-form colloids (Figure 4-22). The DOE analyses

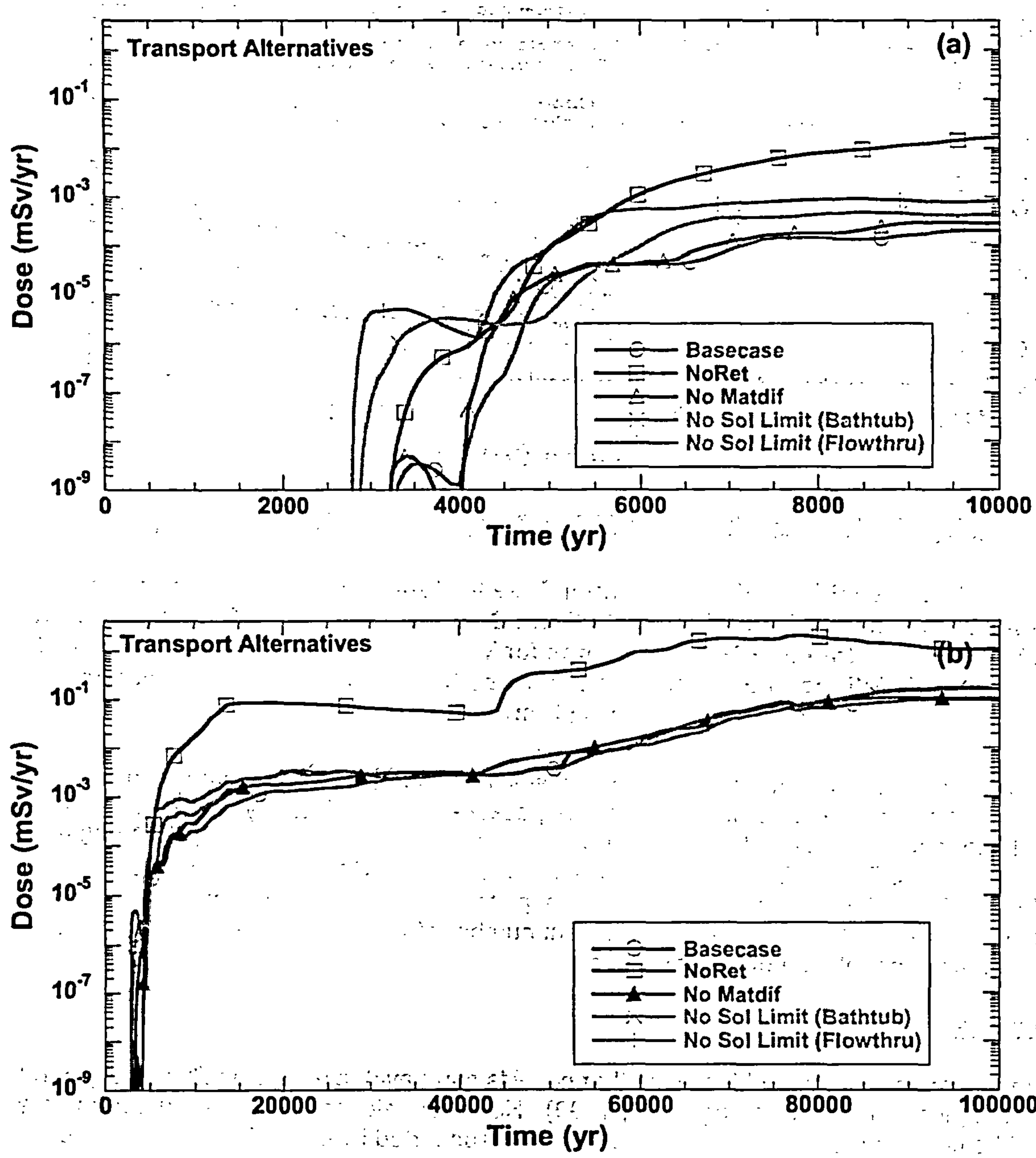
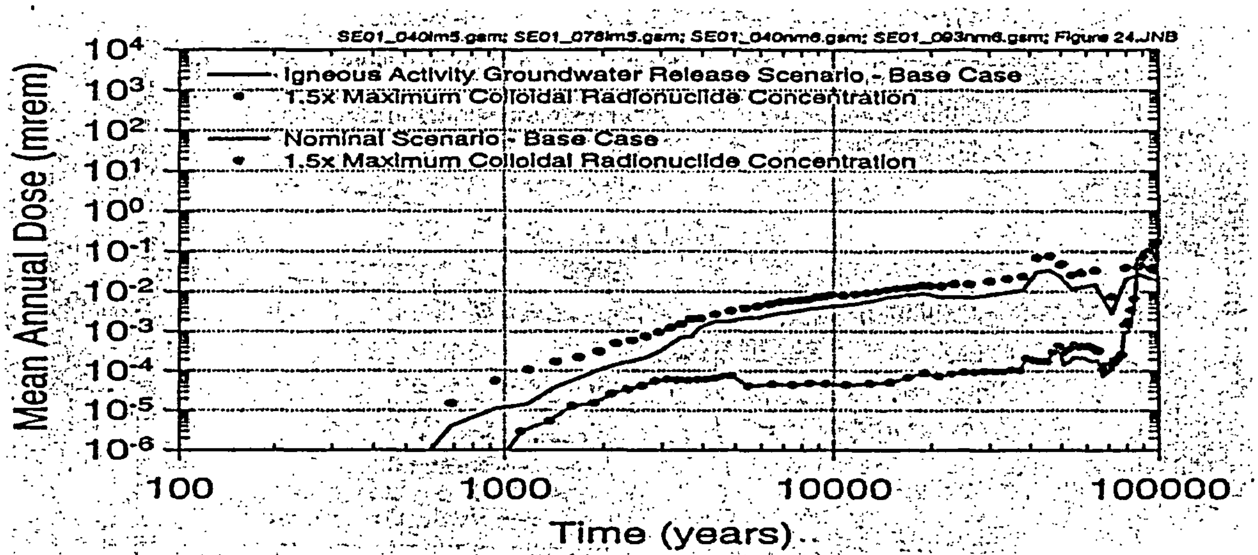


Figure 4-21. Dose Curves for Alternative Transport Models in TPA Version 4.1 Code Basecase Model (Basecase); Assumption of No Retardation (NoRet); Assumption of No Matrix Diffusion (No Matdif); and Assumption of No Solubility Limits (no Sol Limit) with the Bathtub and Flow-Through Models. The NoRet Curve Provides a Conservative Upper Bound to Colloidal Effects Simply by Assuming No Retardation of Plutonium, Americium, and Thorium Isotopes. The NoRet Case Yields Doses about One Order of Magnitude Higher than the Basecase, Which Is Less Than 10^{-3} mSv/yr [10^{-1} mrem/yr] (Mohanty, et al., 2002, Figure 3-38).



NOTE: Each mean annual dose curve is a probability-weighted average. However, the results of the sensitivity studies do not correspond to expected risk (see Introduction to Section 3).

Figure 4-22. Sensitivity of Mean Annual Dose to Concentration of Plutonium and Americium Irreversibly Sorbed to Waste Form Colloids (Bechtel SAIC Company, LLC, 2002, Figure 24. Note that Dose Estimates for Variations from the Basecase Do Not Represent Variations in Expected Risk because the Probability of the Variation Is Not Considered) (1 mrem = 0.01 mSv)

indicated that colloidal concentrations were only significant in 10,000 years, under an intrusive igneous event, wherein a large number of waste packages are significantly damaged. The potential importance of colloidal transport, if all waste packages were to fail within 10,000 years, is evident in the DOE Total System Performance Assessment—Site Recommendation (CRWMS M&O, 2000b), which indicated colloidal plutonium is the second highest dose contributor after 70,000 years, when a significant number of waste packages are estimated to have failed, allowing release of radionuclides.

<u>Uncertainties</u>

Some measurements in the field indicate that colloids can travel relatively easily in the ground under the right conditions (Kersting, et al., 1999). However, release and transport parameters for colloid effects for the proposed repository are not supported by extensive field and laboratory data and near-field effects are not well-constrained.

Invert Flow and Transport: Low Significance to Waste Isolation

The invert has a short travel pathway relative to the geologic barriers and is not expected to have a significant effect on radionuclide transport in the aqueous phase.

Discussion

Although the invert is likely to consist of a porous or crushed rock material and have desirable properties for radionuclide sorption and possibly colloid filtration, it is very thin compared to other porous materials in the pathway of radionuclide transport, such as the Calico Hills vitric unit and alluvium. Performance assessment studies showed practically no effect of eliminating the invert as a barrier (Mohanty, et al., 2002).

Uncertainties

Any benefit of the invert may be lost over time if precipitation of minerals from ground water or alteration of minerals in the material by heat cause the porosity to decrease, thereby allowing short-circuiting around the porous material.

Criticality: Low Significance to Waste Isolation

The potential for criticality to occur either within the waste package or in the geosphere is considered unlikely; in addition, if it were to occur, the consequences would be limited (e.g., at most doubling of the inventory of fission products and locally increasing the temperature).

Discussion

Commercial spent nuclear fuel that would be stored in the potential repository cannot become critical unless there is sufficient water or other neutron moderator material in the waste package, and criticality controls (e.g., poisons) are removed or rendered ineffective. Neither the drip shield nor the waste package are expected to fail within 10,000 years. Furthermore, their failure is not expected to result in water sufficiently filling the waste package to submerge fuel elements. Criticality is also limited by the presence of nuclear poisons such as the borated stainless steel fuel baskets and the actinides and fission products within spent nuclear fuel. The boron in the stainless steel may eventually leach out, depending on the corrosion rate of the material and the rate of water circulation through the waste package to carry it away.

Should a criticality eventually occur, the event has been postulated to be either steady-state or transient in nature. In the steady-state case, power from the nuclear chain reaction could be limited by the availability of the water moderator, which would be controlled by the balance of heat generation and removal of heat by conduction and evaporation. The consequences of this situation would be modest, leading to elevated temperature of the waste package, and the generation of additional radioactive inventory in the spent nuclear fuel (Figure 4-23). However, steady-state criticality events may extend for thousands of years at low power levels provided that the waste package remains filled with water. Transient criticality could occur if there were rapid reactivity insertion caused by, for example, the sudden rearrangement of fuel and the water moderator from seismic shaking of partially failed waste packages, or seismically induced sloshing providing more moderation to the less-burned ends of the fuel rods. A transient criticality could potentially disrupt the waste form, cladding, and the waste package through a steam explosion (Figure 4-24).

Criticality outside of the waste package is not expected because there are no likely mechanisms that could reasonably reconcentrate the released fissile materials into a critical configuration.

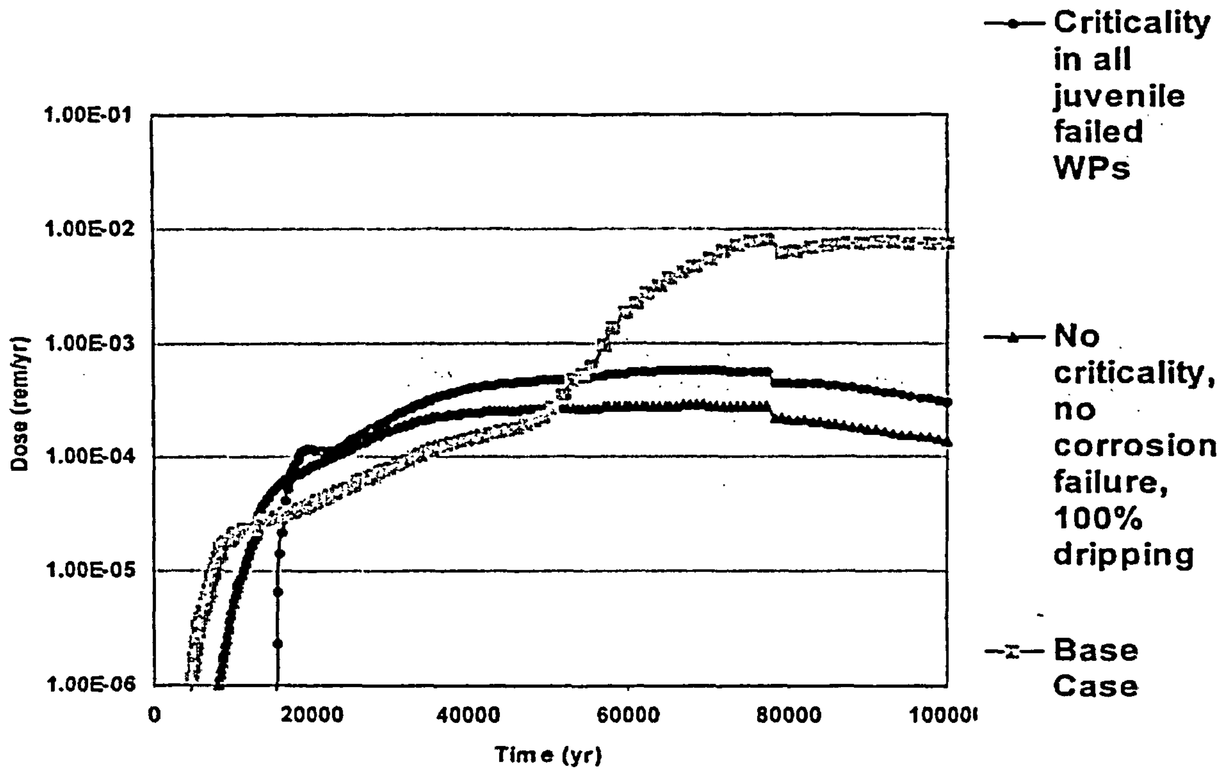


Figure 4-23. Dose Consequence of In-Package Steady-State Criticality (Waste Packages) (Mohanty, et al., 2002, Figure G-2) (1.0 rem/yr = 0.01 Sv/yr)

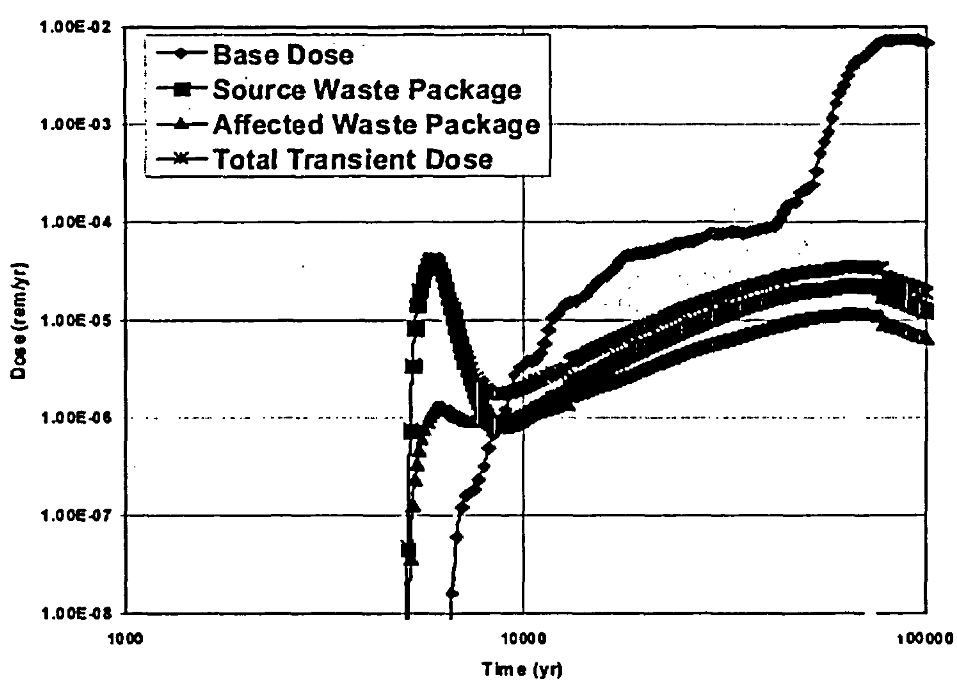


Figure 4-24. Dose Consequence of In-Package Transient Criticality (Mohanty, et al., 2002, Figure G-3) (1.0 rem/yr = 0.01 Sv/yr)

Uncertainties

The identification of scenarios resulting in a significant number (greater than 40) of simultaneously long-lived critical waste packages or transient criticality would merit further refinement of the consequence evaluation only if they could be shown to be likely to occur.

4.3.5 Climate and Infiltration (UZ1)

Risk Insights:	
Present-day Net Infiltration Rate	Medium Significance
Long-term Climatic Change	Medium Significance

4.3.5.1 Discussion of the Risk Insights

Present-day Net Infiltration Rate: Medium Significance to Waste Isolation

Estimates of present-day net infiltration rates are important for estimating the deep percolation rate. The deep percolation rate, in turn, affects the quantity of water coming into contact with the waste packages and waste form.

Discussion

Some of the precipitation that falls on Yucca Mountain is expected to move into the bedrock as net infiltration. Estimates of present-day net infiltration rates are used to directly estimate deep percolation rate at the repository horizon, assuming no lateral diversion of flow. Some fraction of this deep percolation is expected to seep into the repository drifts and come into contact with the waste packages, and, potentially, the waste form. Water coming into contact with waste packages will likely affect the integrity of the waste packages and the release of radionuclides from the waste form. The quantity of water has a more significant effect on the rate of release of radionuclides that have lower solubility limits. Of these radionuclides, Np-237 has the greatest potential to contribute to dose during the period of regulatory interest. Deep percolation rate and, thus, net infiltration, also directly affects the transport of radionuclides from the repository horizon to the saturated zone.

Net infiltration is directly related to climatic and surface conditions. Precipitation occurs episodically at Yucca Mountain, with years between rain events that lead to infiltration below the surface. Near-surface processes such as evaporation, plant transpiration, and overland runoff reduce net infiltration to approximately 5 percent of total precipitation on an annual average basis (Figure 4-25). Net infiltration estimates are the highest along the Yucca Mountain crest and the eastward trending ridge tops, because of the incidence of thin soils, precipitation increasing as a function of elevation, intermediate permeability of the caprock units, and high permeability of the open and soil-filled fractures. Surface water runs off toward channels and the toes of steep slopes and can increase net infiltration at these locations, though these locations tend to have relatively small surface areas.

Thin soil layers allow infiltration to enter fractures in the underlying bedrock more quickly and, thus, escape loss through evaporation. Simulations of bare soil infiltration indicate that mean

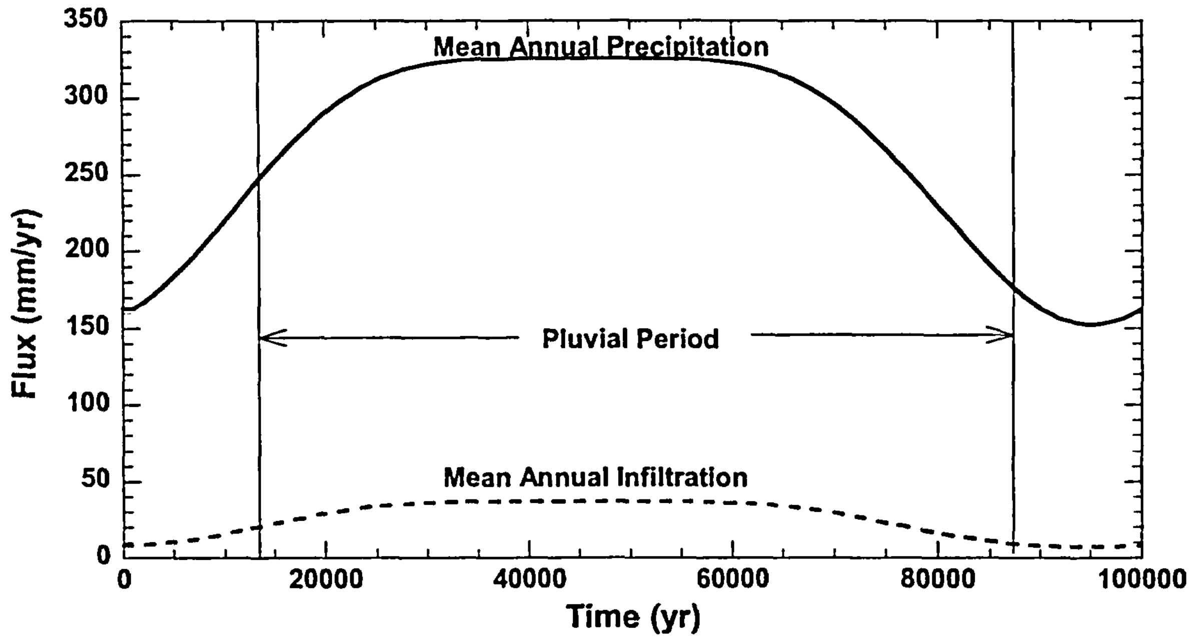


Figure 4-25. Mean Annual Precipitation and Infiltration at the Repository Horizon Averaged Over All Subareas and Encompassing Both the Current and Pluvial Periods for the Mean Value Data Set (Mohanty, et al., 2002, Figure 3-1)

annual infiltration is strongly dependent on surface soil thickness (Stothoff, et al., 1997; Stothoff, 1999). Mean annual infiltration estimates are generally higher for areas where soil thickness is 0.5 m [20 in]. Whereas exposed bedrock promotes runoff, the high permeability of soils allows for storage of water from intense rain events. Once the water capacity of thin soils is filled, open and soil-filled fractures in the bedrock readily transmit water to sufficient depth beyond the reach of transpiring plant roots, thus becoming net infiltration.

At Yucca Mountain, most of the repository footprint is overlain by thin soil layers less than 0.5 m [20 in] thick, with significant variability across the site. Both the DOE and NRC soil depth models qualitatively represent the system, in their respective performance assessment models, with consideration of the significant variability across the site.

The spatial variation in precipitation, soil thickness, and bedrock properties over the repository footprint have been explicitly incorporated into the calculation of mean annual infiltration, and thus deep percolation, for each subarea of the repository.

Using TPA Version 4.1 code in sensitivity analyses, Mohanty, et al. (2002) determined that the mean areal average infiltration into the subsurface was one of the two most influential parameters corresponding to overall peak risk (Table 4-5). The peak dose estimates from each realization were also found to be most sensitive to the mean areal average infiltration into the subsurface (Figure 4-26). In addition, the subarea wetted fraction, which is correlated to mean annual net infiltration, was also found to be an influential parameter (Table 4-5 and Figure 4-26).

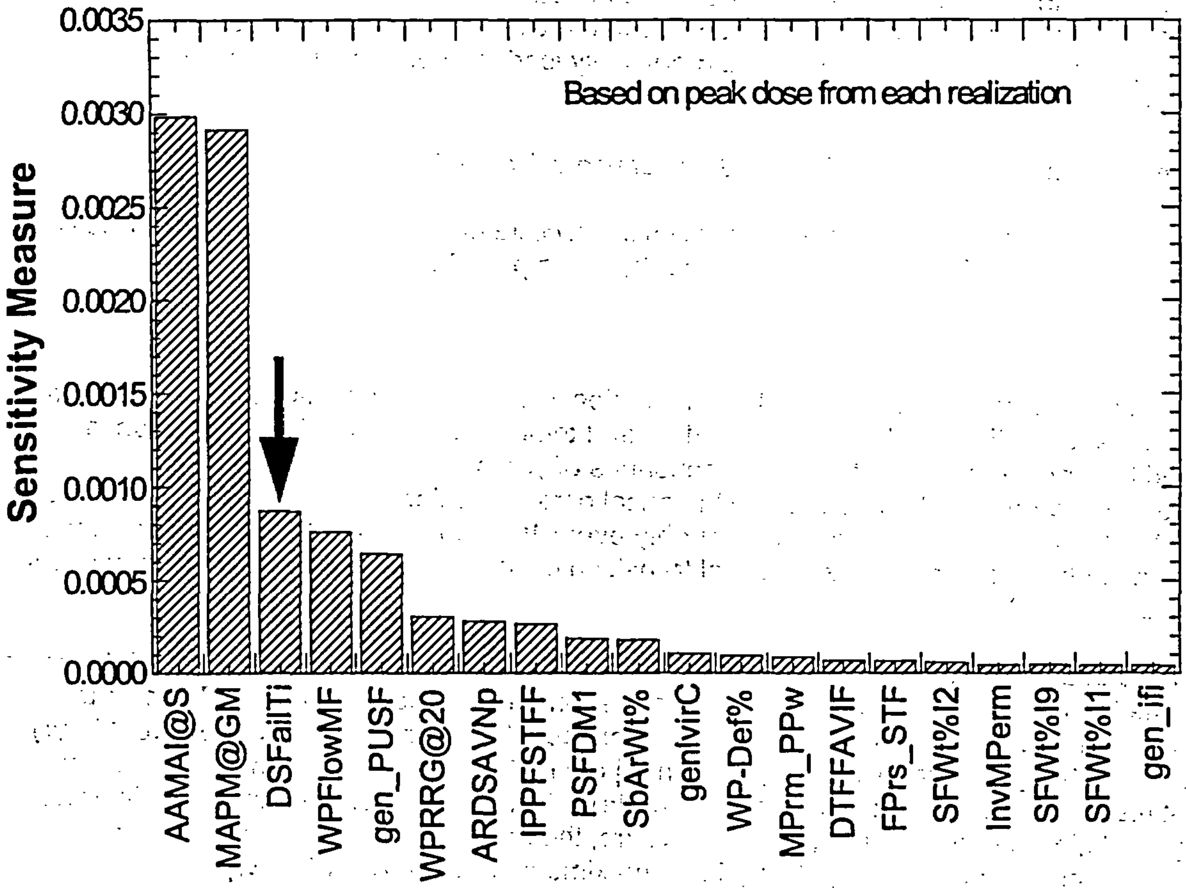


Figure 4-26. Influential Parameters Identified Using the Peak Dose from Each Realization (Mohanty, et al., 2002, Figure 4-6)

Uncertainties

Estimates of uncertainty for net infiltration are mostly based on modeling analyses that take into consideration the uncertainty in individual model parameters. The average net infiltration rate for the repository footprint area is estimated, in the TPA Version 4.1 code, to range from 4 to 13 mm/yr [0.2 to 0.5 in/yr] for the modern climate. The DOE performance assessments probabilistically consider a set of low-, medium-, and high-infiltration scenarios, which, for the modern climate conditions, spans a similar range of area-averaged infiltration rates. Reducing the uncertainties in net-infiltration estimates remains difficult because it is not possible to accurately measure net infiltration in environments where thin soils overlay bedrock. It is also difficult to estimate appropriate representative values for bulk bedrock permeability and soil thickness, which are important input parameters for net-infiltration models. Nevertheless, confidence in the current range of uncertainty estimated for net-infiltration rates is gained through other lines of evidence, such as analysis of temperature data and chloride content in perched water and in rock matrix.

A representative soil thickness is not easily supported by measurements because of the high degree of natural variability over small spatial scales. However, because most of the potential repository footprint at Yucca Mountain is estimated to be overlain by soil layers less than 0.5 m (20 in) thick, and is correspondingly represented in the DOE and NRC soil depth models, the uncertainty in the soil cover thickness would not likely lead to overly optimistic estimates of repository performance.

Long-Term Climatic Change: Medium Significance to Waste Isolation

Long-term climatic change, in terms of changes in precipitation and temperature, will directly affect the rate of net infiltration and, subsequently, deep percolation rate.

Discussion

One of the main processes that control net infiltration is climatic conditions, expressed in terms of temporal and spatial variation of precipitation and temperature. Annual net infiltration is expected to vary over the long term (i.e., thousands of years) because of variation in temperature and precipitation. Based on historical data and paleoclimatic markers, a full cycle of climatic changes is assumed to occur roughly every 100,000 years. Monsoonal conditions (wetter and hotter than present) and glacial transition conditions (wetter and cooler) may occur within the next 10,000 years.

In the NRC analyses (e.g., the TPA Version 4.1 code basecase scenario), the full glacial climate is assumed not to occur during the 10,000-year performance period. Figure 4-27 shows the mean net infiltration rates across all subareas is expected to increase from 8 mm/yr (0.3 in/yr) for the present-day climate to 15 mm/yr [0.6 in/yr] during the 10,000-year period of regulatory interest (i.e., a partial transition to a glacial climate), which is less than a factor of two increase. During a full glacial period starting at 30,000 years, the net infiltration rate is expected to range between a minimum of 4 mm/yr [0.2 in/yr] to a maximum of 30 mm/yr [1.2 in/yr].

In particular, the DOE performance assessment approach assumes an early and instantaneous transition to a monsoonal climate in an average time of 600 years from present and another instantaneous change to a glacial transition climate in about 2,000 years from present. These climate changes have a significant effect on net infiltration estimates. For example, in the DOE medium-infiltration case, the area-averaged net infiltration over the unsaturated zone model domain is increased from 4.6 to 12.2 mm/yr [0.2 to 0.5 in/yr] after the change to a monsoonal climate, and subsequently increases to 17.8 mm/yr [0.7 in/yr] for the glacial transition climate. Thus, the DOE performance assessment approach considers approximately a factor of four increase in net infiltration (for the medium-infiltration case) as a result of climate change during the performance period. As previously discussed in this section, this increased net infiltration significantly affects both drift seepage rates and the rate of radionuclide transport in the unsaturated zone.

Uncertainties

Important uncertainties pertaining to climate change are the timing of the onset of climate change, and the magnitude of temperature and precipitation changes that may occur as a result of the climate changes. NRC and DOE use different approaches to estimate future climatic conditions. NRC uses a smooth transition from the modern climate to a glacial-transition climate, combined with random sampling of a precipitation multiplier and a temperature shift. DOE uses an instantaneous step-function approach, combined with upper-bound, mean,

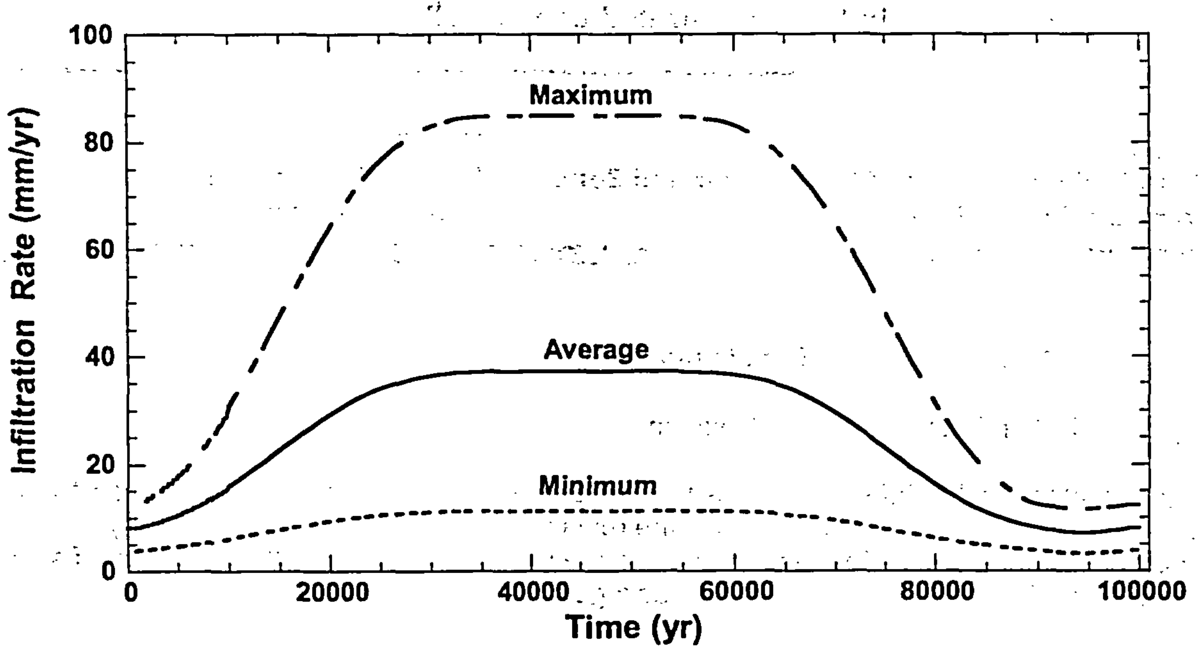


Figure 4-27. Mean, Maximum, and Minimum Infiltration Rates in the Unsaturated Zone for All Subareas (The Subarea Average Infiltration Rate Is Obtained by Averaging Over All 350 Realizations.) (Mohanty, et al., 2002, Figure 3-21)

and lower-bound precipitation and temperature records, which results in higher estimates of net infiltration rates over the 10,000-year performance period. The DOE step-function approach is based on recent evidence presented in the scientific community supporting much faster climate transitions than previously believed likely to occur. The DOE upper-bound, mean, and lower-bound precipitation and temperature records are based on measurements obtained from a range of analog sites that are believed to adequately bound the likely magnitude of climate changes that might occur at Yucca Mountain.

Neither NRC nor DOE approaches consider the potential effects of anthropogenically induced global warming. In general, the exclusion of anthropogenic effects on climate is believed to be conservative because global warming would increase temperature and reduce precipitation in the Yucca Mountain region.

Another model uncertainty is that periods of climate transition may lead to increased net infiltration as vegetation and soil thickness (e.g., erosion) do not immediately adjust to the new climate conditions; however, climate-induced changes in vegetation and soil cover would be relatively short-lived compared to the 10,000-year performance period, and thus this uncertainty is believed to be relatively unimportant.

4.3.6 Flow Paths in the Unsaturated Zone (UZ2)

Risk Insights:	
Seepage	High Significance
Hydrologic Properties of the Unsaturated Zone	Medium Significance
Transient Percolation	Low Significance

4.3.6.1 Discussion of the Risk Insights

Seepage: High Significance to Waste Isolation

Seepage of water into the drifts determines the amount of water that comes into contact with the drip shields and waste packages and affects the release and transport of lower-solubility radionuclides (e.g., Np-237). The amount of seepage is expected to affect the formation of salts on the surfaces of the drip shield and waste packages.

Discussion

Seepage is important for estimating releases from the repository because: (i) the amount of seepage affects the release of radionuclides that have low solubility limits, (ii) the spatial variability in seepage affects the number of waste packages that are estimated to be dripped on, and (iii) the amount of seepage affects the formation of salts on the surfaces of the drip shield and waste package. In part, because of the technical difficulties in determining the location and extent of dripping, performance assessments have generally assumed that dripping will occur in a significant portion of the repository (e.g., on the order of 25 percent) and a portion of this dripping water will enter breached waste packages.

Releases are estimated to be greatest where dripping water (seepage) enters a waste package and radionuclides are transported by the water out of the package. Thus, the spatial variability of seepage will affect releases by affecting the number of waste packages that are dripped on. If only a small number of waste packages experience dripping, the estimates of dose would be expected to diminish accordingly.

Seepage is expected to be the primary mechanism for transporting radionuclides out of the waste package. The amount of dripping water is not expected to significantly affect radionuclides with high solubility limits (e.g., I-129 and Tc-99) because estimates indicate only a small amount of water is needed to mobilize these radionuclides. However, solubility-limited radionuclides (e.g., Np-237 and Am-241), which comprise the bulk of the radionuclide inventory, can be affected by the amount of seepage (Table 4-6). Estimates indicate these radionuclides are generally slowed or retarded during transport in the geosphere during the first 10,000 years.

Seepage also affects the rate of corrosion of the drip shield and waste package. The formation of aggressive salts due to evaporation of seepage on the waste package may result in accelerated corrosion. These issues are discussed in greater detail in Sections 4.3.1 and 4.3.3.

Table 4-6. Water Flow into Waste Package Water Influx Sensitivity				
	WP Breach at 5,0000 Years		WP Breach at 1,000 Years	
Nuclide	Low Flow	High Flow	Low Flow	High Flow
Tc-99	>7,000	>7,000	>7,000	3,100
I-129	>7,000	>7,000	>7,000	6,700
NP-237	>7,000	120	>7,000	40
Am-241	>7,000	65	>7,000	1
Pu-240	>7,000	2	>7,000	1
*Packages Needed to Release {15 mrem/year [0.15 mSv/year]} at Drift Wall—No Geologic Delay				

Uncertainties

Quantitative assessments of potential seepage of water into repository drifts and onto waste packages are complicated by factors such as heterogeneity in the unsaturated zone, thermal perturbations to the flow field, capillary processes in fracture networks intersecting large openings, drift degradation, and thermal effects. Current approaches estimate the location and amount of dripping based on a variety of information (e.g., mining experience, numerical modeling, and field experiments) to provide a range for expected behavior. It is difficult to accurately quantify the effect of the waste heat on the unsaturated flow field. However, the uncertainties cannot increase dripping by more than a factor of four, at most, because performance assessments have generally assumed dripping will occur in a significant portion of the repository (e.g., on the order of 25 percent). The waste heat is expected to cause areas of evaporation and condensation in the unsaturated zone, especially during the first few hundred years when it is greatest (e.g., waste package temperature of approximately 170 °C [338 °F]. The effects of this temperature change on drift seepage and relative humidity are important for estimating the effects of seepage water chemistry and deliquescent salt formation on corrosion rates of the drip shields or waste packages. (See also Section 4.3.3.) Generally, these effects are evaluated in performance assessments by considering different water chemistries and deliquescent salt formations in conjunction with corrosion, rather than explicitly representing the spatial and temporal variation in seepage and water chemistries.

Hydrologic Properties of the Unsaturated Zone: Medium Significance to Waste Isolation

For unsaturated zone flow paths that occur mainly within fractured welded or zeolitized tuff units, where matrix conductivities can be significantly lower than the percolation rate, the unretarded radionuclide traveltimes from the repository horizon to the water table are on the order of a few tens of years, because water flows primarily in fractures. Longer unsaturated zone traveltimes, on the order of several hundreds of years, are estimated for areas beneath the repository where the Calico Hills nonwelded vitric unit is present. The longer traveltimes in the Calico Hills nonwelded vitric unit are attributed to its relatively large matrix conductivity such that water tends to flow in the matrix rather than the fractures. The areal extent and thickness of the Calico Hills nonwelded vitric unit are considered to be moderately important aspects of unsaturated zone flow and transport.

Discussion

The Calico Hills nonwelded vitric unit is characterized by a relatively large matrix hydraulic conductivity; thus, for the range of anticipated percolation rates, the water flow in this unit is expected to remain in the matrix (i.e., no fracture flow) and be slow. Currently, the NRC performance assessment estimates that approximately half of the repository footprint will be underlain by sufficient thickness of the Calico Hills nonwelded vitric unit to have a significant effect on performance. If the thickness were to increase over a significantly larger portion of the footprint (e.g., 90 percent or greater), the unsaturated zone below the potential repository would have an ever increasing effect on performance. For example, Winterle, et al. (1999, Figure 2-2) evaluated the effects of Calico Hills nonwelded vitric unit extent and thickness using the TPA Version 3.2 code. The original basecase model for the TPA Version 3.2 code represented the Calico Hills nonwelded vitric unit beneath only two of seven potential repository subareas. Winterle, et al. (1999) stated that available borehole data suggest the presence of at least thin lenses of nonwelded vitric layers {as thin as 2 m [6.6 ft]} underneath all potential repository subareas. The Winterle, et al. (1999) analysis with the TPA Version 3.2 code indicated that consideration of Calico Hills nonwelded vitric unit layers under all subareas resulted in a reduction in the 10,000-year peak dose by a factor of about four.

Additionally, Figure 4-28 depicts unretarded radionuclide traveltimes from TPA Version 4.1 code analyses that fall into two distinct categories. The first category reflects flow paths with rather short unsaturated zone traveltimes (tens of years) and is representative of portions of the repository where the Calico Hills nonwelded vitric unit is not present beneath the repository (Figure 4-29). The second category represents much longer traveltimes (on the order of several hundreds of years) and is representative of areas beneath the potential repository primarily where the Calico Hills nonwelded vitric unit is present (Mohanty, et al., 2002, Section 3.3.5). If the unretarded traveltime is 500 years or longer, and the retardation factor is at least 20, radionuclides will not reach the water table within the regulatory period of 10,000 years. Current information indicates that a significant fraction of the inventory of the potential repository has retardation factors greater than 20. (See Section 4.3.7.) Current information indicates that approximately half the potential repository footprint is underlain by a sufficient thickness of the Calico Hills nonwelded vitric unit to have a significant effect on unsaturated zone unretarded radionuclide traveltimes. The DOE total system performance assessment includes a similar areal and thickness distribution of the Calico Hills nonwelded vitric unit, as is modeled in total TPA Version 4.1. The DOE sensitivity studies of unsaturated zone transport times, presented at the radionuclide transport technical exchange held in December 2000, also indicate that the Calico Hills nonwelded vitric unit is important for longer traveltimes.

Uncertainties

The thickness and areal extent of the Calico Hills nonwelded vitric unit directly below the potential repository are difficult to estimate precisely because there is a limited number of exploratory boreholes within the potential repository footprint. However, previous analyses have assessed the effect of this uncertainty (Winterle, et al., 1999).

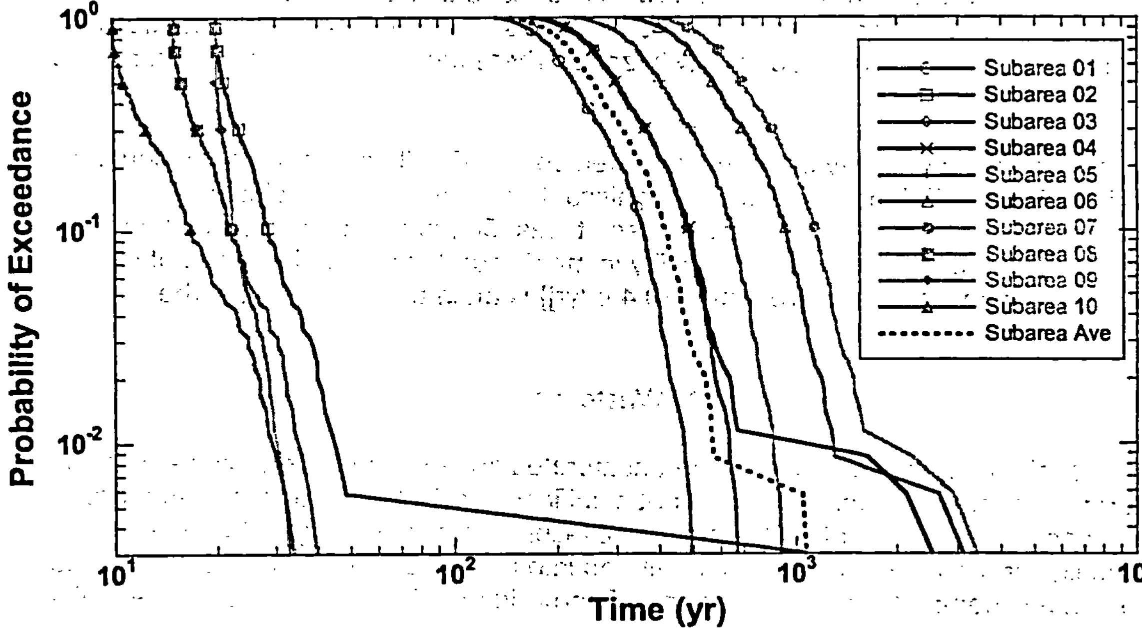


Figure 4-28. Complementary Cumulative Distribution Function of Unsaturated Zone Unretarded Radionuclide Traveltimes for Each of the 10 Repository Subareas and the Average of All 10 Areas (Based on 350 Realizations) (Mohanty, et al., 2002, Figure 3-30)

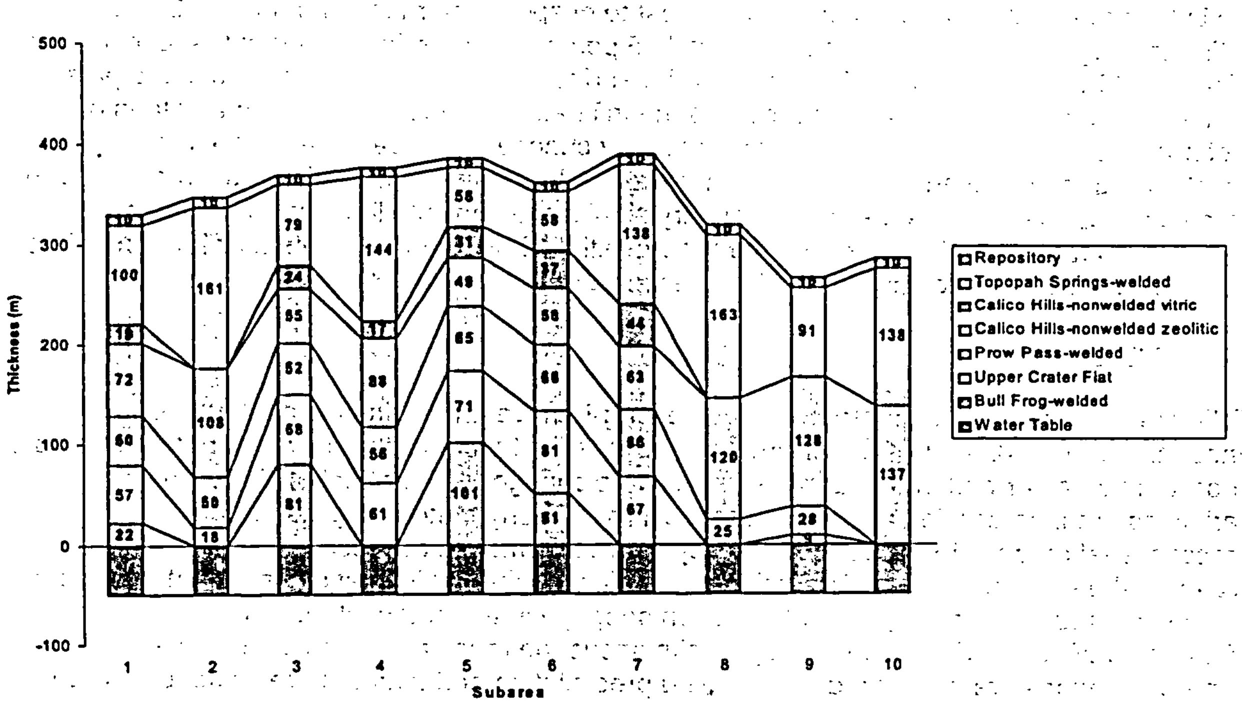


Figure 4-29. Depiction of the Stratigraphic Thicknesses Below Each of the 10 Repository Subareas (Mohanty, et al., 2002, Figure 3-9)

The flow paths in the unsaturated zone are also uncertain because of the potential for focusing of flow into fingers of flow rather than uniform flow or horizontal diversion of flow. It is anticipated that perturbations from focused flow will not have a significant potential for increasing consequences. For example, horizontal diversion of flow around low conductivity increases the flow path in a higher-conductivity zone, where there will be greater potential for matrix flow.

Values for the matrix conductivity of the unsaturated zone tuff units are important when the matrix conductivity is sufficiently large that a significant fraction of the percolation can be expected to flow in the matrix (e.g., conductivities at least 50 percent of the percolation rates). Representation of the uncertainty and variability in matrix conductivity in the range of the anticipated percolation rates {e.g., 10 mm/yr [0.4 in/yr]} is an important aspect of the unsaturated zone performance.

Transient Percolation: Low Significance to Waste Isolation

Episodic or transient percolation through the unsaturated zone below the root zone caused by short-term variation in precipitation does not significantly affect the spatial nor temporal variability of seepage into the drifts. After a precipitation event, infiltrating water moves in pulses vertically through the fractured rock unit and into the underlying rock units, where the pulses are variably damped in the Paintbrush tuff nonwelded unit into more steady vertical flow.

Discussion

Rainfall at the Yucca Mountain site is highly episodic, generally occurring over short periods of time. A small amount of the annual rainfall is estimated to contribute to net infiltration, whereas the bulk of the rainfall at Yucca Mountain is lost to evapotranspiration and runoff. Current estimates suggest, on average, approximately 5 percent of the rainfall contributes to infiltration (Figure 4-30). Although the infiltration near the surface is expected to be episodic, the pulses of infiltration are expected to be dampened as the infiltration moves deep (e.g., many tens of meters) below the surface. Although the rate may change from year to year, it is modeled as constant within any given year. As shown in Figure 4-30, the net infiltration (assumed to be the same as seepage in this figure) does not vary significantly despite larger changes in the precipitation rate. This is especially true for the initial 10,000 years, because infiltration at later years is influenced by cooler temperatures associated with a glacial period.

Uncertainties

Estimates of future short-, intermediate-, and long-term variations in precipitation are uncertain. Both NRC and DOE performance assessment models currently account for effects of short-term weather patterns and long-term climate changes. The effect of short-term variations are incorporated using 10-year records of hourly meteorological data, in process-level models, to support the total system performance assessment abstraction. Although the episodic nature of rainfall has an effect on the net infiltration, transient percolation is not expected to have a significant effect on seepage in the potential repository drifts, because of damping of flow variations in geologic units above the repository. The effects of long-term climate variations are addressed by including precipitation and temperature shifts, based on historical information on climate change, in performance assessments.

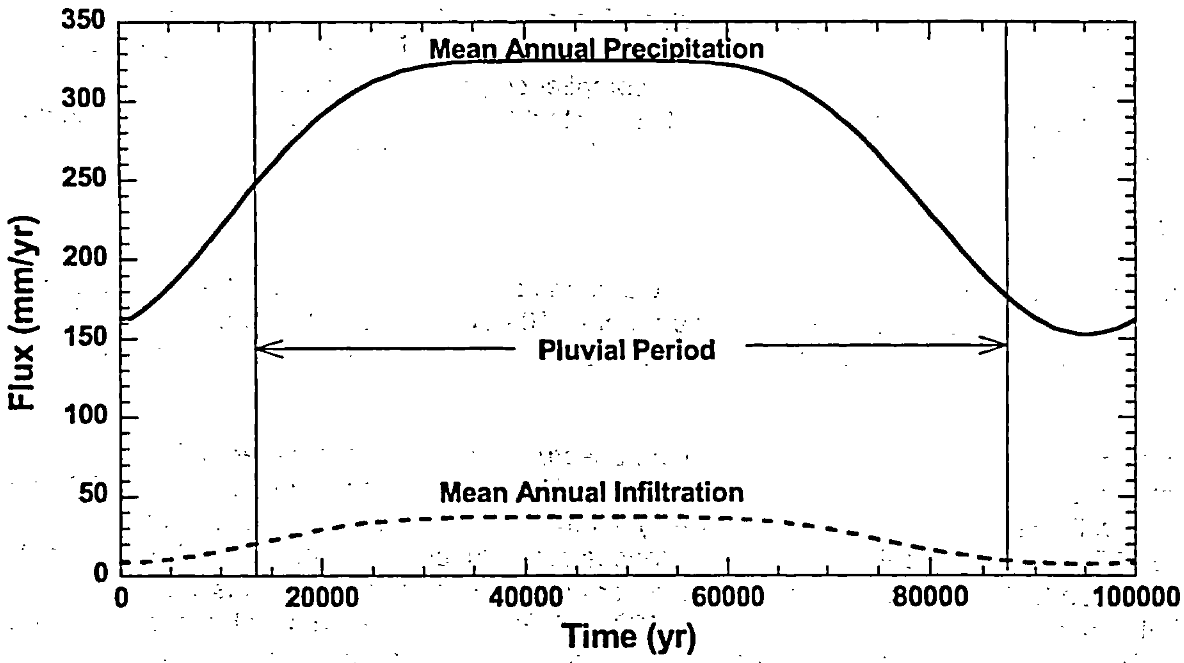


Figure 4-30. Predicted Mean Annual Precipitation and Infiltration at the Repository Horizon Averaged Over All Subareas and Encompassing both the Current and Pluvial Periods for the Mean Value Data Set (Mohanty, et al., 2002, Figure 3-1)

4.3.7 Radionuclide Transport in the Unsaturated Zone (UZ3)

Risk Insights:	
Retardation in the Calico Hills nonwelded vitric Unit	Medium Significance
Matrix Diffusion in the Unsaturated Zone	Medium Significance
Effect of Colloids on Transport in the Unsaturated Zone	Medium Significance

4.3.7.1 Discussion of the Risk Insights

Retardation in the Calico Hills Nonwelded Vitric Unit: Medium Significance to Waste Isolation

Retardation in the Calico Hills nonwelded vitric unit has the potential to delay the movement of most radionuclides for very long time periods (e.g., thousands to tens of thousands of years and longer) for nuclides that tend to sorb onto rock surfaces (e.g., Np-237, Am-241, and Pu-240).

Certain nuclides do not readily sorb onto rock surfaces (i.e., I-129 and Tc-99). Where the Calico Hills nonwelded vitric unit is present below the repository, sorption of radionuclides may limit releases to the saturated zone, within the compliance period, to insignificant quantities for all radionuclides except I-129 and Tc-99. In this context the retardation factor for Np-237 is the most significant because of the large inventory and long half-life for this radionuclide.

Discussion

Retardation in the Calico Hills nonwelded vitric unit has the potential to delay the transport of sorbing radionuclides for time periods on the order of 10,000 years and beyond. Table 4-7 shows the effect of the range of retardation in the Calico Hills nonwelded vitric unit on the transport time for key radionuclides through the unsaturated zone to the water table (i.e., saturated zone). Radionuclides that do not readily sorb onto rock surfaces (i.e., I-129 and Tc-99) show limited delay time (i.e., 450 years) relative to sorbing or retarded radionuclides (i.e., Np-237, Am-241, and Pu-241) where releases are delayed on the order of 10,000 years for low retardation factors and significantly greater for high retardation factors. It is important to note that nonsorbing radionuclides such as I-129 and Tc-99 represent a small fraction (less than 1 percent) of the overall inventory of the potential repository, whereas sorbing radionuclides, such as Np-237, Pu-240, and Am-241 represent a large fraction (greater than 99 percent) of the inventory (Table 4-1) (McCartin, 2003).

Uncertainties

The proclivity for matrix flow in the high-conductivity Calico Hills nonwelded vitric unit is key to the significant retardation provided by this unit. As described in Section 4.3.6, the areal extent and thickness of the Calico Hills nonwelded vitric unit between the potential repository and the water table are important uncertainties.

Matrix Diffusion in the Unsaturated Zone: Medium Significance to Waste Isolation

Matrix diffusion may have an effect on delaying radionuclide transport in the unsaturated units where the water flow is primarily in fractures.

Table 4-7. Saturated Zone Retardation Sensitivity (Calico Hills Nonwelded Vitric Unit) (Years for Initial Release into Unsaturated Zone to Exit Unsaturated Zone)

Nuclide	Rf (low)	Rf (high)
Tc-99	450	450
I-129	450	450
Np-237	9,000	60,000
AM-241	>100k	>100K
Pu-240	>100K	>100K

Discussion

Radionuclides transported within fractures may be delayed because of diffusion from the fracture water into matrix water (i.e., matrix diffusion) when radionuclide concentrations are higher within the fracture water versus the matrix water. This process will affect all radionuclides. However, radionuclides that sorb onto rock surfaces (i.e., are retarded) will show longer delays than those radionuclides that are not sorbed. The NRC modeling approach in TPA Version 4.1 code for unsaturated zone flow and transport estimates matrix diffusion is likely minor in fractured tuffs in the unsaturated zone because the estimated effect in the saturated zone is also limited (Winterle, et al., 1999, Figure 2-3). However, the DOE sensitivity analyses for matrix diffusion in the unsaturated zone indicate that a significant reduction in the simulated dose-rate history occurs when credit is taken for matrix diffusion (CRWMS M&O, 2000b, Figure 5.2-14). Figure 4-31 shows the reduction is highly time-dependent and ranges from a factor of 2 to more than a factor of 10. Another example of the effects of including matrix diffusion in the unsaturated zone transport model is provided by the impact of the Topopah Spring welded tuff unit (flow primarily in fractures) on the short traveltimes for ground water through the unsaturated zone. DOE sensitivity studies indicate that traveltimes are reduced by an order of magnitude when matrix diffusion is not included for the TSw unit (Eddebbarh, et al., 2000).

Uncertainties

The process of matrix diffusion is uncertain because of complexities of the interaction of potentially fast-moving water (e.g., meters per year) in fractures with the matrix water. Differences in the chemistries of fracture water and matrix water suggest that the interactions between fracture and matrix water may not be very significant (Murphy and Pabalan, 1994).

Effect of Colloids on Transport in the Unsaturated Zone: Medium Significance to Waste Isolation

Transport of radionuclides attached to natural colloids may reduce the effectiveness of sorption properties of the Calico Hills nonwelded vitric unit.

Discussion

Radionuclides that attach to colloids have the potential to be transported in a manner that may substantially reduce or eliminate the beneficial effect of sorption in geologic materials such as the Calico Hills nonwelded vitric unit. Although performance effects have not been explicitly examined using the total system performance assessment code, the code was used to bound colloid effects by allowing unretarded transport of relatively immobile actinides such as plutonium, americium, and thorium. That conservative analysis, which assumes a bounding unretarded transport, yielded an increase in dose by more than a factor of 10 (Figure 4-21). DOE has performed analyses to evaluate the sensitivity of colloids where plutonium and americium are irreversibly sorbed to waste-form colloids (Figure 4-22). The DOE analyses indicated that colloidal concentrations were only significant in 10,000 years, under an intrusive igneous event, wherein a large number of waste packages are significantly damaged. The potential importance of colloidal transport, if all waste packages were to fail within 10,000 years, is evident in the DOE total system performance assessment for site recommendation (CRWMS M&O, 2000b), which indicated colloidal plutonium is the second highest dose contributor after 70,000 years, when a significant number of waste packages are estimated to have failed, allowing release of radionuclides.

Uncertainties

Some field studies (Kersting, et al., 1999) suggest that colloids can travel relatively easily under particular conditions, which are not expected to be relevant to transport in the unsaturated zone at Yucca Mountain. There is considerable uncertainty both with the determination of the colloidal concentration and the extent to which colloids will be transported or filtered in the geosphere as they move through small fracture openings and matrix pores.

4.3.8 Flow Paths in the Saturated Zone (SZ1)

Risk Insights:	
Saturated Alluvium Transport Distance	Medium Significance

4.3.8.1 Discussion of the Risk Insights

Saturated Alluvium Transport Distance: Medium Significance to Waste Isolation

The saturated flow path is comprised of both fractured tufaceous rock and porous alluvium. Alluvium comprising a portion of the flow path is important because of the large capacity of the alluvium to retard a majority of the radionuclides. To have a significant influence on retarded radionuclides, the alluvium needs to comprise at least 500 m [1,640 ft] of the total flow path of 18 km [11.2 mi].

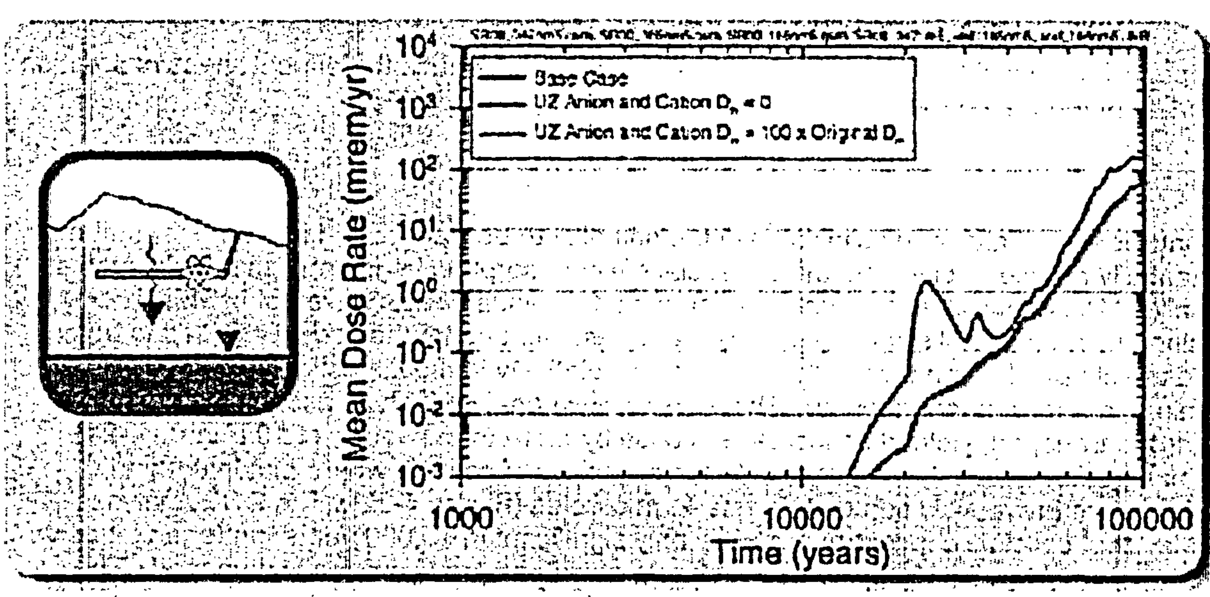


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Figure 4-31. Sensitivity to Matrix Diffusion in the Unsaturated Zone. (From CRWMS M&O, 2000b; page F5-37) (1.0 mrem/yr = 0.01 mSv/yr)

Discussion

Both fractured tufaceous rock and porous alluvium comprise the saturated flow path. The velocity of the water flow within these two units can be quite different because of differences in the hydrologic properties, specifically between the porosity of the alluvium (i.e., on the order of 15 percent of the overall volume) and the porosity of the fractured tuff (i.e., on the order of 0.1 to 1 percent of the overall volume). The unretarded radionuclide traveltime for the saturated zone is estimated to be on the order of several hundreds of years and longer (Figure 4-32). Because flow velocities in the alluvium are small relative to the fractured tuff, the majority of the traveltime is in the alluvium. Radionuclides traveling through the alluvium are especially important because of the potential capability of the porous media to delay a majority of radionuclides due to chemical sorption onto mineral surfaces. (See Section 4.3.9.) An alluvium flow path length of only 500 m [1,640 ft] {relative to a total saturated zone flow path length of 18 km [11.2 mi]} has a significant capacity to retard radionuclides (Table 4-8). Current information indicates alluvium is present for at least 2 km [1.2 mi] along the flow path.

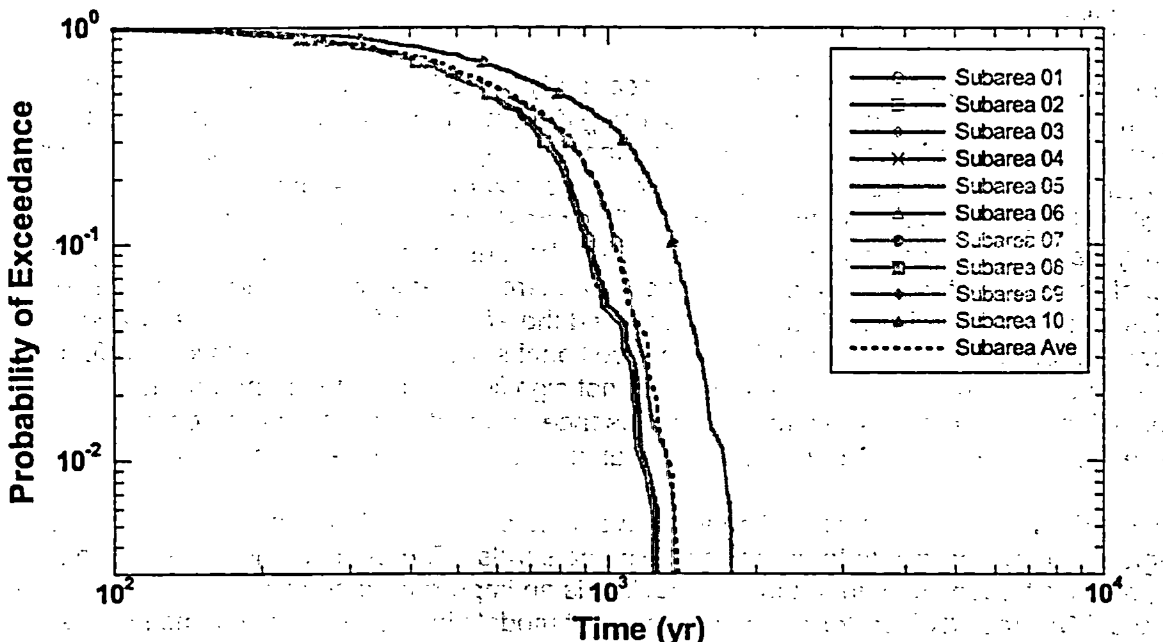


Figure 4-32. Complementary Cumulative Distribution Function of Saturated Zone Unretarded Radionuclide Traveltimes for 350 Realizations (Mohanty, et al., 2002, Figure 3-33)

Table 4-8. Saturated Zone Retardation Sensitivity (Years for Initial Release into Saturated Zone to Exit Saturated Zone)				
Nuclide	Alluv {1 km [0.6 mi]} Rf (low)	Alluv {1 km [0.6mi]} Rf (high)	Alluv {5 km [3.1 mi]} Rf (low)	Alluv {5 km [3.1 mi]} Rf (high)
Tc-99	350	350	550	550
I-129	350	350	550	550
Np-237	950	76.000	1,050	>100K
Am-241	>100K	>100K	>100K	>100K
Pu-240	54,000	>100K	>100K	>100K

Uncertainties

Based on the results shown in Table 4-8, uncertainty in the length of the flow path in the alluvium {i.e., 1 km [0.6 mi] versus 5 km [3.1 mi]} does not have a significant impact on performance, and the variation of retardation factor is significant only for Np-237. Flow within the saturated zone is affected by heterogeneity. For example, variations in structure (e.g., fault zones) and permeability (e.g., high-permeability zones) are present. Although these types of heterogeneity are expected to result in local perturbations in the flow field, the flow regime, on a regional scale, is not expected to be significantly altered. Detailed hydrological modeling studies of the saturated zone that have examined the effects of fault zones on flow and transport (Figure 4-33) indicate inclusion of additional structure in the model would affect the spreading of a contaminant plume, but would not significantly affect the unretarded radionuclide traveltime. For example, the presence of a fault tends to spread pathlines vertically (Figure 4-33a) while retaining the general leading-edge shape of the plume (Figure 4-33b).

Borehole data suggest that alluvial sediments can be strongly heterogeneous, ranging from fine-grained clay sediments to coarse gravels and sands. The effect of this heterogeneity on flow paths and traveltimes in saturated alluvium is an important uncertainty that is handled in both the DOE and NRC performance assessment models by stochastically sampling the effective porosity of alluvium. Lower values of effective porosity have the effect of increasing ground water velocity and thus decreasing unretarded radionuclide traveltime estimates.

4.3.9 Radionuclide Transport in the Saturated Zone (SZ2)

Risk Insights:

Retardation in the Saturated Alluvium	High Significance
Matrix Diffusion in the Saturated Zone	Medium Significance
Effect of Colloids on Transport in the Saturated Zone	Medium Significance

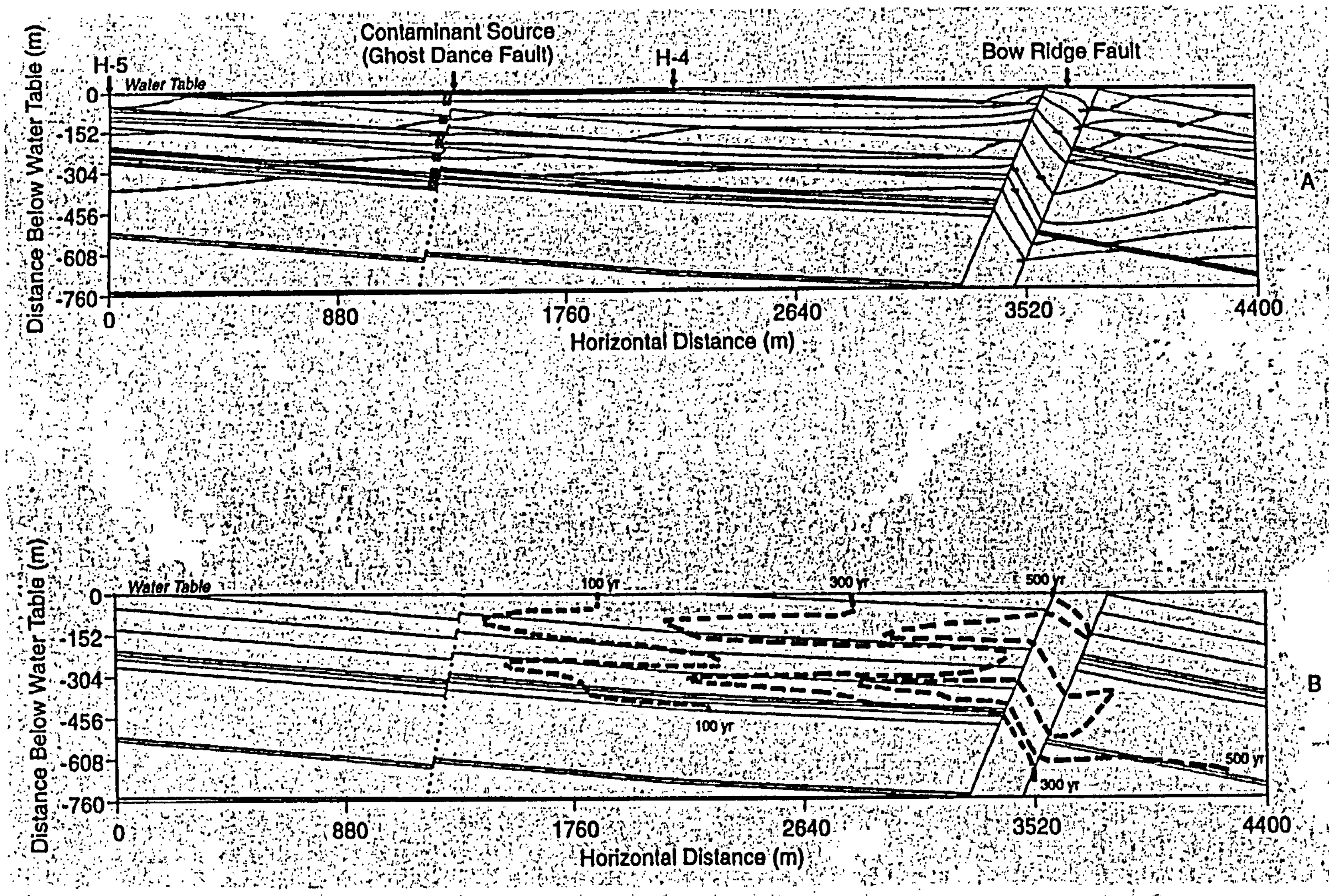


Figure 4-33. Effect of Faults on Pathlines (a) and Unretarded Traveltimes (b) for Vertical Cross-Sectional Flow Model (NRC, 2001, Figure 3-9)

4.3.9.1 Discussion of the Risk Insights

Retardation in Saturated Alluvium: High Significance to Waste Isolation

Retardation in the alluvium unit has the potential to delay the movement of most radionuclides for very long time periods (e.g., thousands to tens of thousands of years and longer) for nuclides that tend to sorb onto porous materials (e.g., Np-237, Am-241, and Pu-240). In this context, Np-237 is the most significant radionuclide affected by retardation in the alluvium, because of the large inventory and long half-life for this radionuclide.

Discussion

The transport of the vast majority of the radionuclides is expected to be significantly delayed by the saturated alluvium, because of chemical sorption on mineral surfaces (Table 4-7). Although certain radionuclides (e.g., I-129 and Tc-99) are not typically sorbed onto mineral surfaces under the geochemical conditions that predominate in the saturated zone, these radionuclides comprise a small fraction of the inventory of spent nuclear fuel (i.e., less than 1 percent). In contrast, radionuclides such as Am-241 and Pu-240, which comprise a majority of the inventory of spent nuclear fuel (Figure 4-1), are characterized by delay times in the alluvium on the order of tens of thousands of years and greater for the full range of expected retardation factors for these nuclides. The range of expected retardation factors for Np-237 is characterized by limited delays (i.e., on the order of 1,000 years) to very significant delay times (i.e., on the order of 100,000 years). Because most radionuclides are retarded or delayed in the alluvium, estimates of dose are typically characterized by the releases of only three radionuclides (I-129, Tc-99, and Np-237). Initial dose is typically from I-129 and Tc-99 and is followed by a later peak from Np-237. The estimated dose from Np-237 tends to be larger than the estimated dose from I-129 and Tc-99 because of the large dose-conversion factor associated with Np-237.

Uncertainties

The DOE sensitivity studies also indicate that the retardation factor used for Np-237 in the saturated alluvium has a significant impact on Np-237 traveltime through the alluvium. The range of the retardation factor used for Np-237 depends on the geochemistry and mineralogy of the saturated zone. Although the retardation factors currently used in the DOE performance assessment of Yucca Mountain likely provide a reasonable estimate of Np-237 sorption, the technical bases for these values are based on experiments with limited accounting of saturated zone chemistry or variation in alluvium mineralogy. The effectiveness of the alluvium in delaying certain radionuclides may be lessened if they are transported as colloids (further discussion of colloids is provided below). Current data for Np-237 transport parameters do not include colloids.

Matrix Diffusion in the Saturated Zone: Medium Significance to Waste Isolation

Matrix diffusion is a somewhat effective process for delaying radionuclides, especially those radionuclides that are sorbed onto rock surfaces (e.g., Np-237, Pu-240, and Am-241). The extent of the rock volume that is available for matrix diffusion, and each radionuclide retardation factor, are the controlling factors.

Discussion

Radionuclides transported within the fractures of the saturated tuff may be delayed because of diffusion from the fracture water into matrix water (i.e., matrix diffusion) when radionuclide concentrations are higher within the fracture water than within the matrix water. This process will affect all radionuclides; however, radionuclides that sorb onto rock surfaces will show longer delays than those radionuclides that are not sorbed. For example, the delay time for Np-237 in the fractured tuff is increased by 1,100 years, when matrix diffusion is varied from low to high effectiveness (Table 4-9). Unlike the unsaturated zone where the flow path is relatively short (i.e., a few hundreds of meters), the saturated zone flow path in fractured tuff is long {i.e., at least 10 km [6.2 mi]} and thus there will be a longer period of time for matrix diffusion to occur.

The inclusion of saturated zone matrix diffusion appears to have only a minimal benefit for lowering dose estimates in performance assessment models. Ziegler (2002), provided in response to a key technical issue agreement, showed comparisons of the median radionuclide transport time for nominal case, in the total system performance assessment for site recommendation, to a case with essentially no matrix diffusion (diffusion coefficient reduced 10 orders of magnitude), and to a case with enhanced matrix diffusion (flow interval spacing reduced 2 orders of magnitude). The results of the comparison showed a significant increase in radionuclide transport time for the most optimistic cases of matrix diffusion, but transport times for the nominal case were not substantially greater than for the case with essentially no matrix diffusion. Winterle, et al. (1999, Figure 2-3) evaluated the effects of matrix diffusion in the saturated zone using the TPA Version 3.2 code. This analysis indicated that the upper bound of the diffusion parameter uncertainty distribution reduced the effective peak dose by less than 10 percent during a 10,000-year performance simulation. (The 10,000-year doses are primarily from I-129 and Tc-99, which are nonretarded radionuclides.)

Uncertainties

Uncertainties in factors that affect matrix diffusion in the saturated zone include the effective spacings between flowing fractures, the extent to which fracture surfaces are coated with secondary minerals, and effective *in-situ* diffusion coefficients for various radionuclides. These uncertainties have led to development of performance assessment abstractions, by both

Table 4-9. Saturated Zone Retardation Sensitivity (with Matrix Diffusion) (Years for Initial Release into Saturated Zone to Exit Saturated Zone)

Nuclide	Alluv {1 km [0.6 mi]} Rf (low) Mat Diff (low)	Alluv {1 km [0.6 mi]} Rf (low) Mat Diff (high)	Alluv {5 km [0.31 mi]} Rf (high) Mat Diff (high)
Tc-99	300	600	700
I-129	300	600	700
Np-237	700	1,800	>100K
Am-241	>100K	>100K	>100K
Pu-240	45,000	>100K	>100K

NRC and DOE, that use conservative or bounding approaches for estimating the effect of matrix diffusion on radionuclide transport.

Effects of Colloids on Transport in the Saturated Zone: Medium Significance to Waste Isolation

Transport of radionuclides attached to natural colloids may reduce the effectiveness of sorption properties of the alluvium.

Discussion

Radionuclides that attach to colloids have the potential to be transported in a manner that may substantially reduce or eliminate the beneficial effects of sorption in the alluvium. The TPA code was used to bound colloid effects by allowing unretarded transport of relatively immobile actinides such as plutonium, americium, and thorium. More realistic approaches for colloids would account for dissolved species as well as colloidally-bound species, reversible sorption onto colloids, and filtration of colloids. That conservative analysis, which assumes a bounding unretarded transport, yielded an increase in dose by more than a factor of 10 (Figure 4-21). However, accounting for more realism is expected to reduce the effects of colloids on dose. DOE has performed analyses to evaluate the sensitivity of colloids where plutonium and americium are irreversibly sorbed to waste-form colloids (Figure 4-22). The DOE analyses indicated that colloidal concentrations were only significant under an intrusive igneous event, wherein a large number of waste packages were significantly damaged. The potential importance of colloidal transport, if all waste packages were to fail within 10,000 years, is evident in the DOE total system performance assessment for site recommendation (CRWMS M&O, 2000b), which indicated colloidal plutonium is the second highest dose contributor after 70,000 years, when a significant number of waste packages are estimated to have failed, allowing release of radionuclides.

Uncertainties

There is uncertainty both with the determination of the colloidal concentration and the extent to which colloids will be transported in the geosphere (i.e., will colloids be filtered as they move through small fracture openings and matrix pores). Some field studies suggest that colloids can travel relatively easily under particular conditions (Kersting, et al., 1999). Sensitivity analyses of colloid-facilitated transport models indicate that filtration is the most important parameter in understanding and estimating the importance of colloids to radionuclide transport (Cvetkovic, et al., 2002).

4.3.10 Volcanic Disruption of Waste Packages (DIRECT1)

Risk Insights:

Probability of Igneous Activity	High Significance
Number of Waste Packages Affected by Eruption	High Significance
Number of Waste Packages Damaged by Intrusion	Medium Significance

4.3.10.1 Discussion of the Risk Insights

Probability of Igneous Activity: High Significance to Waste Isolation

The risk from igneous activity is directly proportional to the probability of igneous activity. Recent aeromagnetic surveys in the Yucca Mountain region improve estimates of the number of igneous events that have occurred in the past. The number, age, and location of past igneous features are used to constrain the estimates for the probability of future events.

Discussion

Sporadically throughout the past 11 million years, basaltic volcanoes have formed in the region around the potential Yucca Mountain repository site. The probability of igneous disruption is important to risk calculations, because of the relatively low likelihood of future igneous events at the potential Yucca Mountain repository site. Analyses used to demonstrate compliance with licensing requirements must factor the likelihood of a potential disruptive event into the performance calculations, to determine probability-weighted dose. In addition, disruptive events with likelihoods of occurrence less than 1 in 10,000 during the 10,000-year postclosure performance period (i.e., less than 1×10^{-8} per year) do not need to be included in the total system performance calculations. Most DOE estimates for the annual probability of igneous disruption at the potential repository site range from approximately 10^{-10} to 10^{-8} (e.g., CRWMS M&O, 2000). In contrast, alternative probability estimates generally range from approximately 10^{-8} to 10^{-7} (e.g., NRC, 1999), to values as high as 10^{-6} using Bayesian methods (Ho, 1995; Ho and Smith, 1997). None of these models have considered current uncertainties in the number and age of past volcanic events (Hill and Stamatakos, 2002).

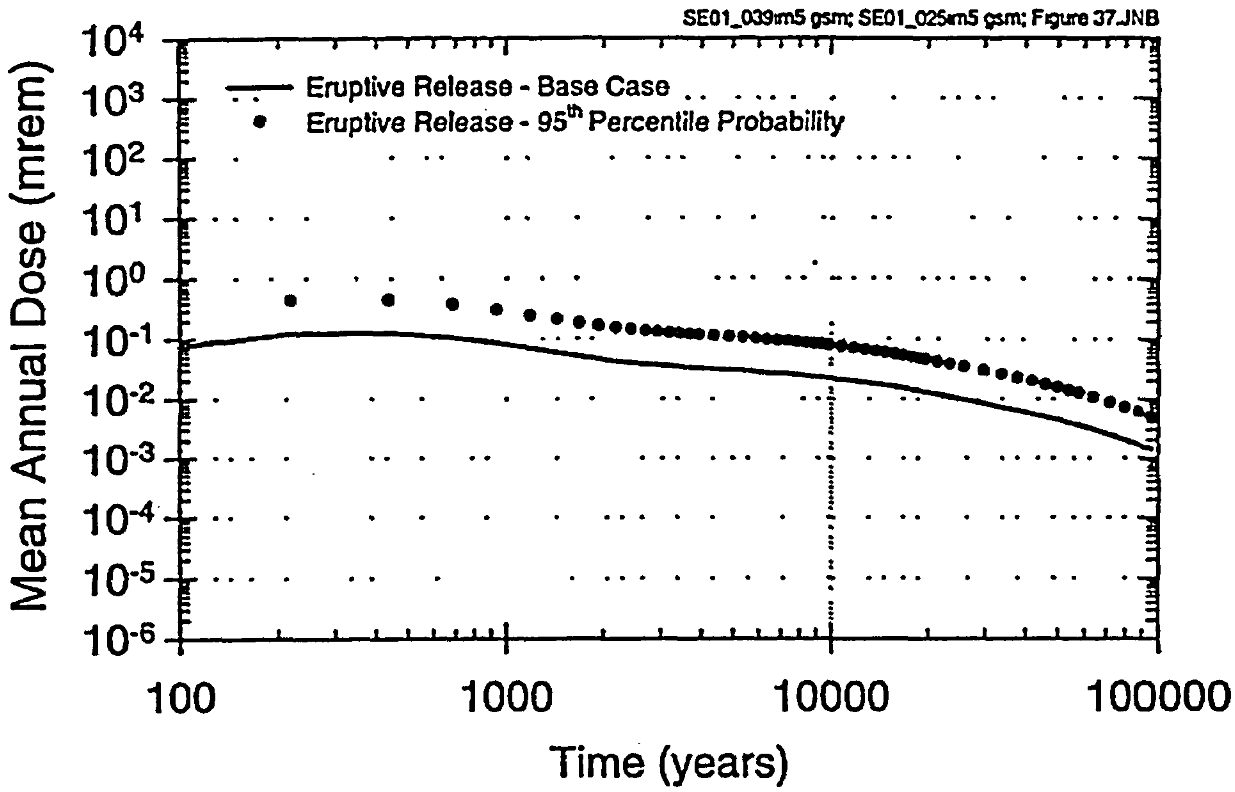
Figure 4-34 shows an increase in the calculated probability-weighted dose from igneous eruption by about a factor of three, when the DOE basecase mean annual probability (1.5×10^{-8}) is replaced by its 95th percentile value (4.8×10^{-8}). This result is consistent with earlier analyses indicating direct proportionality between igneous activity probability and risk (e.g., NRC, 1999; CRWMS M&O, 2000b). Thus, these current differences between the DOE models and alternative probability models may affect igneous activity risk calculations by factors of 10 to 100.

Uncertainties

Potentially significant uncertainties in the probability estimate for igneous activity currently arise primarily from uncertainties in the number, age, and composition of basaltic volcanoes possibly buried around Yucca Mountain. Variations in the size and location of the repository footprint also may increase the probability for igneous activity relative to previously published estimates. Using a range of alternative conceptual models, Hill and Stamatakos (2002) described how these uncertainties may have negligible to order of magnitude effects on probability model uncertainty.

Number of Waste Packages Affected by Eruption: High Significance to Waste Isolation

The consequences of extrusive igneous activity are directly proportional to the number of waste packages intersected by an erupting volcanic conduit. At present, this number is estimated based on observed conduit size at analog volcanoes. Alternative models of how a volcano may



NOTE: Each mean annual dose curve is a probability-weighted average. However, the results of the sensitivity studies do not correspond to expected risk (see introduction to Section 3).

Figure 4-34. Sensitivity of Mean Annual Dose to Igneous Activity Probability. (Bechtel SAIC Company, LLC, 2002, Figure 37. Note that Dose Estimates for Variations from the Basecase Do Not Represent Variations in Expected Risk Because the Probability of the Variation is not Considered) (1.0 mrem = 0.01 mSV)

interact with repository drifts and develop a conduit could increase the number of entrained waste packages and thus increase the concentration of radionuclides in erupted ash.

Discussion

Figure 4-35 shows the sensitivity of extrusive igneous activity dose to the number of waste packages entrained in a volcanic eruption. Normally, in the absence of subsurface drifts, volcanoes form roughly cylindrical conduits along the vertical plane of magma ascent. Based on analogy with deposits at active or deeply eroded volcanoes, staff determined that conduit diameters from 5 to 50 m [16 to 160 ft] represent the most likely range of diameters for a potential future eruption at the potential repository site (NRC, 1999; Doubik and Hill, 1999). In contrast, DOE considers potential conduit diameters up to 150 m [500 ft], albeit with very low likelihoods of occurrence (e.g., CRWMS M&O, 2000; Bechtel SAIC Company, LLC, 2003). Actively erupting volcanic conduits have high temperatures and large physical stresses that most likely would completely disrupt any waste package directly intersected by the conduit

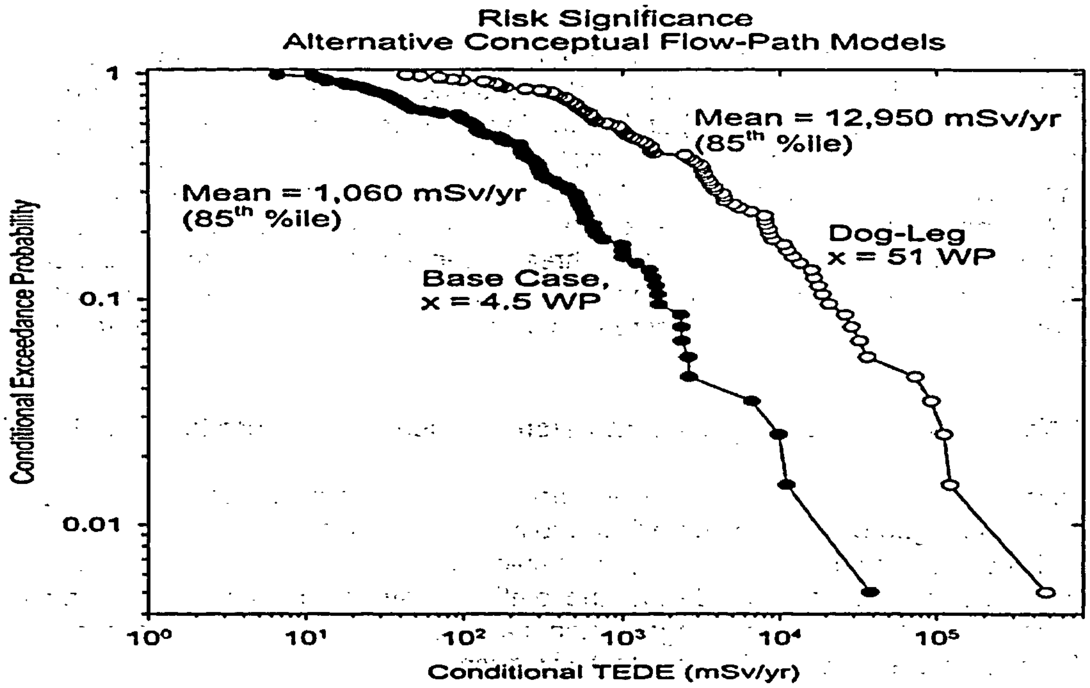


Figure 4-35. Sensitivity of Number of Waste Packages Affected during an Extrusive Igneous Event [Waste Packages (WP), Total Effective Dose Equivalent (TEDE)]

(NRC, 1999; CRWMS M&O, 2000b). Thus, both NRC and DOE have concluded that any waste package entrained in an erupting volcanic conduit would reasonably fail to provide containment and release its contents into the rapidly flowing magma.

Open drifts located at depths of 300 m [1,000 ft] could potentially cause magma ascent and flow processes to behave differently than at undisturbed geologic settings. This is because rising magma is a fluid with an overpressure sufficient to fracture and dilate surrounding wall rock. Intersection with a subsurface drift at essentially atmospheric pressure provides a horizontal pathway out of the original plane of vertical magma ascent, allowing flow localization and nonequilibrium expansion of volatiles (NRC, 1999; Woods, et al., 2002). Using the alternative conceptual model from Woods, et al. (2002), magma could potentially flow down an intersected drift and break out at some point away from the point of original intersection. For randomly located points of intersection and breakout and a single drift containing 155 waste packages, an estimated average of 51 waste packages would be located along the alternative flow path. In contrast, a normal, vertical conduit would intersect an estimated average of 4.5 waste packages using the TPA Version 4.1j code. Figure 4-35 indicates that there is a directly proportional relationship between the number of waste packages entrained and conditional dose (i.e., dose not weighted by the probability of scenario occurrence). This sensitivity appears reasonable, as the mass of high-level waste potentially entrained is relatively small compared to the mass of magma. It is assumed that high-level waste is uniformly distributed in the mass of a modeled eruption; thus, high-level waste behaves as a trace phase in the magma and does not appreciably affect the transport characteristics of a modeled eruption plume (NRC, 1999; CRWMS M&O, 2000b; Bechtel SAIC Company, LLC, 2003).

Uncertainties

In addition to alternative conceptual models for the magma-flow pathway, the number of volcanic conduits created during an igneous event also is uncertain. Using vent location information in Hill and Stamatakos (2002) and assuming medium-to-high confidence magnetic anomalies represent buried volcanoes, it is estimated that there are 17 paired and 13 nonpaired volcanoes in the Yucca Mountain region; most volcano pairs occur in alignments of three to five volcanoes. Volcano pairs have an average spacing of 2.0 ± 1.3 km [1.2 ± 0.8 mi]. Assuming that there is a uniform probability of one, two, or three volcanoes intersecting the repository during a potential extrusive event, and that the overall eruption character remains unaffected by the number of volcanic conduits, dose increases by approximately a factor of two from this process.

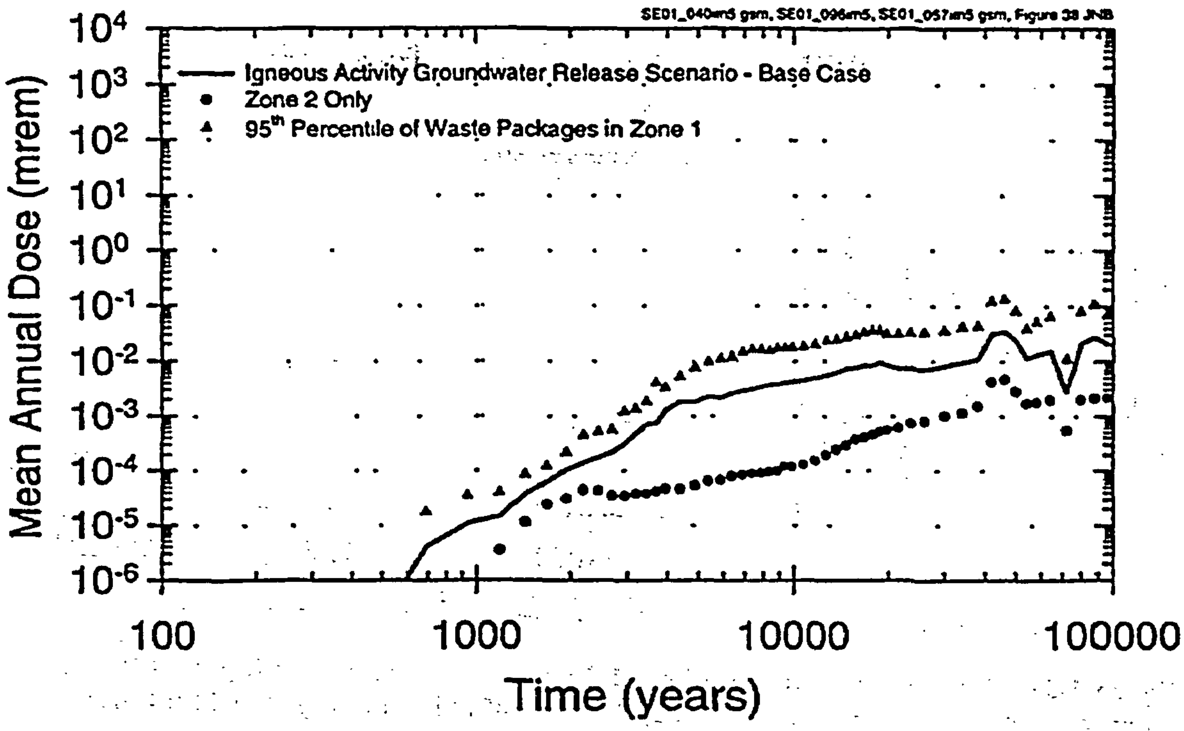
Number of Waste Packages Damaged by Intrusion: Medium Significance to Waste Isolation

The consequences from intrusive igneous activity are directly proportional to the number of waste packages damaged by direct magma flow into intersected drifts. Damage to waste packages likely occurs from the high thermal, mechanical, and chemical stresses created by basaltic magma. Although process models for these effects have not been developed, available information suggests current waste package design may not provide the physical integrity necessary for waste isolation after direct contact with basaltic magma.

Discussion

At depth of 300 m (1,000 ft), rising basaltic magma is a mixture of gas and melt with sufficient overpressure to fracture and dilate surrounding rock to apertures of approximately 1 m [3 ft] wide. If this confined fluid encounters an open or partially backfilled drift at essentially atmospheric pressure, it will preferentially flow into this drift. Depending on the amount of gas expansion, unobstructed flow speeds can range from the order of 10 m/s [30 ft/s] (Lejeune, et al., 2002) to potentially the order of 100 m/s [300 ft/s] (NRC, 1999; Woods, et al., 2002). Thus, intersected drifts could rapidly fill with magma. Based on current understandings of waste package responses to high-temperature, high-mechanical-load environments, waste packages in direct contact with magma will most likely lose physical integrity and provide no further protection against subsequent hydrologic flow and transport (NRC, 1999, 2002; Bechtel SAIC Company, LLC, 2003). In addition, the high temperatures and complex reducing-to-oxidizing chemical environment created by an igneous intrusion may alter the waste, which could result in more soluble waste forms than intact spent nuclear fuel.

Figure 4-36 shows that the estimated dose from igneous intrusion increases by about a factor of 3 when the number of waste packages damaged is increased from a base value of approximately 300 to a 95th percentile value of more than 900. Earlier analyses (Figure 4-37) have shown similar sensitivity of the calculated igneous intrusion dose to the number of waste packages damaged. These sensitivity analyses also do not account for uncertainties in the amount of possible damage to waste packages not directly contacted by magma, but still exposed to potentially corrosive volcanic gasses. Nevertheless, these results indicate that the consequences from releases of radionuclides to the ground water from igneous intrusion are directly proportional to the number of waste packages intersected by magma in a drift. More waste packages damaged by an igneous intrusion lead to higher waste concentrations in the ground water at the reasonably maximally exposed individual location. However, given the low probability of occurrence for this event, the estimated risk due to the effect of magma on a large



NOTE: Each mean annual dose curve is a probability-weighted average. However, the results of the sensitivity studies do not correspond to expected risk (see introduction to Section 3).

Figure 4-36. Sensitivity to Number of Waste Packages Hit During an Intrusive Igneous Event (Bechtel SAIC Company, LLC, 2002. Note that Dose Estimates for Variations from the Basecase Do Not Represent Variations in Expected Risk Because the Probability of the Variation Is Not Considered) (1.0 mrem = 0.01 mSv)

numbers of waste packages is expected to be low {i.e., probability weighted dose is approximately 0.0001 mSv/yr [0.01 mrem/yr] at 10,000 years for 900 damaged waste packages} (Figure 4-36).

Uncertainties

The high temperatures and complex chemical environment created by an igneous intrusion would likely alter the waste form, which could affect subsequent solubility and transport processes. These may be significant depending on uncertainties in the appropriate model for waste dissolution and near-field transport.

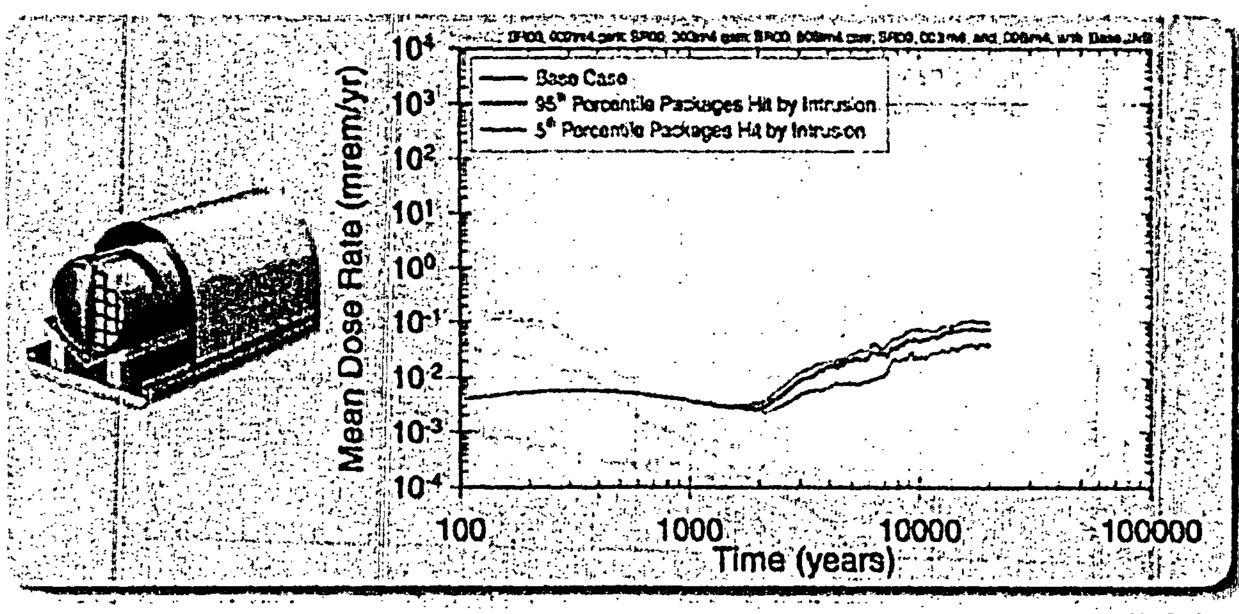


Figure 4-37. Sensitivity to the Number of Waste Packages Hit During an Intrusive Igneous Event (From CRWMS M&O, Page F5-46) (1.0 mrem/yr = 0.01 mSv/yr)

4.3.11 Airborne Transport of Radionuclides (DIRECT2)

Risk Insights:	
Volume of Ash Produced by an Eruption	Medium Significance
Remobilization of Ash Deposits	Medium Significance
Inhalation of Resuspended Volcanic Ash	High Significance
Wind Vectors During an Eruption	Medium Significance

4.3.11.1 Discussion of the Risk Insights

Volume of Ash Produced by an Eruption: Medium Significance to Waste Isolation

The concentration of radionuclides in ash is affected by the volume of ash released during an igneous event. Relative to small-volume eruptions, larger-volume eruptions dilute the concentration of high-level waste in the volcanic deposit.

Discussion

Basaltic volcanoes in the Yucca Mountain region have many characteristics of basaltic cinder cones that have erupted with historical observations. Although most eruption deposits from volcanoes in the Yucca Mountain region are poorly preserved, sufficient information exists to conclude that the range of past activity at these volcanoes is analogous to that observed at historical eruptions (e.g., Connor, 1993; NRC, 1999). Comparison of Yucca Mountain basaltic volcanoes to historical volcanoes with magmatic water contents of at least 2 wt % shows the ubiquity of an eruption plume that deposits tephra for tens of kilometers away from the vent (e.g., NRC, 1999). Erosion has removed most of the tephra-plume deposits from Yucca Mountain volcanoes; thus, these volumes need to be estimated. NRC (1999) used deposit ratios from well-characterized historical eruptions to estimate volumes of tephra deposits for Yucca Mountain volcanoes, with a similar approach adopted in CRWMS M&O (2000b).

The current TPA Version 4.1 code uses a relationship between eruption power and duration to calculate ash volume during an eruption. The power and duration ranges used to represent potential igneous events correspond to estimated ash-volume ranges of 6×10^5 to 3×10^8 m^3 [2×10^7 to 1×10^{10} ft^3], with an average volume of 3×10^7 m^3 [1×10^9 ft^3]. For comparison, the ash volume for Lathrop Wells volcano is estimated at 5×10^7 m^3 [2×10^9 ft^3] (NRC, 1999). DOE currently uses a range of ash volumes from 2×10^6 to 4.4×10^8 m^3 [7×10^7 to 2×10^{10} ft^3], with an average volume of 1×10^8 m^3 [4×10^9 ft^3]. The effect of these different volume ranges is shown in Figure 4-38. In this analysis, a factor of 2 increase in average ash volume resulted in a factor of 3 decrease in average conditional dose (i.e., dose not weighted by the probability of scenario occurrence).

Uncertainties

Because most of the ash deposits have been eroded from old volcanoes in the Yucca Mountain region, ash volumes for these volcanoes are uncertain. Ash-to-cone volume ratios at historical

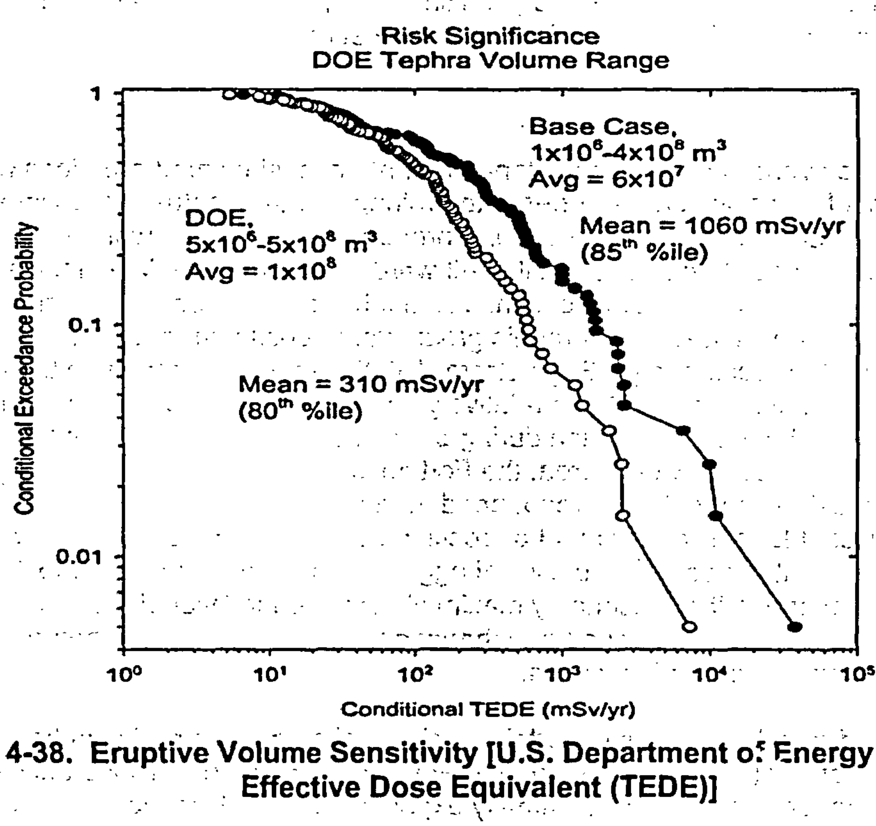


Figure 4-38. Eruptive Volume Sensitivity [U.S. Department of Energy (DOE), Total Effective Dose Equivalent (TEDE)]

analog volcanoes can range from approximately 1:1 to 6:1 (NRC, 1999); ratios of 1:1 to 2:1 were used in the NRC (1999) estimates for Yucca Mountain volcanoes. In addition to the presented analyses for areal concentration of entrained waste at 20 km [12 mi], the eruption volume also will affect the potential source-term for remobilization modeling. Although smaller tephra volumes can result in relatively higher initial waste concentrations at 20 km [12 mi], the amount of material available for subsequent remobilization to the 20-km [12-mi] location may be significantly less than for larger volume eruptions. Thus, larger volume eruptions, which may produce deposits with initially lower waste concentrations at 20 km [12 mi], could provide a larger amount of material that would be available for remobilization over time. Remobilization may result in the accumulation of tephra at the 20-km [12-mi] location that is equivalent to or greater than the thickness or concentration of the initial eruption deposit. Both the concentration of radioactive material in air and inhalation dose are sensitive to the deposit thickness and waste concentration in the deposit. As the deposit at the 20-km [12-mi] location evolves through time, remobilization processes could increase the probability-weighted expected annual dose at a time significantly (i.e., tens of years) after the initial eruption. However, current dose estimates, which assume a southerly wind direction, are dominated by the dose occurring in the year immediately following the eruption.

Remobilization of Ash Deposits: Medium Significance to Waste Isolation

After a potential eruption, contaminated ash could be deposited over hundreds to perhaps thousands of square kilometers (tens to perhaps hundreds of square miles). Through time, some of this ash can be eroded and transported by wind and water, with later deposition at or near the reasonably maximally exposed individual location. An influx of remobilized ash could affect the airborne mass loads at the reasonably maximally exposed individual location, depending on the rate of remobilization and dilution with existing soils.

Discussion

For a potential volcanic event within the repository footprint, most simulated eruptions would deposit some amount of volcanic ash on slopes with drainages that eventually feed into the reasonably maximally exposed individual location. Through time, wind and water will erode some fraction of the ash deposit and transport it southward down Fortymile Wash toward the reasonably maximally exposed individual location. Although tephra-fall deposits can erode within decades from areas with steep topographic gradients, deposits on relatively flat-lying areas are more resistant to erosion (e.g., Segerstrom, 1960). Sediment residence times in the confined channel of Fortymile Wash could be relatively short. Bed-load transport will move sediment down the main channel of the wash during periods of high water flow. In the reasonably maximally exposed individual area, the Fortymile Wash drainage morphology changes from a steep-sided channel to a broad, braided fan system. This location represents the point where significant long-term sediment deposition occurs within the Fortymile Wash drainage system. Sediment deposition and alluvial aggradation continues south into the Amargosa Desert and overlaps the reasonably maximally exposed individual location. Consequently, there is likely an initial period of enhanced tephra remobilization before sediment transport rates drop back to preeruption values.

The risk significance of remobilization is uncertain. Using a simple mass redistribution relationship, Hill and Connor (2000) suggested that remobilization could increase the net amount of ash at the general reasonably maximally exposed individual location by a factor of 2 to 10, relative to the original mass deposited by an eruption. This analysis also indicates that, if the wind is directed away from the reasonably maximally exposed individual during a simulated eruption (i.e., no deposition and, thus, no dose the year immediately following the event), the effect of ash remobilization could result in a dose at some time after the eruptive event at the reasonably maximally exposed individual location.

Current total system performance assessment calculations assume the potential eruption plume is always directed at the reasonably maximally exposed individual location, as a means to account for post-eruption remobilization. These calculations, however, assume that airborne mass loads above ash deposits decay after a potential eruption and that the ash deposit undergoes leaching and erosion with no influx of new material from remobilization. A relatively straightforward approach to evaluating potential risk significance of the remobilization issue is to examine the effect of sustaining airborne particle concentrations at post-eruption values. This effect can be simulated in the TPA Version 4.1j code by slowing the reduction in the airborne mass load with time (i.e., using larger values for the half-life of this process). Larger values represent slower decreases in airborne mass loads from the presumed influx of resuspendable ash through remobilization. Figure 4-39 shows the relative sensitivity of the decay function parameter in the average conditional dose for 100 realizations of an eruption occurring 1,000 years after repository closure. As a proxy for risk significance, the conditional doses for each year from 1,000 years to 2,000 years are individually weighted by a 10^{-7} annual probability of occurrence and summed. Compared to the risk proxy for a 14-year half-life, half-lives of 143 and 1,430 years result in increases by factors of approximately 2 and 5, respectively.

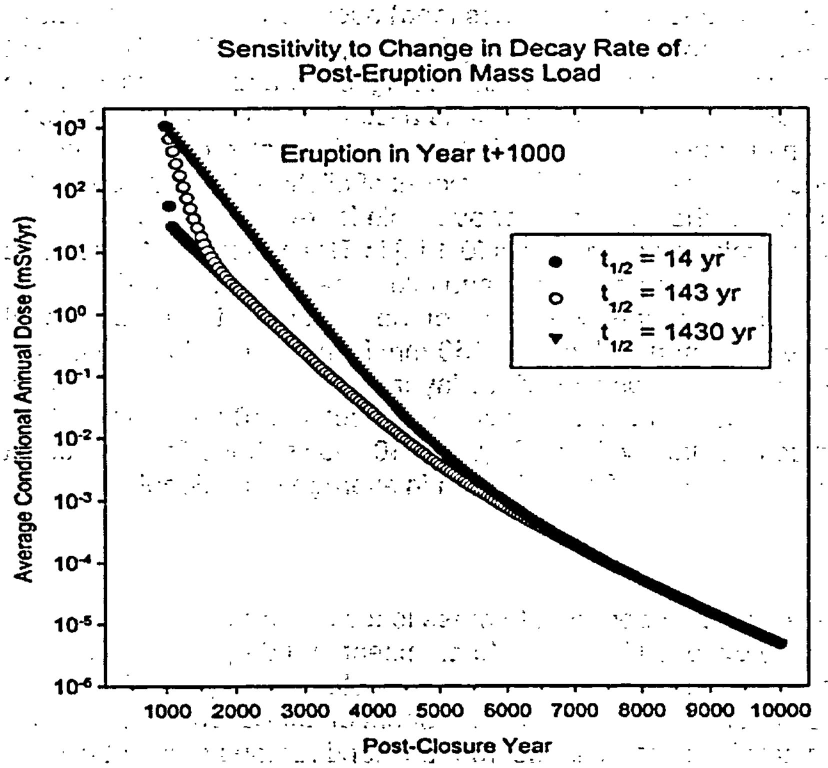


Figure 4-39. Relative Sensitivity for Assumptions of Airborne Mass-Load Decay Function [Time (t); half life ($t_{1/2}$)]

Uncertainties

Remobilization processes are not well-understood, and supporting data are sparse. Nevertheless, the airborne mass load for the years after a potential volcanic eruption is a highly sensitive parameter in total system performance assessment calculations, and uncertainties in this parameter strongly affect calculations of expected annual dose. However, tephra remobilized as a result of surface water is expected to mix with other soils, and transport of tephra by water is expected to result in reduced mass loading, relative to the air transport of tephra during the eruption.

Inhalation of Resuspended Volcanic Ash: High Significance to Waste Isolation

Inhalation of resuspended volcanic ash dominates the total dose for the igneous scenario. Thus, assumptions regarding the amount of fine ash particles in the air significantly influence the calculated dose. The thickness of the deposited ash layer and extent of potential mixing with the underlying soil affects the proportion of ash in the airborne particle load.

Discussion

The amount of fine ash particles resuspended above a deposit depends on the type and duration of surface-disturbing activities and on thickness of the deposit available for entrainment. Based on sensitivity studies using the NRC TPA Version 4.1 code, the parameter for the airborne particle concentration (mass load) above a fresh ash deposit was identified as the most influential to igneous activity dose (Mohanty, et al., 2002). The inhalation dose from a volcanic eruption increases or decreases according to the airborne mass load of waste. The decrease in total mass load after an eruption is assumed to follow an exponential decay in the model. The fraction of contaminated ash in the mass load also can be decreased by mixing ash with underlying uncontaminated soil. The amount of dilution depends on the thickness of the ash deposit and depth of the surface layer available for resuspension. In undisturbed areas, the resuspension layer is relatively thin {3 mm [0.1 in] in TPA Version 4.1j code}; activities such as agriculture disturb a thicker surface layer, and dilute the ash content of the mass load where the thickness of the disturbed layer exceeds that of the ash deposit. The DOE analyses using deeper surface layers {10 mm [0.4 in] and 150 mm [6 in]} lead to lower estimated annual doses that decrease with increasing surface layer thickness. To evaluate the sensitivity of the soil-mixing depth, thickness of the mixing zone was set to 150 mm [6 in], with all other parameters sampled at default values. Figure 4-40 shows that a factor of 50 increase in the soil mixing depth results in a factor of 12 reduction in average conditional dose.

Uncertainties

Further uncertainties exist for appropriate mass loads under different conditions local to the reasonably maximally exposed individual (e.g., extent and degree of disturbance, indoor or outdoor activities). Use of a soil-mixing zone may not be appropriate for reasonably maximally exposed individual that has only a minor component of agricultural habits and only limited surface-disturbing activities. Mass loads from semiarid regions may not accurately represent appropriate mass loads for the reasonably maximally exposed individual during the period of peak calculated risk (i.e., first 1,000 years postclosure), and many arid terrains may not have soil or vegetation conditions reasonably analogous to the reasonably maximally exposed individual location. The rate at which mass loading may decrease in the years following an eruption is also uncertain because of complex interrelationships between deposit erosion and

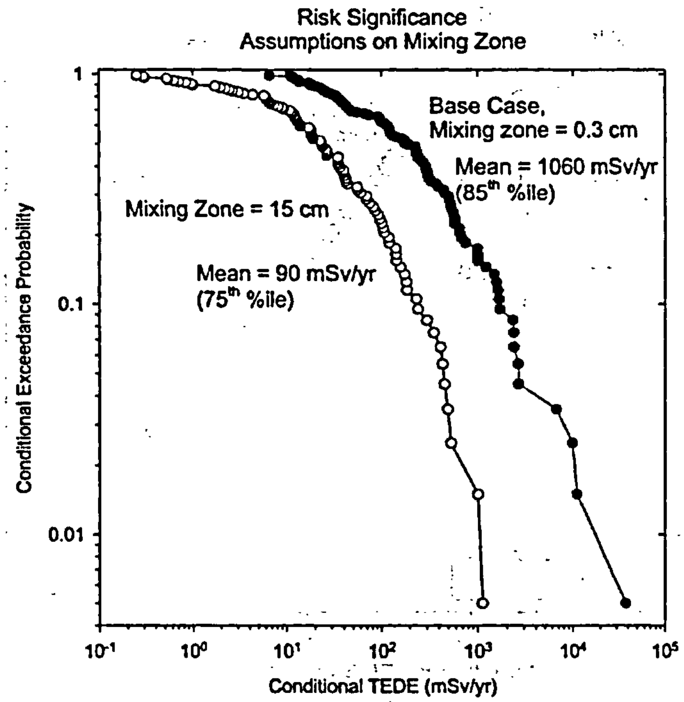


Figure 4-40. Sensitivity to Soil Mixing Depth [Total Effective Dose Equivalent (TEDE)]

the redistribution of inhalable particles. The upper bound of this uncertainty, however, does not appear to affect risk estimates significantly.

Wind Vectors During an Eruption: Medium Significance to Waste Isolation

Both wind speed and wind direction affect the transport of contaminated ash from the eruption source to the location of the reasonably maximally exposed individual. Wind speed has been shown to be an influential parameter in the sensitivity studies conducted with performance assessment codes. A distribution of wind speeds appropriate to model eruption columns 2 to 7 km [1.2 to 4.4 mi] high needs to be considered. The current total system performance assessment approach also fixes the wind direction toward the reasonably maximally exposed individual to simulate potential effects of post-eruption ash remobilization.

Discussion

In modeling potential volcanic eruptions, the TPA Version 4.1j code uses an exponential distribution of wind speeds with an average of 12 m/s [27 mi/hr], based on limited data. Further analysis of 28,000 measurements from 0 to 7 km [0 to 4.3 mi] altitude at the National Oceanic and Atmospheric Administration Desert Rock Airstrip suggest that a lognormal distribution with roughly the same median value is more appropriate. Calculations using this distribution give doses similar to those computed with TPA Version 4.1j code (Figure 4-41). Greater wind speeds yield proportionally greater dose, presumably because of thicker ash deposits at the reasonably maximally exposed individual site. In the DOE total-system performance assessment, setting the wind speed to the 95th percentile value [23 m/s [51 mi/hr]} gives roughly twice the dose as the basecase median wind speed of 11 m/s [25 mi/hr] (Figure 4-42).

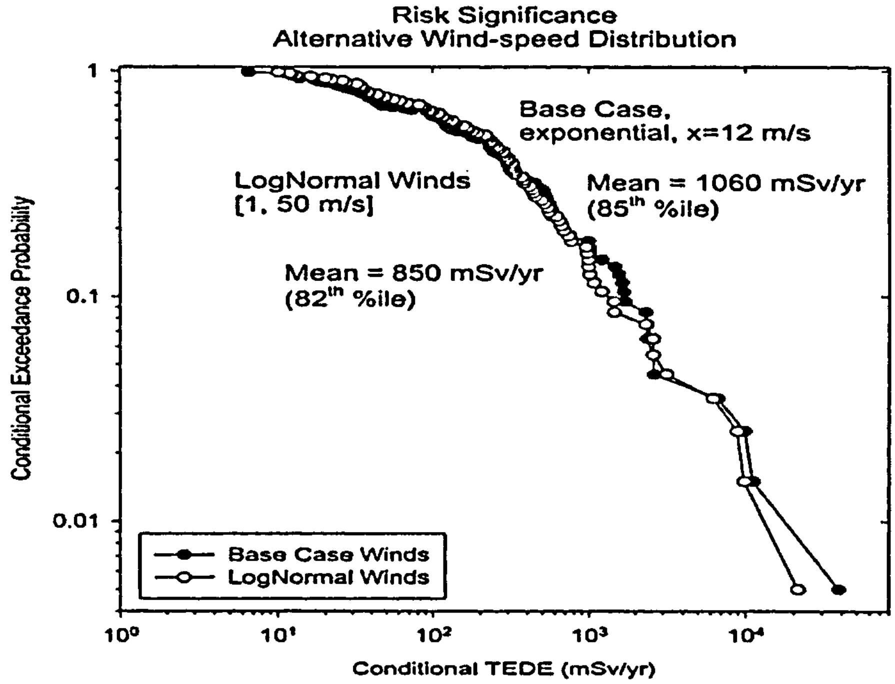


Figure 4-41. Variations in Conditional Annual Dose Using an Alternative Wind Speed Distribution [Total Effective Dose Equivalent (TEDE)]

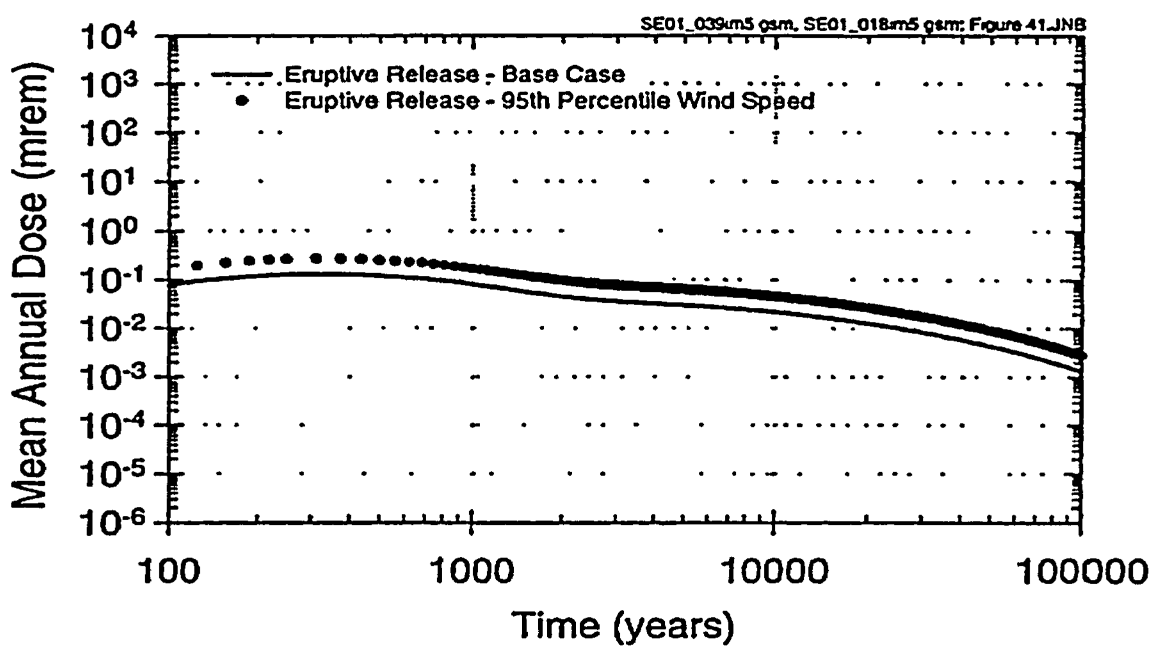


Figure 4-42. Sensitivity to Higher Wind Speed. (Bechtel SAIC Company, LLC, 2002. Note that Dose Estimates for Variations from the Basecase Do Not Represent Variations in Expected Risk Because the Probability of the Variation Is Not Considered) (1.0 mrem = 0.01 mSv)

Variations in wind direction during an eruption have not been fully analyzed. In both the DOE total system performance assessment and TPA Version 4.1j code, wind direction was fixed toward the reasonably maximally exposed individual site to compensate for the lack of any posteruption movement of contaminated ash. Clearly, if the wind direction is allowed to vary over a realistic range and the potential effects of ash remobilization are ignored, many total system performance assessment realizations will not deposit ash at the reasonably maximally exposed individual location. Scoping analyses presented in Hill and Connor (2000), however, indicated that long-term remobilization processes could result in ash deposits that exceed the thickness of primary volcanic deposits. Calculations that allow wind direction to vary without accounting for potentially significant effects of ash remobilization therefore provide limited insight on risk significance. Because of a lack of information on potential ash remobilization, a medium-risk significance is given to developing an appropriate representation of a realistic wind field above Yucca Mountain.

Uncertainties

The level of detail necessary to reasonably represent a complex wind field is uncertain, given the short transport distances being modeled relative to typical volcanic plume or particle modeling. Variations in deposit thickness on scales of less than a kilometer may be significant to dose calculations, if a realistic wind field and remobilization modeling are used. The time an erupted tephra particle remains at the top of the tephra plume is significantly longer than its rise time from the vent, or its depositional fallout time from the plume. Wind speeds are generally faster at higher altitudes; thus, realistic modeling must consider wind velocity profiles for rapid particle rise, extended lateral advection at the top of the plume, and depositional fallout through gravitational settling. Modeling assumptions (e.g., wind direction fixed in a southerly direction) and sensitivity analyses (e.g., variation of wind speed) have been used to understand the effects of many of these uncertainties.

4.3.12 Concentration of Radionuclides in Ground Water (DOSE1)

Risk Insights:	
Well-Pumping Model	Low Significance

4.3.12.1 Discussion of the Risk Insights

Well-Pumping Model: Low Significance to Waste Isolation

In the current well-pumping model, all radionuclides that enter the accessible environment are assumed to be captured in the volume of ground water projected to be withdrawn annually. This assumption limits the risk significance of modeling radionuclide concentrations in ground water.

Discussion

This abstraction relates to estimating the impacts of well pumping on the concentration of radionuclides in water. To limit speculation, this stylized calculation is described in 64 FR 8646 and its implementation is constrained by requirements at 10 CFR Part 63. The calculation involves dividing the estimate of the annual amount of radionuclides entering the accessible environment, that are captured by the pumping well (or wells), by the volume of water assumed to be pumped to the surface. The annual amount of radionuclides that enter the accessible environment is the result of the release and transport calculations in previously discussed model abstractions, so the risk insights for those abstractions will not be repeated here. The remaining parameters in the concentration calculation do not vary and, therefore, do not have any potential to increase or decrease the resulting concentration. For example, the annual water demand (i.e., pumping volume) is specified by regulation, at 10 CFR Part 63, as 3.7×10^6 m^3 [3,000 acre-ft], and all the radionuclides that enter the accessible environment are assumed to be captured in this specified water demand (a conservative assumption).

Uncertainties

No variation or uncertainty is generated in this abstraction because the regulation at 10 CFR Part 63 sets the pumping volume as 3.7×10^6 m^3 [3,000 acre-ft] and all radionuclides in the plume are conservatively assumed to be captured by the pumping well.

4.3.13 Redistribution of Radionuclides in Soil (DOSE2)

Risk Insights:	
Redistribution of Radionuclides in Soil	Low Significance

4.3.13.1 Discussion of the Risk Insights

Redistribution of Radionuclides in Soil: Low Significance to Waste Isolation

Ground water-based dose estimates are primarily influenced by the drinking water pathway, thereby limiting the importance of pathways related to radionuclides in soil. Igneous activity-based dose estimates are dominated by inhalation of radionuclides that have low mobility in soil, so leaching processes do not significantly affect estimated doses (low soil leaching leads to higher crop ingestion doses).

Discussion

The model abstraction for redistribution of radionuclides addresses the movement of radionuclides after deposition on the ground, either through surface application of ground water or settling of volcanic ash after an eruption. Redistribution affects the quantity and concentrations of radionuclides accessible to human receptors in the biosphere, and therefore, influences the dose estimates from radionuclides deposited on the ground. Redistribution can increase exposure if the transport processes involved move material closer to human intake pathways (e.g., resuspension to the breathing zone of an individual) or decrease exposure if transport is away from human exposure pathways (e.g., leaching to deep soil layers) or transport substantially dilutes initial radionuclide concentrations.

For ground water-based dose estimates, biosphere modeling results (Figure 4-43) show that, for the radionuclides that dominate the current dose estimates (Table 4-10), the drinking water pathway, which is not affected by soil redistribution processes, would contribute approximately

50 percent of the all-pathway dose estimates. Because only the remaining half of the all-pathway dose can be influenced by redistribution processes and this portion of the dose is dominated by the crop-ingestion pathway (Figure 4-43), the effect of redistribution processes on the all-pathway dose is limited. In the biosphere model, crops can become contaminated through root uptake or deposition of resuspended material. As a result, redistribution processes that alter the soil concentration on the soil surface and in the root zone of the crops can affect the crop-ingestion dose. These processes include leaching of contaminants to deeper soil layers away from roots, and buildup of contaminants from irrigation. Any potential impacts from contaminants leaching from the soil to the ground water are not addressed by the current model. Such secondary-use consequences are assumed to be lower than consequences attributed to initial reasonably maximally exposed individual use, because of the attenuating effects of dilution during transport.

To test the impact of soil leaching on dose-modeling results, the most variable parameter in the leaching calculation—the distribution coefficient—was input at the extremes of the range used in TPA Version 4.1d code biosphere calculations. The results (Figure 4-44) indicate that the greatest potential change in dose from variation in this parameter is about a factor of five. Because it is unlikely that the value of every distribution coefficient would be at the highest value of its known range, the effect on dose estimates from more realistic changes to this parameter is expected to be far less than the factor of five and is therefore considered of low-risk significance. This conclusion is further supported by the results of a system-level sensitivity analysis (Mohanty, et. al., 2002) that found no consistent significant influence on dose from soil-leaching parameters when all other total system model parameters were sampled.

DOE analyzed effects of soil buildup on biosphere dose-modeling results (CRWMS M&O, 2000) by modeling irrigation for time periods sufficient for soil concentrations to reach equilibrium (e.g., soil concentration remains constant with time). Results suggest the dose results for most radionuclides would be expected to change by 15 percent. Some radionuclides (i.e., americium, cesium, nickel, protactinium, plutonium, radium, strontium, thorium, and uranium) showed changes above this level (CRWMS M&O, 2000); however, these radionuclides are not contributing to the ground water-based dose estimates. In general, the properties that lead to buildup in soil (e.g., low mobility) also favor slow transport times in ground water.

For the igneous activity dose calculations, both NRC (Figure 4-45) and DOE (Bechtel SAIC Company, LLC, 2001) results indicate that the dose is dominated by inhalation of resuspended contaminated ash deposited from an eruption. Both NRC (Figure 4-46) and DOE (CRWMS M&O, 2000b, Figure 4.2-3) analyses indicate over 90 percent of the direct-release dose is from radioactive species of the elements americium and plutonium. The chemical properties of these elements lead to low leaching in soils, as indicated by the data and related information presented in Sheppard and Thibault (1990). A simple quantification of the low-leaching effect, using the environmental deposition and removal calculation described in the GENII v1.485 user manual (Napier, et al., 1988) and leaching factors calculated in the TPA Version 4.1 code for plutonium and americium, indicates that the annual surface soil concentration is reduced by less than 1 percent when leaching to deeper soil layers is considered.

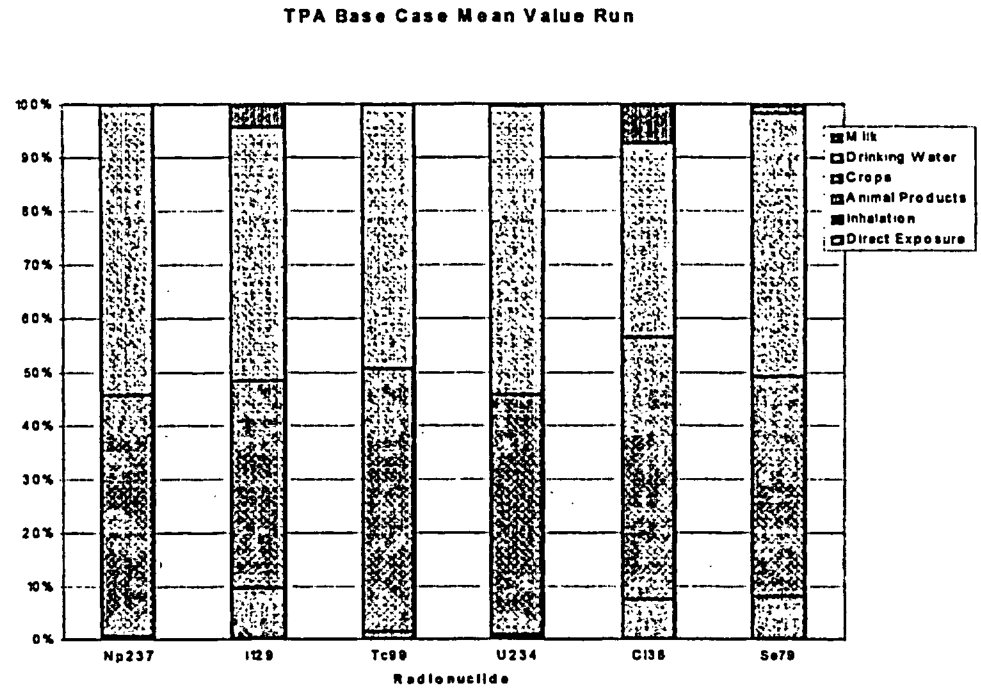


Figure 4-43. Ground Water Release Scenario: Exposure Pathway Contributions to Dose for Important Radionuclides (Using the TPA Version 4.1 Code)

Table 4-10. Primary Radionuclides Contributing to Peak Expected Dose (Mohanty, et al., 2002, Table 3-13)

	10,000 Years		100,000 Years	
Radionuclide	**Mean Value Data Set (mSv/yr)**	**Multiple-Realization Data Set (mSv/yr)**	**Mean Value Data Set (mSv/yr)**	**Multiple-Realization Data Set (mSv/yr)**
Np-237	0	4.29×10^{-5}	3.69×10^{-2}	9.54×10^{-2}
I-129	1.30×10^{-4}	5.34×10^{-5}	3.90×10^{-4}	1.33×10^{-3}
Tc-99	2.15×10^{-4}	1.09×10^{-4}	6.17×10^{-4}	2.09×10^{-3}
U-234	0	1.77×10^{-9}	4.62×10^{-7}	6.80×10^{-5}
Cl-36	7.11×10^{-7}	2.64×10^{-7}	1.35×10^{-6}	5.10×10^{-6}
Se-79	0	3.74×10^{-8}	9.31×10^{-6}	1.14×10^{-5}

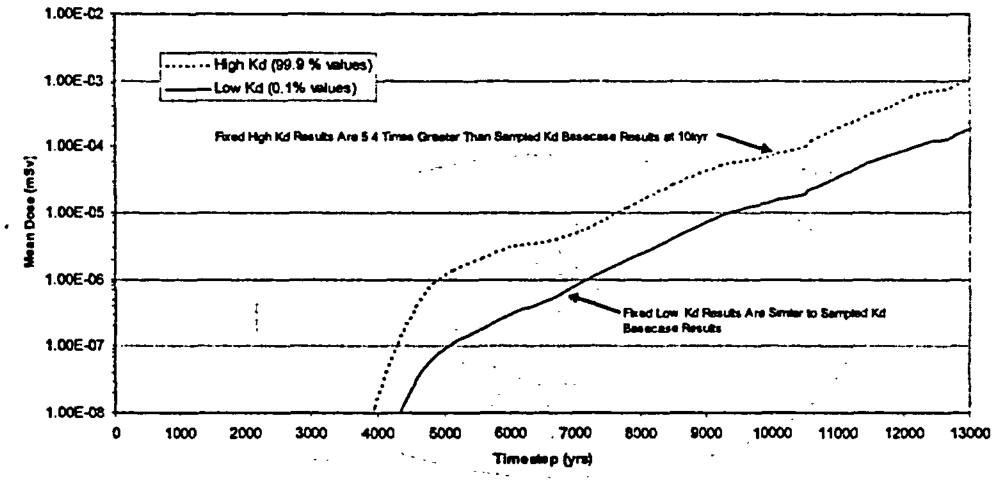


Figure 4-44. Comparison of Dose Curves from Basecase and High and Low Perturbations of Soil Distribution Coefficients (Kd) Using the TPA Version 4.1d Code

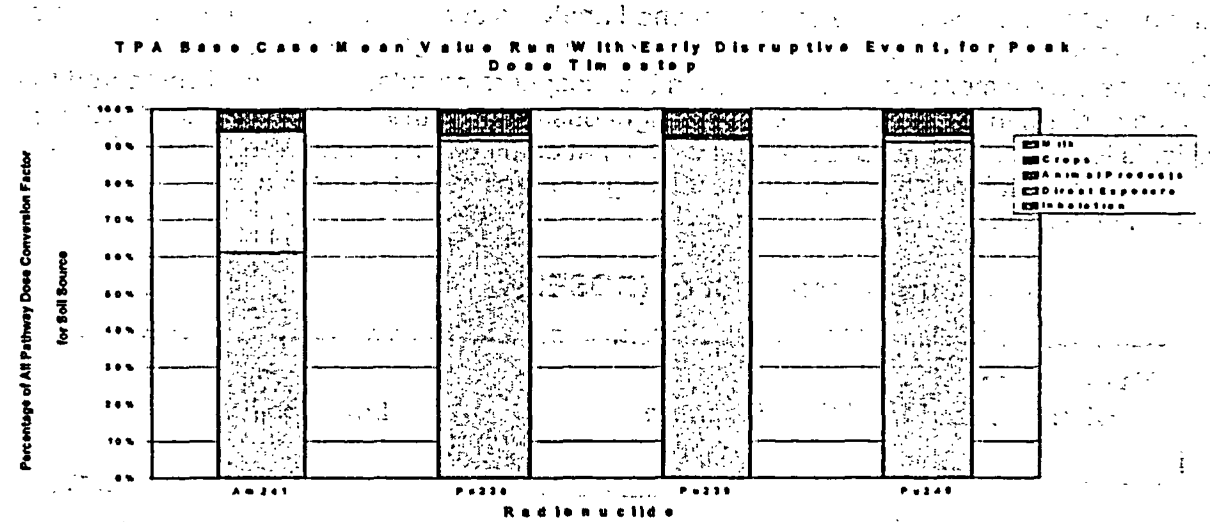


Figure 4-45. Igneous Activity Release Scenario: Exposure Pathway Contributions for Important Radionuclides (Using the TPA Version 4.1 Code) (Am-241, Pu-238, Pu-239, Pu-240)

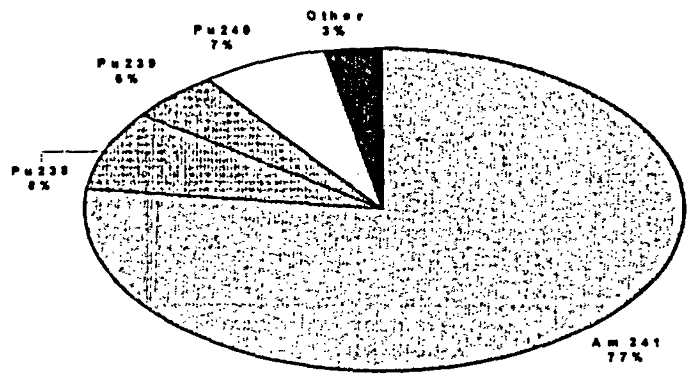


Figure 4-46. Key Radionuclides for Igneous Activity Disruptive Event Dose (Using the TPA Version 4.1 Code) (Am-241, Pu-238, Pu-239, and Pu-240)

Uncertainties

For the ground water-release biosphere calculations, leaching of radionuclides in soils is an uncertain process. However, the aforementioned analyses suggest the magnitude of the impacts of this uncertainty on dose is low when evaluated in the context of other uncertainties in the performance assessment (i.e., the variation in the biosphere calculations is small compared to the rest of the performance assessment). For the igneous release, the uncertainty in the leaching behavior is less important because radionuclides that dominate the dose have low mobility in soils. Other potential redistribution processes (e.g., surface remobilization) are somewhat uncertain.

4.3.14 Biosphere Characteristics (DOSE3)

Risk Insights:	
Characterization of the Biosphere	Low Significance

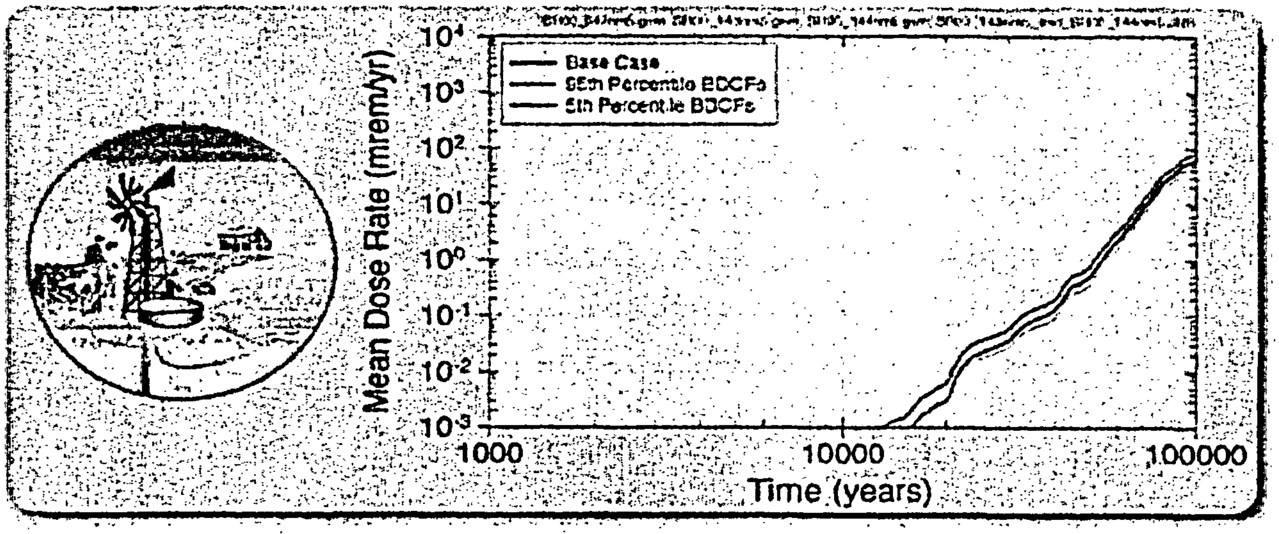


Figure 4-47. Sensitivity to Biosphere Dose Conversion Factors. (From CRWMS M&O, Page F5-38) (1.0 mrem/yr = 0.01 mSv/yr)

4.3.14.1 Discussion of the Risk Insights

Characterization of the Biosphere: Low Significance to Waste Isolation

The regulation at 10 CFR Part 63 specifies mean values to be used for many important biosphere parameters, thereby limiting the effect of biosphere modeling assumptions and parameters on total system risk estimates.

Discussion

NRC regulations at 10 CFR Part 63 specify the use of mean values for behavioral input parameters (i.e., diet and living style) such as consumption rates and exposure times, which reduces the range of variation in the ground water-release biosphere model abstraction calculations (NRC, 2002; page 3.3.14-11). The DOE evaluation of the impact of the biosphere modeling variation on estimated dose results is shown in Figure 4.47.

Uncertainties

As noted in the discussion, the uncertainties in the biosphere calculations are limited by requirements at 10 CFR Part 63. Based on the available parameter information used for the ground-water-release biosphere dose calculations, the staff does not expect that a significant increase in the uncertainty propagated in the biosphere calculations would occur from additional information. For igneous activity biosphere dose calculations, the modeling of features and processes that lead to resuspension of contaminated volcanic ash (e.g., the mass-loading factor) at the location of the reasonably maximally exposed individual is both highly uncertain and important to dose results. Although conceptually this is a biosphere abstraction issue, it is also addressed in the igneous disruptive event abstraction in Section 4.3.11 and is not considered further in ranking the significance to waste isolation of the biosphere.

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Southwest Research Institute
6220 Culebra Road, Bldg. 189
San Antonio, TX 78238-5166

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10. SUPPLEMENTARY NOTES

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11. ABSTRACT *(200 words or less)*

This Integrated Issue Resolution Status Report provides background information about the status of prelicensing interactions between the U.S. Department of Energy (DOE) and the U.S.Nuclear Regulatory Commission (NRC) concerning a potential high-level waste geologic repository at Yucca Mountain, Nevada. The NRC staff has, for many years, engaged in prelicensing interactions with DOE and various stakeholders. In recent years, DOE and NRC have reached a number of agreements related to key technical issues important to repository performance after permanent closure and items important to safety during the period before permanent closure. During the prelicensing period, the NRC staff also have undertaken a risk insights initiative to enhance the use of available risk information and develop, as a common basis for understanding, the significance of features, events, and processes that may affect the performance of potential engineered and natural barriers at Yucca Mountain.

This report provides an overview of available information and status (as of March 2004, with exceptions as noted) of the Key Technical Issue agreements reached between DOE and NRC. The report also documents the risk insights (Appendix D) and information considered by the NRC staff in formulating their views, including in-depth reviews of available DOE and contractor documents; the independent confirmatory work of NRC and its contractor, the Center for Nuclear Waste Regulatory Analyses; published literature; and other publicly available information.

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