Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

Importance to System Performance - This subissue focuses on the information and technical needs related to the development of abstracted models for TSPA. Specifically, the following aspects of model abstraction are addressed under this subissue: (i) data used in development of conceptual approaches or process-level models that are the basis for abstraction in a TSPA, (ii) resulting abstracted models used to perform the TSPA, and (iii) overall performance of the repository system as estimated in a TSPA. In particular, this subissue addresses the need to incorporate numerous features, events, and processes (FEPs) into the PA and the integration of those factors to ensure a comprehensive analysis of the total system.

ENG1: Degradation of Engineered Barriers

AC1 - System description and model integration are adequate

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Mon Pasu	ENG1.1.1	The general corrosion of a waste package is resampled part way through the degradation calculation. Technical basis is needed that the resampling of corrosion rates part way through the degradation calculation appropriately represents the physical processes occurring and that the results obtained when applied such a technique are in agreement with the original data (e.g. failure distribution and surface area failed over time). Reference: NRC 2000. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration.* Rev. 3. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 249045. pg. 194, TSPA QA Audit (July 2000)	The "resampling" is used to account for the dual closure lid waste package design used in TSPA-Site Recommendation (CRWMS M&O 2000ar). The closure lids are properly modeled as two separate entities (i.e., the model parameters are sampled for each closure lid). The remainder of the waste package outer barrier is indeed modeled as being composed of two "pseudo-barriers." Since failure of the closure lid weld regions determines the waste package failure time, the pseudo-barrier modeling approach used for the remainder of the waste package outer barrier is of little consequence to the expected mean annual dose rate. It is also expected that the current modeling approach does not affect significantly the waste package degradation analysis results and the peak doses. It should be noted that in reality, general corrosion rates of the patches are likely to switch over time (i.e., rather than corroding at the same rate) throughout such a long exposure time period, and the current approach with the re-sampling of the rates a half way through is considered still highly conservative in light of the first breach time. Details of the justification for the insignificant consequence of the re-sampling of the general corrosion rate a half way through to the waste package degradation analyses will be documented in a future revision of the Waste Package Degradation Analysis/Model Report (CRWMS M&O 2000az).

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			Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.
Lee Pasu Mackinnon	ENG1.1.2	The model abstraction for the transport of water through stress corrosion cracks in the drip shield and diffusive transport of radionuclides through the stress corrosion cracks in the waste packages are also based on a beneficial FEP (2.1.03.10.00 Container Healing) that was included for the EBS in the TSPA-SR (CRWMS M&O 2000ar, Table B-12 p. B-37) and the Engineered Barrier System Process Model Report (CRWMS M&O 2000q) even though it has been excluded on the basis of low consequence in the Drip shield and Waste Package FEPs AMR (CRWMS M&O 2001e) as well as the Engineered Barrier System FEPs AMR (CRWMS M&O 2001b). The screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation (CRWMS M&O 2001e), specifically addresses transport of both water and radionuclides and states in FEP 2.1.03.10.00 "Plugging (or healing) of corrosion holes or pits in the waste container by corrosion products and mineral precipitates is a possible process in the repository. However there are large uncertainties associated with the quantification of the effect of the processes on water flow and radionuclide transport through the openings. Because of this, potential performance credit from the plugging	The arguments of the tightness of stress corrosion cracks and plugging of the cracks by corrosion products and mineral precipitates were used to screen out the drip shield stress corrosion cracking. Recent analysis has shown that these cracks are expected to be plugged by mineral precipitates (e.g., calcite) within a few decades (BSC 2001d, Tables 6-3 and 6-5). The very limited flow of water through the plugged cracks would not compromise the intended function of the drip shield (i.e., diversion of dripping water). Moisture would still be available from the humid air in the emplacement drift, and condensation of water occur on the waste package surface provided the humidity of the surrounding air in the emplacement drift is high enough. The water condensation would be greatly enhanced if the waste package surface were contaminated with dust and/or hygroscopic salts. Therefore, the plugged stress corrosion cracks in the drip shield would not affect the intended function of the drip shield, and the drip shield stress corrosion cracking has been screened out (CRWMS M&O 2001e). The TSPA-Site Recommendation assumes (CRWMS M&O 2000ar) diffusion is the dominant transport process for radionuclide release through the plugged stress corrosion cracks in the waste package. It is acknowledged that the screening

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		(or healing) of the corrosion penetration openings are not taken into account in the TSPA analysis. Therefore this FEP is excluded based on low consequence to the expected annual dose." The model abstraction for transport through stress corrosion cracks in the drip shield and waste packages should be consistent with the FEP screening arguments. The technical basis for the tight crack geometries that prevent advective transport through stress corrosion cracks in the waste package should be provided. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000q. *Engineered Barrier System Degradation, Flow, and Transport Process Model Report.* TDR-EBS-MD-000006 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000724.0479. CRWMS M&O 2001e. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004. CRWMS M&O 2001b. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010312.0024.	arguments for FEP 2.1.03.10.00 (Container Healing) need to be updated to incorporate the latest analysis for the SCC crack plugging and to be consistent with the TSPA analysis. The waste package FEPs Analysis/Model Report (CRWMS M&O 2001e) will be revised to update the screening argument. References: BSC 2001d. *Plugging of Stress Corrosion Cracks by Precipitates.* CAL-EBS-MD-000017 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. Submit to RPC. CRWMS M&O 2001e. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL20010216.0004. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045

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AC3 - Data uncertainty is characterized and propagated through the model abstraction

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Summers McCright	ENG1.3.1	DOE should explain why crevice samples yield higher corrosion rates than non-crevice samples in the Long Term Corrosion Testing experiments. Is it possible that enhanced corrosion rates as a result of a less protective film are occurring in the crevice area? Is the equation to compute corrosion rates (CRWMS M&O 2000bc, Equation 3-15) adequate if there are small regions of enhanced dissolution? Equation 3-15 in (CRWMS M&O 2000bc) is $r = w/(\Delta A t)$ **r** : corrosion rate (m/yr) **w** : weigh loss (kg) Δ : Alloy 22 density (kg/m^3) **A** : surface area of coupon sample (m^2, 30.65 and 57.08 cm^2 for weight loss and crevice samples, respectively, CRWMS M&O 2000bc, p 3-41) **t** : duration of weight loss test (yr) A corrosion rate derived using Equation 3-15 can be interpreted as an average rate on the surface of the sample. It is not clear that this average is a valid corrosion rate in case of existence of small regions with high dissolution rates. Reference: CRWMS M&O 2000bc. *Waste Package Degradation Process Model Report.* TDR-WIS-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000717.0005.	Container Life and Source Term agreement 1.4 will address the higher corrosion rates in crevice samples versus non-crevice (weight loss) samples. Overall, the crevice specimens do not systematically indicate higher general corrosion rates than the weight loss coupons, but there are some data sets where the average rate and range of rates from crevice specimens do appear higher. DOE is in the process of performing a more detailed analysis of the data sets to determine whether there is bias in the results and if so, what factors may be responsible. When the 5 year corrosion data become available in February 2002, additional physical measurements will be performed and the difference between the corrosion rates for crevice and non-crevice samples will be reassessed.

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Gordon Pasu	1.3.2	DOE should explain why corrosion rates tend to decrease with test duration in the Long Term Corrosion Testing experiments. It has been explained that decreasing corrosion rates is the result of a passive film that thickens with time (CRWMS M&O 2000bc, p 3-42). Is there any evidence that the passive film on 2-year samples is thicker than the 0.5 and 1-year samples? The inner chromium-rich oxide film, which is responsible for passivity, is likely to achieve steady-state in short time (few weeks), at which time the inner film may maintain a constant thickness. The outer layer(s) in the film are not necessarily responsible for passivity. Reference: CRWMS M&O 2000bc. *Waste Package Degradation Process Model Report.* TDR-WIS-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000717.0005.	The observed decrease in corrosion rate with time for long term corrosion test samples exposed for 0.5, 1.0 and 2-2.3 years is attributed to a combination of factors as indicated below: 1. The actual Alloy 22 corrosion rates measured on the currently used small surface area specimens in the various Long Term Corrosion Test Facility environments at 60 and 90°C are too low to allow accurate measurement by descaled weight loss. Whereas the measured corrosion rates indicate a decrease with time (mean rate decreases from 0.05 microns/year at six month to 0.01 microns/years), the calculated weight loss uncertainty due to various measurement errors is equivalent to ~0.04 microns metal loss at one standard deviation (CRWMS M&O 2000be, p. 74). Thus, any corrosion rate trend at shorter test times is partially masked by the measurement uncertainty. 2. For the most passive materials, and the types of expected environments, the passive film thickness and resulting corrosion rate rapidly reach an essentially constant value. Thus, as the test time increases, the measured corrosion rate would be expected to approach the true value since the weight loss uncertainty becomes a smaller fraction of the actual weight loss. The Container Life and Source Term agreement 1.6 indicates that DOE will resolve the corrosion rate uncertainty by using higher sensitivity corrosion rate measurement techniques and by directly measuring the passive film growth kinetics using techniques such as the Tunneling Atomic Force Microscope.

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			Reference: CRWMS M&O 2000be. *General Corrosion and Localized Corrosion of Waste Package Outer Barrier.* ANL-EBS-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000202.0172.
Summers McCright	ENG1.3.3	DOE should provide additional technical basis in support of the interpretation of the experimental data from the Long Term Corrosion Test Facility. For example, **(A)** Deposition of corrosion products producing "weight gain" may compete with dissolution through the film causing "weight loss," thus weight loss measurements may underestimate corrosion rates. Precipitates have been observed on Alloy 22 under transpassive conditions (Dunn et al. 2001). **(B)** It has been explained that the observed weight gain is due to the formation of silica precipitates. Do silica precipitates form an insulating coating? Is it possible that the apparent decrease in the corrosion rate with time is due to a decrease in the extent of the reactive surface area? Note that longer term testing tended to yield more samples with weight gain (up to 40% of the total number of samples). **(C)** It has been estimated that correcting apparent corrosion rates by 63 nm/yr is sufficient to provide an estimate of intrinsic corrosion rates. Note the following computations: Simulated Dilute Water conditions (SDW), Weight Loss Specimens - 6 month Average corrosion rate = 27 nm/yr Penetration of corrosion front = 27x0.5 = 13.5 nm SDW, Weight Loss Specimens - 1 year	**(A, B & C)** The current DOE analysis includes a correction to the general corrosion rates from the weight loss measurements for potential incomplete de-scaling of silica deposit on the sample coupons. Observations of limited number of sample coupons with atomic force microscope showed varying degrees of coverage of the sample coupon surface by the silica scale. The maximum correction of 63 nm/yr is for the complete coverage of the coupon surface by silica scale. In the DOE analysis, the correction for potential incomplete de-scaling of the silica deposit from sample coupons is accomplished by sampling the correction factor from uniform distribution between 0 and 63 nm/yr and adding the sampled factor to the general corrosion rate distribution. The maximum corrosion rate adjustment of 63 nm/yr is consistent with current experimental data. If ongoing experiments show a higher corrosion rate adjustment is appropriate, then a higher rate adjustment will be incorporated into the corrosion models. It should be noted that the presence of silica scale on the Alloy 22 coupons would provide a certain level of protection against corrosion attack. With silica scale forming on the waste package (and drip shield) surface, which is very likely under expected repository exposure conditions, the current analysis is a realistic measure for the general corrosion rate of the waste package. The Container Life and Source Term agreement 1.6 identifies specific activities to resolve the ambiguity regarding silica

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		Average corrosion rate = -22 nm/yr Penetration of corrosion front = -22x1 = -22 nm Penetration of the corrosion front from 0.5 yr to 1 yr = -22 nm - 13.5 nm = -35.5 nm If the "outward" motion of the surface is due to silica deposits, the rate of deposition would be 35.5/0.5 = 71 nm/yr This number of 71 nm/yr is greater than the correction of 63 nm/yr used in the abstraction. **(D)** Caution must be taken when defining corrosion rates with PDFs having wide variances so as to avoid risk dilution. References: CRWMS M&O 2000bc. *Waste Package Degradation Process Model Report.* TDR-WIS-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000717.0005. D.S. Dunn, C.S. Brossia, and O. Pensado. *Long-Term Dissolution of Alloy 22: Experiments and Modeling.* Paper 01125 in the Symposium Corrosion in Nuclear Systems, CORROSION/2001. Houston TX, March 11-16, 2001. Corrosion data transmitted to NRC on 4/10/01	deposition and calculation of a factor to account for its influence in the general corrosion rate of Alloy 22 specimens. Corrosion data for silica-free environment will provide additional valuable information to resolve the issues associated with potential effect of silica deposit on the general corrosion rate. **(D)** Sensitivity analyses were conducted for effect of varying number of waste packages and patches on a waste package (CRWMS M&O 2000az, Section 6.4.3), which provides good indications on the stability of the analysis results from the perspective of the sampling of the tails of the stochastic input parameters (e.g., general corrosion rate distribution). The analysis results show that a larger number of waste packages and patches per waste package than the current analysis (i.e., 400 waste packages per simulation and 1,000 patches per waste package) do not have impact on the waste package degradation results (CRWMS M&O 2000az, Section 6.4.3). This demonstrates that the tails of the current general corrosion rate distribution are represented appropriately in the current analysis. Reference: CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.
Mon Pasu Jolley Mackinnon	ENG1.3.4	Corrosion rates and TSPA computations. **(A)** Including a factor for MIC uniformly sampled in the range (1,2) and a factor for thermal aging and phase instability uniformly sampled in the range (1,2.5) empirical PDF for corrosion rates (including 0.5-yr, 1-yr, and 2-yr test data) may produce general corrosion failure times as early as 5,000 yr See	A. The Alloy 22 2-year exposure corrosion rates were used to develop the general corrosion rate distribution used in Performance Assessment. The corrosion rate distributions obtained from the Long Term Corrosion Test Facility show that as the exposure time increases, the median and variance of the corrosion rates decrease. This indicates that longer-term

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		Figure 2. Similar computations with only 2-yr test data produce much later failure times (Figure 2). Thus, it is very important to provide appropriate technical basis to disregard the 0.5-yr and 1-yr test data in the model abstraction. **(B)** The computations for Figure 2 followed a simple approach. Corrosion rates were sampled from empirical PDFs, enhanced by the MIC and thermal aging factors. Failure times were computed as 2 cm/r, where r is the corrosion rate in cm/yr This approach disregards the delay in the onset of aqueous environments (<<1,000 yr); however, these simple computations are expected to yield results comparable to those derived from complex models. In particular, Figure 3.4-20 in TSPA-SR (CRWMS M&O 2000ar) is directly comparable to Figure 2. DOE should explain why only at most 1% of the waste package surface is degraded by general corrosion at 100,000 yr, while simple computations indicate an expected value of ~30% at 100,000 yr (see Figure 2). Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	measurements would result in lower corrosion rate distributions. Furthermore, it has been shown that as exposure time increases the error in the Long Term Corrosion Test Facility measurements decreases (CRWMS M&O 2000ar, Table 16). These observations provide appropriate technical basis to disregard the 0.5-yr and 1-yr test data in the model abstraction. Analyses of corrosion rates appropriate for use over long time periods are part of existing Container Life and Source Term agreements (1.4, 1.7, 1.8). B. Figure 3.4-20 in the TSPA-SR (CRWMS M&O 2000ar) shows the percentage of waste package patch breaches per failed waste package. In the DOE model, waste packages may breach by cracks or patches. In Figure 2, only general corrosion processes are considered (no cracks were considered). Therefore, Figure 2 is not directly comparable to Figure 3.4-20 in the TSPA-Site Recommendation. The results of the cases in Figure 2 were reproduced in Waste Package Degradation Model and the results are in general agreement with those shown in Figure 2. In a telecon (7/11/2001) between DOE and NRC, it was confirmed that with the discrepancies in the approach resolved, the NRC results are sufficiently close to the current DOE analysis results. The basis for not excluding microbial induced corrosion from a microbial communities standpoint is documented in the In-Drift Microbial Communities Analysis/Model Report (CRWMS M&O 2000ac).

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			References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000ac. *In-Drift Microbial Communities.* ANL-EBS-MD-000038 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0066.
Mon Pasu	ENG1.3.5	High corrosion rates, upper tails of PDFs. **(A)** It is assumed that corrosion rates are normally distributed (CRWMS M&O 2000bc, p 3-36, 3-113), assumption that seems adequate for the 2-yr testing data. However, this assumption is not valid if all the testing data (0.5, 1, and 2 yr) is considered in the statistical population. Furthermore, for the extended population set (0.5, 1, and 2 yr), the normal distribution underestimates the high corrosion rates. Using the Gauss-Variance partitioning scheme is not enough to define confidence intervals for the high corrosion rates. Figure 1a in the attachment supports this statement. Figure 1b, shows that much earlier failure times are predicted on the basis of an empirical PDF (i.e., defined using experimental corrosion rates) than those derived using normal PDFs of the Gauss-Variance Partitioning approach. The intention of this comment is suggesting that if all data available is used to define normal PDFs, there is some risk of predicting larger than expected early failure times, because normal PDFs do not capture the high corrosion rates. **(B)** High corrosion rates are most relevant to model abstraction. The size of the statistical population should be large	**(A)** The corrosion rates are not assumed to be normally distributed. They are given by an empirical Cumulative Distribution Function derived from the two-year experimental data and corrected for silica deposition. Gaussian-Variance Partitioning (GVP) preserves the span of the general corrosion rate distribution. The highest and lowest values are present in every GVP output. The Cumulative Distribution Function probabilities are mapped to normal probabilities; the variance is partitioned; and the probabilities are mapped back to real space. The net effect is that variance is partitioned between uncertainty and variability. The resulting distribution is not normally distributed. The Alloy 22 2-year exposure corrosion rates were used to develop the general corrosion rate distribution used in Performance Assessment. The corrosion rate distributions obtained from the Long Term Corrosion Test Facility show that as the exposure time increases, the median and variance of the corrosion rates decrease. This indicates that longer-term measurements would result in lower corrosion rate distributions. Furthermore, it has been shown that as exposure time increases the error in the Long Term Corrosion Test

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		enough to define the upper tail of the PDF for the corrosion rate with confidence. Reference: CRWMS M&O 2000bc. *Waste Package Degradation Process Model Report.* TDR-WIS-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000717.0005.	Facility measurements decreases (CRWMS M&O 2000be, Table 16). These observations provide appropriate technical basis to disregard the 0.5-yr and 1-yr test data in the model abstraction. Analyses of corrosion rates appropriate for use over long time periods are part of existing Container Life and Source Term agreements (1.4, 1.7, 1.8). **(B)** TSPA simulations use 100 (sometimes 300) realizations with 400 waste package/drip shield pairs per realization. Each drip shield has 500 patches and each waste package has 1000 patches. In all some 40,000,000 patches are simulated to determine the mean annual dose. Reference: CRWMS M&O 2000be. *General Corrosion and Localized Corrosion of Waste Package Outer Barrier.* ANL-EBS-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000202.0172.
Mon Pasu	ENG1.3.6	Staff believes that the interpretation of the corrosion-rate data could make a significant difference in the regulatory dose, and therefore disagrees with the DOE conclusion in section 5.2.3.3 of the TSPA results that there is little effect from Gaussian Variance Partitioning (GVP). NRC staff has developed a highly abstracted model of the relationship between failed WP area and peak mean dose, and believes there are circumstances where assuming that the corrosion rate data represent mostly spatial variability will lead to a higher peak mean dose than if the same data represented mostly experimental uncertainty.	Assuming enough samples are considered, one would expect little effect of a sampling scheme on the mean dose. This is shown in Section 5.2.3.3 of the TSPA in Figures 5.2-7 and 5.2-8. In a given realization, increased spatial variability should lead to the potential for earlier failure and decrease the peak doses. It is agreed that increased spatial variability could lead to higher peak doses for the mean dose. Review of the NRC analysis results provided to DOE and subsequent discussion of the results during a recent DOE and NRC telecon (7/11/2001 teleconference) confirmed that the NRC results of the relationship between failed waste package area and peak

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		Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	mean dose are driven mostly by the modeling assumptions made for the radionuclide transport from the failed waste packages and through the failed area. In the NRC analysis, the effect of the waste package failed area and its subsequent degradation (i.e., additional failed areas) with time on the peak mean dose that result from the two end-member cases assuming 100% variability and 100% uncertainty in the Alloy 22 general corrosion rate is secondary to the effect of the transport modeling assumptions. The discrepancies of the peak mean dose to the conceptual understanding for the two end-member cases (i.e., higher peak mean doses with the 100% variability case) become greater when more conservative assumptions are employed for the transport modeling. In comparison, the DOE analysis results for the two end-member cases show no significant difference in the peak mean doses. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Lee Gordon Gross Mackinnon	ENG1.4.1	The DOE model abstraction assumes diffusive transport of radionuclides through stagnant water that fills stress corrosion cracks in the waste packages and lack of water transport through cracks in the drip shield. This assumption has a direct effect on dose because it is assumed that advective transport of radionuclides by flowing water through stress corrosion cracks in the waste package does not occur. In addition, the DOE model (CRWMS M&O 2000aq) assumes that the quantity of water that is transported through cracks in the titanium alloy drip shield is limited by diffusion. Stress corrosion cracking of the drip shield has been excluded as a FEP on the basis of low consequence because water transport though cracks in the drip shield will not significantly increase the quantity of water contacting the waste packages and waste forms. The assumption of diffusive transport of radionuclides with the exclusion of advective transport relies on stress corrosion crack geometries that will remain tight for thousands of years. The tight geometry of stress corrosion cracks are in turn based on unsupported assumptions. For the waste packages, it is assumed that the stress corrosion cracks will cease to propagate when the lid is penetrated. Secondary cracks and crack branching, which may contribute to crack opening displacement and subsequently allow advective transport of radionuclides by slow flowing water, are not considered in the DOE model. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The previous analyses using the fundamental relation of fracture mechanics have shown that the stress corrosion crack openings in drip shield and waste package are very "tight" (CRWMS M&O 2000ao, Section 6.5.5). The cracks in the drip shield due to rockfall (CRWMS M&O 2000am, Section 6; CRWMS M&O 2000ao, Section 6.5.5) and hydrogen induced cracking (CRWMS M&O 2000x, Section 6.3.4) are self-limited and remain tight. These tight cracks will be plugged by corrosion products and mineral precipitates. Recent analyses have shown that stress corrosion cracks are expected to be plugged by calcite within a few decades (BSC 2001d, Tables 6-3 and 6-5). Very limited water flow is expected through the plugged stress corrosion cracks. Because such plugged stress corrosion cracks would not affect the intended function of the drip shield (i.e., diversion of dripping water), the drip shield stress corrosion cracking was screened out and not modeled in the waste package degradation analysis and TSPA-Site Recommendation. Secondary cracks and crack branching are not modeled explicitly in the TSPA-Site Recommendation waste package degradation analysis. Because, when a crack propagates through the wall thickness, the tensile stress that has driven the crack propagation is relieved, no additional crack growth is assumed in the "immediate" vicinity of the through-wall crack. In the TSPA-Site Recommendation waste package degradation analysis, multiple cracks are allowed to grow in a single patch, and when that patch is breached by a stress corrosion crack, all remaining cracks in that patch cease to grow because of the stress relief in the immediate vicinity of the through-wall crack. The waste package closure-lid weld region is represented with a

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AC4 - Model uncertainty is characterized and propagated through the model abstraction			
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		CRWMS M&O 2000ay. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0332.	total of 32 patches. Because one through-wall stress corrosion crack per patch is assumed in the waste package degradation analysis, the modeled maximum number of through-wall stress corrosion cracks per waste package is 32. In the TSPA-Site Recommendation analysis, the number of through-wall stress corrosion cracks estimated from the waste package degradation analysis is increased conservatively by a factor of 10 for the actual number of through-wall stress corrosion cracks used for transport calculations. The factor of 10 increase in the number of through-wall stress corrosion cracks is based on the "2T" rule, where T is the thickness of material subject to stress corrosion. The area represented by the "2T" rule is referred to a unit area in this discussion. The rule indicates that within an area that is represented by approximately two times the thickness of the material, a stress corrosion crack can grow without interfering with the neighboring stress corrosion cracks. For the weld region of the outer closure-lid (25-mm thick) of the waste package outer barrier, the "unit" area represented by the 2T rule is approximately 25 cm^2 [(2x2.5 cm) x (2x2.5 cm)]. The unit area for the weld region of the inner closure-lid (10-mm thick) of the outer barrier is approximately 4 cm^2 [(2x1.0 cm) - (2x1.0 cm)]. With the area of a single patch of approximately 234 cm^2 (CRWMS M&O 2000az, Section 5.1), there are approximately 9.4 unit areas for the outer closure-lid weld region. This is the technical basis to increase conservatively the number of through-wall stress corrosion cracks from the waste package degradation analysis by a factor of 10 for the TSPA analysis. This is a highly conservative approach because it assumes that when a patch is breached by a through-wall stress corrosion crack, there are nine additional through-wall stress corrosion cracks penetrating that patch at the same time.

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ENG1: Degradation of Engineered Barriers			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			For the inner closure-lid weld region, the number of the unit areas per patch is much higher (approximately 59 unit areas) than the outer closure-lid weld region. However, the same number of the unit areas per patch as the outer closure-lid weld region is assumed for the inner closure-lid weld region. Because the approach used for the outer closure-lid weld region is already highly conservative, use of the same number of the unit areas per patch for the inner closure-lid weld region is considered reasonably conservative. Accordingly, the maximum possible number of through-wall stress corrosion cracks per waste package used in the TSPA-Site Recommendation analysis is 320. Details of the technical basis and accompanying assumptions will be documented in a future revision of the Waste Package Analysis/Model Report (CRWMS M&O 2000az). As discussed above, the through-wall crack and secondary cracks (although not modeled explicitly) would be plugged by corrosion products and mineral precipitates in a relatively short time period (BSC 2001d, Tables 6-3 and 6-5), and exclusion of explicit representation of secondary cracks should not underestimate the transport rates of radionuclides through the plugged stress corrosion cracks. In a more realistic scenario, secondary cracks would increase tortuosity of the transport pathway, and non-inclusion of secondary cracks may be more conservative for the transport rate of radionuclides. However, potential effects of static loads and/or rockfall on degraded drip shield and waste package by stress corrosion cracking and general corrosion have not been considered. This issue will be addressed under the Container Life and Source Term Agreement Item 2.8 prior to any potential License Application.

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Subissue 3: Model Abstraction

ENG1: Degradation of Engineered Barriers			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			References: BSC 2001d. *Plugging of Stress Corrosion Cracks by Precipitates.* CAL-EBS-MD-000017 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. Submit to RPC. CRWMS M&O 2000ao. *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material.* ANL-EBS-MD-000005 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0340. CRWMS M&O 2000am. *Rock Fall on Drip Shield.* CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000509.0276. CRWMS M&O 2000x. *Hydrogen Induced Cracking of Drip Shield.* ANL-EBS-MD-000006 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001025.0100. CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.

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Subissue 3: Model Abstraction

ENG1: Degradation of Engineered Barriers			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Mon Pasu	ENG1.5.1	Validation of WAPDEG is still pending by DOE's own account, particularly validation of the Gauss Variance Partitioning methodology. Reference: CRWMS M&O 2000bb. *Waste Package Degradation Process Model Report.* TDR-WIS-MD-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000328.0322.	The Waste Package Degradation software was unqualified and has since been qualified. The qualification efforts included execution of approximately100 test cases (CRWMS M&O 2000ax) verifying the operation of various segments of the Waste Package Degradation code. The Waste Package Degradation Model has also been validated in accordance with applicable DOE procedures. The *WAPDEG Analysis of Waste Package and Drip Shield Degradation* (CRWMS M&O 2000az) was reviewed in accordance with applicable DOE procedures. The review included reviewers from quality assurance, waste package materials, and regulatory and licensing organizations. An International/National Waste Package Materials Peer Review is underway to review and improve corrosion testing and modeling approaches. Also, studies are underway of relevant natural analogues. References: CRWMS M&O 2000ax. *Validation Test Report (VTR) for WAPDEG V4.0.* STN: 1000-4.0-00, SDN: 10000-VTR-4.0-00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001205.0014. CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.
Nowak Mackinnon	ENG1.5.2	Model validation is argued to be done implicitly through sub-model validation. It is unclear that this approach satisfies DOE QA requirements for model validation. Reference: CRWMS M&O 2000al. *Physical and Chemical Environmental Abstraction Model.* ANL-EBS-MD-000046 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC:	REV 01 of the Physical and Chemical Environmental Abstraction Model AMR (CRWMS M&O 2001l) describes more clearly the nature and purpose of the document. It presents an overall conceptualization of the physical and chemical environment in the emplacement drift, as stated in Sections 1 and 6 of REV 01. Use of this conceptualization is limited to assistance for the Performance Assessment Department in modeling the physical and chemical

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Subissue 3: Model Abstraction

ENG1: Degradation of Engineered Barriers			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		MOL.20000523.0155.	environment within a repository drift and in answering key technical issues, as stated in Section 7.5 of ICN 01 (CRWMS M&O 2000bf). However, the Physical and Chemical Environmental Abstraction Model Analysis/Model Report, along with the remainder of the project Analysis/Model Reports that support TSPA-Site Recommendation are being re-evaluated as part of Corrective Action Report-BSC-01-C-001. The scope of the Corrective Action Report includes identifying deficiencies in model validation and identifying the subset of the TSPA-Site Recommendation Analysis/Model Reports that need to be carried forward to any potential License Application. References: CRWMS M&O 2000bf. *Physical and Chemical Environmental Abstraction Model.* ANL-EBS-MD-000046 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0023. CRWMS M&O 2001l. *Physical and Chemical Environmental Abstraction Model.* ANL-EBS-MD-000046 REV 01. Las Vegas, Nevada: CRWMS M&O. Submit to RPC. Reference: Letter from S.J. Brocoum to W. Reamer, Total System Performance Assessment Quality Issues, dated July 6, 2001

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Subissue 3: Model Abstraction

ENG1: Degradation of Engineered Barriers			
Transparency and traceability			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Pasu Mon	ENG1.TT.1	The abstraction for degradation of engineered barriers does not use consistent and appropriate assumptions throughout the abstraction process. The stated assumption that the drip shield is not subject to SCC is inconsistent with the discussions for FEP 2.1.03.02.00 (stress corrosion cracking of waste containers and drip shield), which indicate the potential for SCC of the drip shield and the expected attributes of the cracks that would develop (i.e., small crack opening that will fill with corrosion products and carbonate minerals). The discussion of the abstraction in the TSPA should be consistent with the discussions in the supporting Analysis and Model Reports. References: CRWMS M&O 2001e. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The assumption that the drip shield is not subject to stress corrosion cracking in the absence of rockfall is valid. However, the potential for rockfall induced stress corrosion cracking is acknowledged in the Waste Package FEP Analysis/Model Report (CRWMS M&O 2001e). It was concluded that the consequences of the cracking were very low because the cracks are expected to be plugged by corrosion products and deposits. DOE will update the FEPs Analysis/Model Report to clarify the FEPs screening argument and to make it consistent with TSPA-Site Recommendation (CRWMS M&O 2000ar, p. 3-91). References: CRWMS M&O 2001e. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Subissue 3: Model Abstraction

ENG2: Mechanical Disruption of Engineered Barriers			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Swift Stockman Siegmann	ENG2.1.1	The DOE has implemented seismic effects on cladding via random sampling for the occurrence of a seismic event of sufficient magnitude (1.1E-6/yr). Unless thousands of realizations are completed, it is unlikely that the approach adopted results in a stable dose estimate. It is also unclear that risks are not underestimated utilizing this method of abstraction. The DOE should consider alternative methods for abstracting seismic cladding failure events. Reference: NRC 2000. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration.* Rev. 3, p.197. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 249045.	Emphasis in the TSPA-Site Recommendation was on the first 10,000 years of performance, with simulations extended to 100,000 years to evaluate the behavior of the system after the containment of the engineered barriers is significantly degraded and to show that doses remain below the proposed limits well past 10,000 years (CRWMS M&O 2000ar, Section 4.1.1). Because of the robust waste package performance in TSPA-Site Recommendation, seismic cladding failures occurring prior to 10,000 years would not have an affect on releases from the Engineered Barrier System, and therefore do not affect the stability of the expected annual dose during the regulatory period. As discussed at the Structural Deformation &Seismicity technical exchange in October 2000 (P. Swift presentation), the DOE recognizes that the approach taken for including seismic cladding failure in the TSPA-Site Recommendation does not provide full statistical coverage of the uncertainty associated with consequences of low-probability seismic events. However, the approach is considered appropriate for the TSPA-Site Recommendation for the following reasons: 1) There is no impact on the expected annual dose from nominal performance during the first 10,000 years. (Cladding damage is already included in the dose calculated for igneous scenario analyses). 2) During the first 100,000 years, consequences of seismic cladding failure were effectively bounded by the cladding neutralization analysis published in Repository Safety Strategy Rev. 4 (CRWMS M&O 2001i, Figure 3-29) and presented by

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ENG2: Mechanical Disruption of Engineered Barriers

AC1 - System description and model integration are adequate

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			Swift at the October 2000 Structural Deformation &Seismicity technical exchange. This analysis showed an increase in mean annual dose of approximately a factor of ten. 3) The approach provides insight into possible effects of seismic cladding damage on peak dose occurring after 10,000 years, because approximately 60% of million-year simulations include a seismic cladding failure event. As discussed at the Structural Deformation &Seismicity technical exchange in October 2000, if future analyses show the potential for a significant impact of seismic cladding failure on expected annual dose during the regulatory period (such as might occur if ground motion were also to breach waste packages), DOE will revise the approach to ensure that risks are not underestimated. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825

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ENG2: Mechanical Disruption of Engineered Barriers			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Pasu Valentine	ENG2.1.2	Insufficient information is available to evaluate the extent of damage to proposed waste packages during potential intrusive igneous events. The analyses for limited waste-package damage in Zone 2 do not consider physical conditions representative of likely igneous events and do not evaluate the range of physical processes likely to affect waste package response during potential igneous events. References: CRWMS M&O 2000aa. *Igneous Consequence Modeling for the TSPA-SR.* ANL-WIS-MD-000017 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000501.0225. CRWMS M&O 1999f. *Waste Package Behavior in Magma.* CAL-EBS-ME-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991022.0201.	Addressed during the Igneous Activity KTI Technical Exchange meeting in June 21-22, 2001.

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ENG2: Mechanical Disruption of Engineered Barriers			
AC2 - Data are sufficient for model justification			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Lee Pasu	ENG2.2.1	Juvenile and Early Failure of Waste Containers uses the software program entitled RR-PRODIGAL (Chapman and Simonen 1998) to estimate waste package closure lid weld flaws and defects. RR-PRODIGAL is not an appropriate method for estimating nickel alloy or titanium welding flaws or defects because it was developed for ferretic steel nuclear reactor pressure vessels only. Reference: Chapman, O.J.V. and Simonen, F.A. 1998. *RR-PRODIGAL - A Model for Estimating the Probabilities of Defects in Reactor Pressure Vessel Welds.* NUREG/CR-5505. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 244619.	In the TSPA-Site Recommendation waste package degradation analysis, the probability, frequency and size of manufacturing flaws in the waste package outer barrier closure-lid welds are used as input to the stress corrosion cracking analysis of the closure-lid weld region (CRWMS M&O 2000az, Sections 4.1.7 and 5.5). The analyses for the parameters were based on the published of Rolls Royce -PRODIGAL simulation results for the welds of stainless steel piping of nuclear power reactor (Khaleel et al. 1999). It is acknowledged that the results used in the waste package stress corrosion cracking analysis are not for the candidate material (Alloy 22) for the waste package outer barrier and the fabrication techniques proposed for the outer barrier closure-lids. However these are the most relevant information that was available for the TSPA-Site Recommendation. The weld flaw data specific to the waste package design and fabrication techniques will be developed from the on-going testing and measurement with a set of simulated mockups and a planned full-scale mockup. The current weld flaw model will be validated against the waste package design specific data and improved as necessary. The use of Rolls Royce – PRODIGAL will be phased out as applicable data become available. References: CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063. Khaleel, M.A.; Chapman, O.J.V.; Harris, D.O.; and Simonen, F.A. 1999. "Flaw Size Distribution and Flaw Existence Frequencies in Nuclear Piping." *Probabilistic and Environmental Aspects of*

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ENG2: Mechanical Disruption of Engineered Barriers			
AC2 - Data are sufficient for model justification			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			Fracture and Fatigue: The 1999 ASME Pressure Vessels and Piping Conference. PVP-386, 127-144. New York, New York: American Society of Mechanical Engineers. TIC: 245621.
Pasu Bennett Valentine	ENG2.2.2	Insufficient data are available to evaluate the extent of damage to proposed waste packages during potential igneous events. References: CRWMS M&O 2000aa. *Igneous Consequence Modeling for the TSPA-SR.* ANL-WIS-MD-000017 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000501.0225. CRWMS M&O 1999f. *Waste Package Behavior in Magma.* CAL-EBS-ME-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991022.0201.	Addressed during the Igneous Activity KTI Technical Exchange meeting in June 21-22, 2001.

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Henning	ENG3.1.1	Dripping has been observed (e.g., fist-to plate-sized puddles, wet drip cloth, corroded metal) in the sealed portion of the ECRB. This dripping may result from vapor-phase mobilization of water and condensation on surfaces such as rock bolts, ventilation ducts, and utility conduits under small thermal gradients. In an unventilated near-field environment where waste-cannister heat causes spatial temperature variability, this process could result in significant dripping. Condensate could react with metal and grout at elevated but below-boiling temperatures. Dripping in the ECRB may also have resulted from seepage into the drift. Data at present are insufficient to distinguish what processes are primarily responsible for the observed dripping. Reference: Observations in sealed portion of ECRB	DOE is investigating the dripping from condensation within the Enhanced Characterization of the Repository Block. New instrumentation will be installed in late fall 2001. The results of the new measurements could be used to refine the Unsaturated Zone drift-scale seepage model and the Engineered Barrier System Thermal Hydrology Model prior to the any potential License Application.
Mackinnon Wilson Sevougian	ENG3.1.2	"Flux splitting" is performed for the waste package but not for the drip shield (CRWMS M&O 2000aq, p. 214). No technical basis is provided for the perceived inconsistency. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Parts of the wording on p. 214 (CRWMS M&O 2000aq) implies that the flux splitting at the drip shield is based on patch area whereas the flux splitting at the waste package is based on axial length of patches. The Engineered Barrier System-transport Analysis/Model Report (CRWMS M&O 2000bg) indicates that both should be based on axial length. DOE will correct the discrepancy between the TSPA-Site Recommendation and the Analysis/Model Report. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000bg. *EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0029.

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Subissue 3: Model Abstraction

ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Sevougian Mon Pasu	ENG3.1.3	The method used to abstract the in-package environments appears to be inappropriate and likely results in an underestimation of risk. For a given thermohydrological bin, a certain number of packages are assigned. An average package failure time is calculated for the packages in that bin. If the average package failure time is less than 1,000 years, then "early" chemistry conditions are applied. Because waste package failure is distributed in time in the DOE model, only the first few packages that fail in a bin experience the "early" chemistry. All waste packages that fail should experience 1000 years of early chemistry if the process model was abstracted properly into the TSPA. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	As noted on pages 259-260 of the TSPA model for SR (CRWMS M&O 2000aq), a weighted-moving-average of in-package chemistry was selected to assure the in-package chemistry for the different waste package types modeled (co-disposal waste package and commercial spent nuclear fuel), different hydrologic environments (always drip, intermittent drip, never drip), and different infiltration rate bins was representative and reasonable. DOE believes this approximation is appropriate at times when a small number of waste packages have been degraded and the rate of waste package failure is increasing. DOE believes these chemistries are most appropriate during the 10,000-year regulatory period. At times approaching 100,000 years, the calculated weighted-moving average pH will be affected by the average chemistry of all packages that would have degraded prior to that time. Although it is possible that the unzipping rate of the cladding may be increased with a different conceptual representation, this is not expected to have a significant effect on the peak mean dose. The extent of potential non conservatism is expected to be insignificant for the following reasons which relate to the solubility of key radionuclides and the dissolution rate of the commercial spent nuclear fuel and unzipping rate of the Zircaloy cladding on the commercial spent nuclear fuel. While the lower pH of the packages that fail at any particular time would increase the Np (and other actinide) solubilities in the waste package, the invert pH would remain essentially unchanged. The invert would then be the controlling chemistry as far as actinide releases are concerned. In addition, at lower pH, the dissolution rate may be about a factor of 10 greater, which would have a corresponding change on the rate of

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			unzipping of the cladding (CRWMS M&O 2000aq, Table 6-49). Such changes in dissolution rate and cladding degradation are insignificant to peak dose, because the peak is dominated by solubility-limited releases rather than the dissolution rate limited release radionuclides. The conceptual model for in-package chemistry will be reviewed and revised for TSPA-License Application, at which time this issue will be revisited. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.
Jolley Mackinnon	ENG3.1.4	Near-field geochemical variables are discussed as being abstracted to "representative constant values" (CRWMS M&O 2000aq, p. 3-70). More information/technical basis is needed for the simplifications used in the near-field environment abstraction process. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The current abstraction is found in the Abstraction of Drift-Scale Coupled Processes Analysis/Model Report (CRWMS M&O 2000b). The abstraction is being updated to reflect updates to the process model. The values selected for use in the abstraction will be tied to direct results from the process model; thus the validation of the abstraction will hang on the validation of the process model. The location (i.e., the specific Analysis/Model Report) of the documentation has not been determined yet. Reference: CRWMS M&O 2000b. *Abstraction of Drift-Scale Coupled Processes.* ANL-NBS-HS-000029 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0371.

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Nowak Mackinnon	ENG3.1.5	The referenced AMR (CRWMS M&O 2000al) provides a global framework defining connections and interactions of other models. The framework presented appears to be consistent with the expected physical processes that may occur. Other AMRs appear to have followed a different framework for water pathways and related water chemistry calculations, even though their general inputs and outputs were to be defined by the Physical and Chemical Environmental Abstraction Model AMR. *Note: this AMR (Rev. 01) has no direct input to TSPA.* Reference: CRWMS M&O 2000al. *Physical and Chemical Environmental Abstraction Model.* ANL-EBS-MD-000046 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000523.0155.	The Physical and Chemical Environmental Abstraction Model Analysis/Model Report describes several processes, chemical, physical, and transport, that potentially affect the in-drift environment that is relevant to performance assessment, although results from related Analysis/Model Reports and other documents may show that some of them can be neglected (CRWMS M&O 2000bf, Section 6.3). Reference: CRWMS M&O 2000bf. *Physical and Chemical Environmental Abstraction Model.* ANL-EBS-MD-000046 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0023.
Wilson (PA) Houseworth (UZ) Francis (NFE) Sevougian (PA	ENG3.1.6	During the integration of UZ percolation above the repository horizon with the seepage abstraction, DOE combines abstracted statistical distributions (the "seepage bins" from the TH model) with data of positional relevance (the output of the UZ model). This results in a spatial disconnect in the abstractions of the involved process models. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	As stated in the TSPA-Site Recommendation model Analysis/Model Report (CRWMS M&O 2000aq) and the TSPA-Site Recommendation technical report (CRWMS M&O 2000ar), the percolation flux is taken from the Multiscale Thermo-Hydrologic model (CRWMS M&O 2000ag), not the Unsaturated Zone flow model. The binning in the TSPA model is based on infiltration rather than spatial location because infiltration is a more important indicator of performance than spatial location. That is, seepage and transport velocity would both be expected to be higher where infiltration is higher. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000ag. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0062.
Mon Francis	ENG3.1.7	During the TEF technical exchange, there was a discussion pertaining to the abstraction of temperature and RH and the representation of those thermodynamic variables in the waste package corrosion models. It was presented that temperature and drift RH were propagated from 610 calculations. A response was not given as to how 610 results are assigned to 400 waste package groups. Reference: Thermal Effects on Flow technical exchange (January 2001)	In the TSPA-Site Recommendation REV 00 Waste Package Degradation Model, the primary effect of the thermal hydrologic files is in determining the corrosion initiation time (the critical relative humidity for corrosion initiation is a function of exposure temperature). The Waste Package Degradation Model used only one of the thermal hydrology files (WDHLW_nbf_high_bin2.ou) which contains information for the 14 High Level Waste, bin2, high infiltration scenario spatial locations. Approximately 28 waste packages were simulated using the information from each spatial location. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.

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Subissue 3: Model Abstraction

ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Gdowski Pasu	ENG3.1.8	DOE has made an agreement to develop the expected chemical environments considering various sources of uncertainty. An agreement does not exist for DOE to complete testing of corrosion rates in environments similar to those predicted by the modeling. Either this task should be completed to ensure consistency and develop adequate model support for the general and localized corrosion models or a strong argument should be made as to why it is not necessary. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Earlier work on the possible ranges of environment focused on carbonate dominated types of Yucca Mountain waters. Results of these studies were used to identify test environments. Container Life and Source Term agreements 1.1 and 1.10 will address other credible ranges of environment on the surfaces of the drip shield and the waste package. This includes introduced materials and other trace elements that could potentially affect the corrosion rates. As was done in the past, corrosion testing environments will be extended to the results of these studies as appropriate. Also, agreement 6.1 includes corrosion testing cover the ranges of credible environments as applicable.
Mon	ENG3.1.9	The model for engineered barrier system failure (WAPDEG) is stated as using environmental information to determine the corrosion rates. In particular, pH is assessed to determine whether localized corrosion would occur. An explanation is needed as to how this is accomplished in the TSPA model. WAPDEG is apparently executed at the beginning of a simulation. How is the pH available for both the external surfaces of the package and from the in-package chemistry calculations for the engineered barrier system failure calculations when WAPDEG is executed first? This comment is also directed at ionic species like chloride and fluoride. Reference: Total-System Performance Assessment (TSPA) for the Site Recommendation (TDR-WIS-PA-000001 REV 00 ICN 01)	Seepage chemistry in-drift is characterized in the *In-Drift Precipitates/Salts Analysis* Analysis/Model Report (CRWMS M&O 2001f). In-package chemistry is characterized in the *In-Package Chemistry Abstraction* Analysis/Model Report (BSC2001c). These abstraction Analysis/Model Reports provide look-up tables for environmental chemical conditions (e.g., pH and Cl- concentration) as a function of exposure temperature and relative humidity. Because pH is the dominant parameter, among the environmental condition parameters considered, for corrosion potentials and threshold corrosion potentials for localized corrosion initiation, the localized corrosion initiation of waste package and drip shield is expressed as a function of pH only. A thermal hydrology pre-processor is run to provide WAPDEG with time histories of environmental chemical conditions corresponding to the exposure temperature and relative humidity files used.

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			References: BSC 2001c. *In-Package Chemistry Abstraction.* ANL-EBS-MD-000037 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010315.0053. CRWMS M&O 2001f. *In-Drift Precipitates/Salts Analysis.* ANL-EBS-MD-000045 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010220.0008.

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Subissue 3: Model Abstraction

ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC2 - Data are sufficient for model justification			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Pasu Nowak Mackinnon	ENG3.2.1	A comparison is needed between the environments (in particular ionic strength) predicted by the low ionic strength model to the environments utilized in the corrosion tests. The comparison between the testing environments and the modeled environments will determine the amount of support needed for the low ionic strength model (CRWMS M&O 2000ar, page 3-70) Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	On-going corrosion tests in the long- term corrosion test facility include a range of environments based on carbonate dominated Yucca Mountain waters, including dilute waters (10X J-13 type). However, focus of the corrosion tests has been to use highly concentrated environments to bound the environmental issues so that the bounding corrosion rates can be established for performance assessment. The range of chemical environments that could interact with the drip shield and waste package is currently being assessed as part of the Evolution of Near Field Environment agreements 2.6 and 2.10. The results will be compared to the corrosion tests chemistries and modified if, necessary.
Jolley Mackinnon Gdowski	ENG3.2.2	Table 3.3-7 (CRWMS M&O 2000aq, page 3-71) for geochemical environments shows that when RH is increasing, Cl (molal) is increasing. Support for this modeled result is needed. I would expect that Cl (molal) should decrease as RH increased, due to more dilution. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Less than 50% relative humidity, 100% evaporation is assumed and thus left with salts. As the relative humidity increases, the Cl concentration increases due to the dissolution of salts. The technical basis is documented in the In-drift precipitates and salts Analysis/Model Report (CRWMS M&O 2001f). Reference: CRWMS M&O 2001f. *In-Drift Precipitates/Salts Analysis.* ANL-EBS-MD-000045 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010220.0008.

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Houseworth	ENG3.3.1	(CRWMS M&O 2000aq, page 3-35). An assessment is needed of the potential error involved with using calibrated property sets derived for the niches and used for seepage modeling. The different state of the system here is the ventilation processes. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The current assumption in Section 5.6 in the Seepage Calibration Model (CRWMS M&O 2001j) is that the effects of evaporation are small. This assumption carries a TBV (4951). DOE will investigate the impact of the ventilation process on calibrated properties. Reference: CRWMS M&O 2001j. *Seepage Calibration Model and Seepage Testing Data.* MDL-NBS-HS-000004 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010122.0093.
Wilson Houseworth	ENG3.3.2	Page 124. Triangular distributions are utilized for parameters in the modeling and abstraction of seepage processes. Are the ranges of the data and most likely value well known that the use of a triangular distribution is appropriate? Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Data supporting the parameter distributions are included in the seepage model. The distributions are representative of the expected ranges and peak at the best estimate. The data ranges and distributions are discussed in the seepage-abstraction Analysis/Model Report (CRWMS M&O 2001o). References: CRWMS M&O 2001o. *Abstraction of Drift Seepage.* ANL-NBS-MD-000005 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010309.0019.

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Subissue 3: Model Abstraction

ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
Transparency and Traceability			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Wilson Sevougian	ENG3.TT.1	How is the spatial variability of the UZ percolation flux above the repository horizon (see e.g. Fig. 3.2-8 on p. F3-16 of TSPA-SR) carried into the seepage abstraction? What input of percolation flux is used in Fig. 3.2-15 on p. F3-23 of TSPA-SR) to determine seepage properties? Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	1) Spatial variability of the percolation flux comes from the Multi-scale Thermo-Hydrologic Model (CRWMS M&O 2000ag). The way that spatial variability of percolation and other quantities is incorporated in the Multi-scale Thermo-Hydrologic Model is discussed briefly in Section 3.3.3.2.2 of the TSPA-Site Recommendation technical report (CRWMS M&O 2000ar) and in detail in the Multi-scale Thermo-Hydrologic Model Analysis/Model Report. 2) As stated in Sections 3.2.4.1, 3.2.4.3, and 3.3.3.2.3 of the TSPA-Site Recommendation technical report and Section 6.3.1.2 of the TSPA- Site Recommendation model Analysis/Model Report (CRWMS M&O 2000aq), the percolation flux 5 m above the drift from the Multi-scale Thermo-Hydrologic Model is used as input to the seepage abstraction. (The percolation flux is also modified by the flow-focusing factor as discussed briefly in Section 3.2.4.3 of the TSPA-Site Recommendation technical report and 6.3.1.2 of the TSPA-Site Recommendation model Analysis/Model Report and discussed in more detail in the seepage-abstraction Analysis/Model Report [CRWMS M&O 2001o].) References: CRWMS M&O 2000ag. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0062. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002

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ENG3: Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms			
Transparency and Traceability			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2001o. *Abstraction of Drift Seepage.* ANL-NBS-MD-000005 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010309.0019.

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Subissue 3: Model Abstraction

ENG4: Radionuclide Release Rates and Solubility Limits			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Stockman Rechard	ENG4.1.1	The integration and implementation efforts are insufficient since the use of PDFs requires that consistent environmental conditions and assumptions are applied to all of the chemical components. The full range of environmental conditions was not reasonably accounted for in the abstraction of radionuclide concentration limits inside breached WPs. Reference: CRWMS M&O 2000ap. *Summary of Dissolved Concentration Limits.* ANL-WIS-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0372.	The full range of environmental conditions will be emphasized in the next revision of the Analysis/Model Report. Reference: CRWMS M&O 2001p. *Summary of Dissolved Concentration Limits.* ANL-WIS-MD-000010 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010223.0061.
Stockman Rechard	ENG4.1.2	The EQ3/6 thermodynamic database was not used consistently for geochemical modeling throughout the Yucca Mountain Project. Reference: CRWMS M&O 2000ap. *Summary of Dissolved Concentration Limits.* ANL-WIS-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0372.	Data to be used in EQ3/6 will be checked and coordinated between all the affected groups.
Stockman Rechard Sevougian	ENG4.1.3	DOE has completed modeling of solubility limits. Some of the simulations would not converge. This is in contradiction of a statement made for quality assurance purposes, that the model has not been utilized outside of the range for which it was validated. It is also not clear how values taken from non-convergent simulations will not lead to underestimation of risk. Reference: CRWMS M&O 2000ap. *Summary of Dissolved Concentration Limits.* ANL-WIS-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0372.	Non-convergent EQ3NR simulations occurs at extreme conditions (e.g., either high or low pH) and when it occurs, no solubility values are produced. As a result, the valid environmental condition ranges for the solubility model become narrower than desired. However, this drawback can be remedied by ensuring that the response surface is upwardly concave with respect to the environmental conditions (c.f. p.38 of the Analysis/Model Report on Am solubility response surface.) This upward concave property assures that the response surface will generate higher solubility values when it is applied out of the range from which it is derived. More efforts will be devote to assure this property for solubility models in the next revision of this Analysis/Model Report. Reference: CRWMS M&O 2001p. *Summary of Dissolved*

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			Concentration Limits. ANL-WIS-MD-000010 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010223.0061.
McNeish Sevougian Summers Mon	ENG4.1.4	More information is needed on how the abstraction methodology captures the situation where flow into the waste packages is close to the evaporation rate (CRWMS M&O 2000aq, page 252) Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE used 10X J-13 for sensitivity study. The sensitivity effect of turning off anhydrous products used up a lot of water similar to evaporation. 10 X J-13 is considered representative of the expected brines during the current modeling scenarios for a breached waste package: • Early failures with an intact drip shield • Waste package performance > 10,000 years. If additional scenarios are developed that result in more aggressive chemistries during the regulatory period, use of 10 X J-13 within the models will be re-assessed. Reference: BSC 2001g. *In-Package Chemistry for Waste Forms.* ANL-EBS-MD-000056 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010322.0490.
Stockman Rechard Jolley Nowak	ENG4.1.5	The approach of using a random pH over the calculated range is possibly an appropriate way to represent uncertainty in the early time in-package chemistry. However, correlations may be needed in order for the model output to be consistent with the system-state that would be determined by the model input (See page 257) Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The in-package chemistry component sets the hydronium ion concentration (pH), total carbonate concentration ($[CO_3]_T$), ionic concentration [i], carbon dioxide partial pressure (f_{CO2}), and oxygen partial pressure (f_{O2}), that is used by other model components of the waste form model in order to maintain consistency. Hence, there is no need to develop correlations between other distributions to maintain consistency. The terse sentence on p. 257 is referring to the fact that the pH inside the waste package is sampled randomly between pH_{high} and pH_{low}. At each time step, pH_{high} and pH_{low} are calculated as a function of the three regression parameters for each environment ("bins and drip conditions"): the average fraction of

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			intact cladding (f_{clad}), the average seepage (q_{seep}), and rate of High Level Waste degradation (r_{HLW}). The pH range represents the uncertainty not accounted for by these three parameters. Other parameters that influence pH (yet are not important enough to be regression variables) are the degradation rates of various steels and aluminum inside the package. To maximize the differences, these degradation rates were all set at either "high" or "low" values to develop the regression equations for pH_{high} and pH_{low}. In REV 01 of the In-Package Chemistry Abstraction Analysis/Model Report (BSC 2001c), the regression equations have been changed; however, the same approach is used. Rather than discretize the in-package chemistry into two time periods (greater or less than 1000 yr) , four time periods are now used. Also, in REV 01 the degradation rates of various steels and aluminum used to establish pH_{high} and pH_{low} have been decreased. Reference: BSC 2001c. *In-Package Chemistry Abstraction.* ANL-EBS-MD-000037 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010315.0053.
Jolley Nowak Mast	ENG4.1.6	FEP 2.1.08.07.00 (Pathways for unsaturated flow and transport in the waste and engineered barrier system) evaluates unsaturated flow and radionuclide transport that may occur along preferential pathways in the waste and EBS. The DOE indicates that preferential pathways are already "included" via "a series of linked one dimensional flowpaths and mixing cells through the EBS, drip shield, waste package and into the invert (CRWMS M&O 20001g)." Staff are concerned that preferred pathways in the EBS are not being evaluated at the appropriate scale. Water has been observed to drip preferentially along grouted rockbolts in	Analyses and modeling that takes into account the spatial heterogeneity are included in the Evolution of Near Field Environment agreements 2.4 and 2.6; which address trace elements and rock bolt grout, respectively.

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC1 - System description and model integration are adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		the ECRB, for example, demonstrating that the introduced materials themselves can influence the location of preferred flow pathways. Moreover, interactions with engineered materials, such as cementitious and metallic components, can have a significant effect on evolved water and gas compositions. Variations along water and gas chemistry that occur along preferential flow pathways in the EBS cannot be adequately measured by considering their volumetric contribution to the bulk EBS water and gas composition. Reference: CRWMS M&O 2001g. *Miscellaneous Waste-Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0006.	

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC2 - Data are sufficient for model justification			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Gross Sevougian	ENG4.2.1	On page 1-38 a description is provided that states, "The conceptualization of diffusion resulted in very small diffusive releases (drip rate required substantiation)." What information became available to result in the substantial changes to the conceptualization of diffusive releases? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The abstraction for the diffusion coefficient in the TSPA-Site Recommendation [CRWMS M&O 2000ar] is based on the following information that was not incorporated into the TSPA-Viability Assessment [DOE 1998]: • The free water diffusion coefficient for all radionuclides is based on the self-diffusivity of water, 2.299×10^{-5} cm^2/sec (Mills 1973, Table III). The self-diffusivity of water provides a bounding value for all radionuclides of interest to performance assessment (CRWMS M&O 2000bg, Section 6.4.1.1). • The dependence of the diffusion coefficient on porosity and saturation (CRWMS M&O 2000bg, Section 6.4.1.2) is based on the experimental data of Conca and Wright (1992) for a variety of granular materials, including crushed tuff from Yucca Mountain. A statistical analysis (CRWMS M&O 2000b) produced an excellent fit to Conca and Wright's data using a power law dependence on moisture content (Archie's law). • The diffusion coefficient is corrected for temperature variation (CRWMS M&O 2000bg, Section 6.4.1.3). This approach represents the diffusion coefficient as a function of porosity, saturation, and temperature for the TSPA-Site Recommendation. The abstraction for the TSPA-Viability Assessment is a function of saturation only. References: DOE 1998. *Total System Performance Assessment.* Volume 3 of *Viability Assessment of a Repository at Yucca*

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC2 - Data are sufficient for model justification			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			Mountain. DOE/RW-0508. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981007.0030. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. Conca, J.L. and Wright, J. 1992. "Diffusion and Flow in Gravel, Soil and Whole Rock." *Applied Hydrogeology, 1*, 5-24. Hanover, Germany: Verlag Heinz Heise GmbH. TIC: 224081. CRWMS M&O 2000bg. *EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0029. CRWMS M&O 2000. *Invert Diffusion Properties Model.* ANL-EBS-MD-000031 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000912.0208. Mills, R. 1973. "Self-Diffusion in Normal and Heavy Water in the Range 1-45°." *The Journal of Physical Chemistry, 77,* (5), 685-688. Washington, D.C.: American Chemical Society. TIC: 246404.

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Subissue 3: Model Abstraction

ENG4: Radionuclide Release Rates and Solubility Limits			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Mackinnon	ENG4.4.1	In DOE's abstraction of radionuclide transport through the EBS, transport through the invert is dominated by diffusion in the time before advective fluxes are significant (CRWMS M&O 2000ar). Retardation is conservatively neglected under advective transport. Under diffusive transport, the diffusion coefficient employed is adjusted for porosity and water saturation in the invert; an analogous term is used for colloidal transport. DOE analyses show sensitivity of the timing of dose curves to this model (CRWMS M&O 2000ar) and the RSS identifies the invert as a significant barrier (CRWMS M&O 2001i). Because retardation is not assumed under advective transport, invert barrier performance is related to the diffusive transport model. It appears that the invert diffusive transport model is sensitive to the exponential term applied to water saturation, which is itself highly uncertain. DOE has not shown that model uncertainty with respect to saturation in the invert has been accounted for in sensitivity studies. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The formulation for diffusion coefficient in the TSPA-Site Recommendation model directly accounts for uncertainty. The diffusion coefficient in a partly saturated, porous medium, D, is given by: $$D = D_0 \phi^{1.3} s^{1.849} 10^{ND(a=0,\sigma=0.223)}$$ where D_0 is the free water diffusion coefficient, Φ is the porosity, s is the saturation, and ND is a normal distribution with mean of zero and standard deviation of 0.223 (Equation 6.4.1-11). The normal distribution spans the range of variability in the diffusivity measurements by Conca and Wright (1992) for a variety of granular materials, including crushed tuff. This normal distribution is sampled for each realization of the TSPA-Site Recommendation model, providing a direct representation of the uncertainty in the experimental data. Reference: CRWMS M&O 2000bg. *EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0029. Conca, J.L. and Wright, J. 1992. "Diffusion and Flow in Gravel, Soil, and Whole Rock." *Applied Hydrogeology, 1,* 5-24. Hanover, Germany: Verlag Heinz Heise GmbH. TIC: 224081.

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Mackinnon Francis	ENG4.4.2	The abstraction process may result in elimination of important uncertainty/variability in NFE model output. For example, on page 37 the highest and lowest waste package temperatures are listed as 316 and 235 °C. However, the temperatures for the bin-averages resulted in 292 and 274 °C. A demonstration is needed that the abstraction process is not eliminating important uncertainty and variability. Reference: CRWMS M&O 2000c. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000504.0296.	Potential waste package temperature variability is not eliminated during the thermal-hydrologic abstraction process. The thermal-hydrologic abstraction parses the process-level thermal-hydrologic data into 5 discrete infiltration rate ranges (see section 5.1.1 of the referenced AMR). Each raw temperature curve is placed into one of 5 bins until all curves have been placed. From there, a bin weighted average waste package temperature is computed for each of the bins as a function of the entries in a bin. This "average" curve is passed to TSPA as an abstracted TH result. This result is shown in Figure 26 in CRWMS M&O 2000c (Figure 33 in CRWMS M&O 2000d). Additionally, the maximum waste package temperature curve (that is found in a bin) and the minimum max waste package temperature curve (found in a bin) are also passed to TSPA. This is shown in Figure 24 (for the mean infiltration rate case only) in CRWMS M&O 20000c (Figure 30 in CRWMS M&O 2000d). This same procedure is followed for the low, mean, and high infiltration flux cases. Therefore, the TSPA model receives from the thermal-hydrologic abstraction, the maximum waste package temperature curve, the temperature curve with the minimum max, and a bin averaged waste package temperature based on the bin entries. This same procedure followed for every infiltration bin for all flux cases. The 316 and 235 °C are the extreme cases. Since Figure 26 in the Near Field Abstraction Analysis/Model Report (CRWMS M&O 2000c) only shows the plot for the mean infiltration flux case, the 316 °C is not shown. However, the abstraction searches the entire population of parameters within a bin, thus finding the hi max and lo max and feeds these values to TSPA. Although not plotted, all of the data was passed to TSPA.

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ENG4: Radionuclide Release Rates and Solubility Limits			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			Reference: CRWMS M&O 2000c. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000504.0296. CRWMS M&O 2000d. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001206.0143.
Stockman Rechard Aguilar	ENG4.4.3	In the description of the colloid release abstraction in the TSPA-SR model report (CRWMS M&O 2000aq, page 326), it does not appear proper to say that Condition B is 1 if Ionic_Str_CDSP is greater than "either" of the two calculated values. The value to compare with is dependent on the pH range (see Fig 11 of CRWMS M&O 2000ba). Ionic strength may be below one calculated value and above another, and still be in the region of stability. The way Condition B is described ("either"), a combination of Condition A and Condition B both being 1 is not sufficient to be in the zone of instability. This potential inconsistency may be related to CNWRA staff's inability to reproduce results on FeOx colloid concentration in the TSPA-SR colloid model verification discussion (CRWMS M&O 2000aq, page 332, paragraph 3). References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The NRC has asked about an apparent discrepancy in the stepwise procedure that has been programmed into GoldSim to calculate FeOx stability. As the reviewer points out, *pH* is important in this determination, but this parameter is already accounted for in the calculation. At each time step in the GoldSim calculations, ionic strength *(I)* and *pH* derived from in package chemistry calculations are supplied as input (Equations 6-5 and 6-6 on p. 326 of the TSPA-Site Recommendation model report, CRWMS M&O aq) and the code then determines whether [*pH, I*] plots above or below either of the two "slanting" lines in Figure 11. The text in the TSPA-Site Recommendation report on colloid model verification (CRWMS M&O, 2000ar, page 332, paragraph 3) is conceptually correct as currently written, but minor word changes will be made in the next revisions to the document to clarify implementation the of *I* and *pH* in the stepwise procedure that calculates FeOx stability. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.

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Subissue 3: Model Abstraction

ENG4: Radionuclide Release Rates and Solubility Limits			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		CRWMS M&O 2000ba. *Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary.* ANL-WIS-MD-000012 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0397.	CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000ba. *Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary.* ANL-WIS-MD-000012 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0397.
Stockman Rechard Mackinnon	ENG4.4.4	Discussions of colloid release abstraction implementation (CRWMS M&O 2000aq, pages 328 and 333) appear to imply that any Pu or Am removed from a waste cell by irreversible attachment is then subtracted from the amount available to be removed as a soluble species. This does not seem conceptually consistent with the model of irreversible attachment. Radionuclide irreversibly attached to colloids should not reduce the amount in solution. This is potentially significant to the modeled masses released. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	GoldSim calculates the quantities of chemical constituents made available from the degradation of the waste form and components in the waste package. This calculation is executed for each time step in a "mixing cell" subcomponent of the TSPA model report (CRWMS M&O 2000aq). The TSPA calculations partition the chemical constituents into aqueous and precipitated phases. The concentrations in the aqueous phase, as well as in the solid phase(s), are determined according to calculated aqueous chemical conditions, solubility limits, reactions, etc. Pu and Am are also partitioned into waste form colloids (irreversibly attached) which are generated from high level waste glass degradation. The basis for this apportioning is an established relationship based on experimental data. The Pu and Am assigned to the waste form colloids are subtracted from the total Pu and Am quantities in the mixing cell, and not from the Pu and Am calculated for the aqueous phase. The very small quantities of Pu and Am that are in solution and irreversibly attached to the waste form colloids do not materially affect the determination of aqueous species and precipitation of solid phases in the geochemical calculations. Evolution of Near Field agreement 3.5 addresses the bounding concentration of Pu in solution and a Container Life and Source Term agreement 3.5 addresses solubility limits.

Subissue 3: Model Abstraction

ENG4: Radionuclide Release Rates and Solubility Limits			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003
Stockman Rechard Mackinnon	ENG4.4.5	Modeled concentrations of waste form, FeOx, and groundwater colloids during release are extremely sensitive to small shifts in pH and/or ionic strength (CRWMS M&O 2000aq, pages 331-332). The fact that modeled Pu (Am) colloidal concentration drops over three orders of magnitude during one time step, then recovers nearly all that drop in the next time step because of rapid pH change, raises concerns about sensitivity to small uncertainties in modeled pH and ionic strength. A small shift across the line on Figure 12 in CRWMS M&O (2000ba) can cause this factor of 1000 change in concentration. The concentration of FeOx colloids is either 1 mg/L or 0.001 mg/L; there are no transitional values (CRWMS M&O 2000aq, Figure 6-144). A slight shift on the plot of Figure 11 in CRWMS M&O (2000ba) can cause this large change in FeOx colloids available for sorbing radionuclides. Groundwater colloid concentration suffers from the same extreme sensitivity to pH as for waste form colloids. The situation is potentially worse, because the minimum and maximum values range over a factor of 10,000 (CRWMS M&O 2000aq, page 332). References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE agrees with NRC's observation that colloid concentration (and stability) can be extremely sensitive to relatively small shifts in *pH* and/or ionic strength *(I)*. This phenomenon is experimentally observed and can be attributed as much to actual colloid behavior as to the random selection of *pH* and *I* parameters from stochastic distributions during the modeling procedure. For example, experimental data from Argonne National Laboratory, and elsewhere (CRWMS M&O 2001k, Section 6.2.1.3), indicate that smectite and iron-(hydr)oxide colloid stability tends to decrease drastically above ionic strengths of about 0.05M. DOE is currently conducting further literature reviews and interactions with investigators of iron-(hydr)oxide colloid phenomena to obtain a larger data set for iron-(hydr)oxide colloid concentrations. These additional data will improve the model, however, under the current TSPA model (CRWMS M&O 2000aq) colloid behavior will remain "abrupt" over certain small ranges of pH and ionic strength. Calculation of groundwater colloid concentration is based on a compilation of colloid concentrations in groundwaters from many different geologic and hydrologic environments. DOE is currently updating the groundwater colloid database to include additional data specific to the Yucca Mountain region. References: CRWMS M&O, *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00.

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Subissue 3: Model Abstraction

ENG4: Radionuclide Release Rates and Solubility Limits			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		CRWMS M&O 2000ba. *Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary.* ANL-WIS-MD-000012 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0397.	CRWMS M&O 2001k, *Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary,* ANL-WIS-MD-000012 REV 00 ICN01.

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ENG4: Radionuclide Release Rates and Solubility Limits			
Transparency and Traceability			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Sevougian	ENG4.TT.1	(CRWMS M&O 2000aq, page 404). An explanation is needed of what physical processes are causing the strong variation in the release curves from the EBS, such as for 239-Pu. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The variations are a numerical discretization issue caused by chain decay in the particle tracker, and specifically the decay of discrete particles of the parent radionuclide Am-243. The code was optimized to minimize this discrete behavior for as many chains as possible, but some residual "discreteness" remained for a few radionuclides, such as Pu-239 and U-233. Since there was an upper limit on the number of particles that could be injected into the Unsaturated Zone model based on process size and RAM availability, using a very, very large number of particles to resolve the variations was not possible. The maximum number was used while still remaining within these constraints.

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Subissue 3: Model Abstraction

UZ1: Climate and Infiltration			
AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ1.2.1	There is insufficient data to support the use of a distributed-parameter, water-balance plug flow approach for net infiltration. Infiltration is a highly nonlinear process. The effect of capillarity on infiltration and percolation is neglected by the INFIL; it is not clear that the coarse vertical grid spacing would offset the neglect of capillarity. Use of a Richards equation-based solution as a comparison to the water-balance plug flow approach is needed, particularly over the repository where thin soils and bare bedrock dominate the land cover. In addition, corroborating data do not support the results from the INFIL model: chloride mass balance represents a lower bound; temperature and neutron probe data suggest a higher average is supported. The non-uniqueness of the calibration process for parameters in the INFIL model leads to large uncertainty.	Distributed-Parameter, Water-Balance DOE believes that the distributed-parameter, water-balance plug flow approach (aka bucket model) for net infiltration is justified for representing the spatial variability of net infiltration as a function of topography, soil properties, soil depth, bedrock, climate, and surface water re-distribution. However, to demonstrate confidence in the approach, DOE will consider investigating the high uncertainty in net infiltration estimates through comparison with a Richards equation approach. The uncertainty is believed to be due to the coarse vertical resolution and possible over-simplification of physical process with respect to infiltration. INFIL Model Uncertainty Uncertainty in infiltration is included in the process-level models and in TSPA. This is captured through the lower and upper bounds for infiltration identified in the process model analyses and the distribution of mean infiltration identified in the infiltration uncertainty analysis. Reference: Audit Observer Inquiry No. M&O-APR-01-02-02, dated February 9, 2001, for ANL-NBS-HS-000032.

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Subissue 3: Model Abstraction

UZ1: Climate and Infiltration

AC3 - Data uncertainty is characterized and propagated through the model abstraction

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ1.3.1	It is not clear that the evapotranspiration model adequately represents the conditions during future climates at YM. Overestimates of evapotranspiration would lead to underestimates of shallow infiltration. Adjustments of vegetation cover and rooting depth for potential future climates are not supported by data. In addition, it is not clear if the temperature data from geographic analog sites (Arizona and Washington) reflect conditions expected at YM, specifically, the effect of radiation differences on temperature.	Preliminary model sensitivity analysis in the Analysis of Infiltration Uncertainty Analysis/Model Report (CRWMS M&O 2000bi) indicated that the model sensitivity to the vegetation cover term is low, based on most net infiltration occurs during the winter and early spring when potential evapotranspiration is low. Thus, doubling or halving vegetation cover only changes daily evapotranspiration by a small amount. A more important source of uncertainty than vegetation cover is the root density term for the lower soil layers. There is no data on vegetation cover or rooting depths. One method of addressing the effects of vegetation on infiltration during future climates is to calibrate the model using study areas representative of the analog sites. References: CRWMS M&O 2000bi. *Analysis of Infiltration Uncertainty.* ANL-NBS-HS-000027 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0377. USGS 2001. *Simulation of Net Infiltration for Modern and Potential Future Climates.* ANL-NBS-HS-000032 REV 00 ICN 01. Denver, Colorado: U.S. Geological Survey. ACC: MOL.20010405.0002. Audit Observer Inquiry No. M&O-APR-01-02-01, dated February 9, 2001, for ANL-NBS-HS-000033.

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Subissue 3: Model Abstraction

UZ1: Climate and Infiltration			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ1.3.2	Without access to the data, it is difficult to assess the reasonableness of 100-yr synthetic meteorologic records used to calculate shallow infiltration for the mean modern climate, lower bound modern climate, and upper bound modern climate. These data sets need to be analyzed to determine if sufficient annual, multi-year, and decadel oscillations in precipitation are reflected in the meteorological inputs. Initially, DOE maintained that the synthetic records were an intermediate data set, therefore, it would not be included in the technical database available to NRC. The concern is that under-representation of climate variability leads to underprediction of shallow infiltration.	The 100-year synthetic meteorological records used for infiltration calculations are being compiled.

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Subissue 3: Model Abstraction

UZ1: Climate and Infiltration			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ1.5.1	The effect of lateral surface or near-surface flow on net infiltration may be underestimated. The watershed calibrations are constrained by 2 rainfall-runoff events, thus leaving parameterization highly uncertain. Recent integration of data from the ECRB and ESF into the net infiltration analysis suggested an underestimation of net infiltration beneath wash channels in the repository footprint, particularly for potential future climates (L. Flint, Geological Society of America meeting November 13-17, 2000, Reno, NV).	The net infiltration model as documented in the Simulation of Net Infiltration for Modern and Future Potential Climates (USGS 2001) is considered to provide an adequate representation of the areal distribution of net infiltration at spatial scales and over time durations for the intended application of the model (i.e., to provide an upper boundary condition for the site-scale unsaturated zone flow and transport model). Sensitivity studies in the Unsaturated Zone Flow Models and Submodels (CRWMS M&O 2000bj) Analysis/Model Report looked at Chloride using two independent methods. Both methods indicated that spatial variability is not important. References: USGS 2001. *Simulation of Net Infiltration for Modern and Potential Future Climates.* ANL-NBS-HS-000032 REV 00 ICN 01. Denver, Colorado: U.S. Geological Survey. ACC: MOL.20010405.0002. CRWMS M&O 2000bj. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0527. Audit Observer Inquiry No. M&O-APR-01-02-03, dated February 9, 2001, for ANL-NBS-HS-000032.

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Subissue 3: Model Abstraction

UZ2: Flow Paths in the Unsaturated Zone			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Houseworth Wu Ahlers	UZ2.3.1	(CRWMS M&O 2000ar, page 3-32). An assessment is needed of the potential error 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. In addition, an assessment of the applicability of this property set for thermohydrology models is needed. (CRWMS M&O 2000ar, page 3-52). Similar issue but with respect to the use of the active fracture model for thermohydrological processes. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	(CRWMS M&O 2000ar, page 3-32) Test predictions for field tests (such as Alcove 8 – Niche 3) will be conducted at higher flow rates that are expected to encompass flow behavior representative of future climates. Modeling predictions for these tests will be compared with testing results, which should validate the potential error of using property sets calibrated under present-day climate for future climates. These predictions will be in revisions to the referenced Analysis/Model Reports. (CRWMS M&O 2000ar, page 3-52) DOE has modeled the Drift Scale Test using property sets for the active fracture model for thermohydrologic processes. Comparisons between the Drift Scale Test results and model predictions have been performed. The test results validate the model. The results will be documented in the Drift-Scale Coupled Processes thermohydrologic Analysis/Model Report (CRWMS M&O 2000o). References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000bj. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0527. CRWMS M&O 2000bk. *Radionuclide Transport Models Under Ambient Conditions.* MDL-NBS-HS-000008 REV 00. Las

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UZ2: Flow Paths in the Unsaturated Zone

AC3 - Data uncertainty is characterized and propagated through the model abstraction

Resp. Org	Item #	NRC Comment	DOE Proposed Response
			Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0529. CRWMS M&O 2001j. *Seepage Calibration Model and Seepage Testing Data.* MDL-NBS-HS-000004 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010122.0093. CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523.
Houseworth Wu	UZ2.3.2	Current DOE results suggest the Paintbrush Tuff is a barrier to episodic infiltration resulting in no preferential flow paths. However, independent modeling "demonstrates that heterogeneity of rock properties is a primary source of uncertainty in the spatial and temporal distribution of unsaturated flow through fractured rock and reveals development of preferential pathways and flow focusing, both of which can have significant consequences on the performance of waste disposal facilities constructed in unsaturated, fractured rocks." Technical basis is needed that heterogeneity within hydrostratigraphic units is not an important source of uncertainty. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. Illman, W.A. and Hughson, D. *Numerical Modeling of Unsaturated Flow in Thick Vadose Zones of Fractured Rocks,* presentation at the Spring 2001 Meeting of the American Geophysical Union.	It is expected that the overall behavior of site-scale flow and transport processes is determined mainly by relatively large-scale heterogeneities associated with the geologic stratification of the mountain. Stratification and faulting, which places units with highly different properties against each other, are the major heterogeneities within the unsaturated zone at Yucca Mountain. Within the same geologic unit, hydrological properties are relatively uniformly distributed because of the intra-strata homogenization induced by the tuff depositional environments. In the geology-based, deterministic approach, subunits are defined within the major hydrogeologic units to capture variability in the vertical stratification. Within these subunits, important lateral heterogeneity can be accounted for by defining lateral boundaries, differentiating areas with significant differences in hydrological properties. The complexity of a heterogeneity model needs to be consistent with the availability of the data. More complicated models introduce larger degrees of uncertainties in rock property estimations when data are limited. The layered approach is also supported by field observations, such as the relatively uniform matrix water saturations within a given layer. Flow and transport

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UZ2: Flow Paths in the Unsaturated Zone			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			models based on a layered approach can be relatively easily calibrated with multiple data sets and provide a means to incorporate a significant amount of the available site data. It is straightforward to upscale using inverse modeling when a layered approach is employed (CRWMS M&O 2000aw, Section 3.4.1.4.4). DOE agrees that it is important to investigate the effects of smaller-scale heterogeneity. Larger-scale heterogeneity is captured in the flow and transport models in terms of hydrogeologic unit stratification and structure, and major faults. Some aspects of smaller scale heterogeneity were investigated and reported in the Supplemental Science and Performance Analysis, Volume 1 (BSC 2001e). DOE is considering future work that addresses heterogeneity in the PTn (FY02) and in the CHn (FY03 and FY04). The PTn analysis will be used to address Unsaturated and Saturated Flow under Isothermal Conditions agreement 4.4. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.

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UZ2: Flow Paths in the Unsaturated Zone

AC3 - Data uncertainty is characterized and propagated through the model abstraction

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ2.3.3	There are insufficient water potential and geochemical data to support the flow fields predicted by the 3D UZ site-scale model in the CHn, Prow Pass, and Bullfrog units below the repository. Of particular concern is the estimated fraction of water that may travel significant distances through permeable nonwelded vitric tuff matrix versus the fraction that may be laterally diverted atop layers of low-permeability zeolitized or moderate to densely welded tuff to fast pathways to the water table (e.g., through faults). The focus of this concern is areas where no perched water is predicted, and in unsaturated zones in the lower CHn, Prow Pass, and Bullfrog units below the perched water. In addition, a basis should be presented for the use of current hydraulic properties, rather than thermally perturbed properties; specifically, zeolitization of the nonwelded, nonaltered Tptpv1, Tptb1, and upper Tac may be caused by the thermal pulse. Note also that statistics of flow percent in faults versus matrix and fractures that are relevant to the entire 3D UZ site-scale model domain may not reflect flow regimes below the repository footprint.	Uncertainty in the Calico Hills flow model will be addressed through sensitivity studies for unsaturated zone radionuclide transport under a range of potential Calico Hills flow conditions. This will be addressed in the revisions to Unsaturated Zone Flow Models and Submodels (CRWMS M&O 2000bj), Radionuclide Transport Models under Ambient Conditions (CRWMS M&O 2000bk), and in Analysis of Geochemical Data for Unsaturated Zone (BSC 2001h). The Unsaturated Zone Flow Models and Submodels (CRWMS M&O 2000bj) Analysis/Model Report will be updated to include the flow path and flow field for moisture tension and geochemical data. Documentation of the analysis is an extension of Unsaturated and Saturated Flow under Isothermal Conditions agreement 4.5 and related Radionuclide Transport agreement 1.1. References: (future revisions) CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000bk. *Radionuclide Transport Models Under Ambient Conditions.* MDL-NBS-HS-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0529. CRWMS M&O 2000bj. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0527. BSC 2001h. *Analysis of Geochemical Data for the Unsaturated Zone.* ANL-NBS-HS-000017 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010405.0013.

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UZ2: Flow Paths in the Unsaturated Zone

AC3 - Data uncertainty is characterized and propagated through the model abstraction

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ2.3.4	Results of subsurface seepage and tracer studies, including the Passive Cross Drift Hydrologic test, Alcove 8-Niche 3 tests, and Niche 5 test, need to be documented to provide validation of or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum).	See also response to 1.b. The flow model accounts for measurements from boreholes and tunnels. Future revisions to the referenced Analysis/Model Reports will document: • data used for calibration • conflicting results from the different methodologies • tests results The associated Unsaturated and Saturated Flow under Isothermal Conditions agreements for seepage are 4.1a), 4.1 b); 4.2; 4.3 and 6.3 for seepage. Radionuclide Transport agreement 3.4 will address the units below the repository. The results of the agreements will be documented in future revisions to the referenced Analysis/Model Reports. References (future revisions): CRWMS M&O 2000bl. *In Situ Field Testing of Processes.* ANL-NBS-HS-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000504.0304. CRWMS M&O 2001j. *Seepage Calibration Model and Seepage Testing Data.* MDL-NBS-HS-000004 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010122.0093. CRWMS M&O 2000bk. *Radionuclide Transport Models Under Ambient Conditions.* MDL-NBS-HS-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0529.

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AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	UZ2.3.5	The site-scale UZ flow model for TSPA is not calibrated using the most recent in situ measurements of saturations and water potentials.	The flow model accounts for measurements from boreholes and tunnels. Current measurements of moisture tension and saturation are in good agreement with the model. Revisions to the Unsaturated Zone flow model Analysis/Model Reports will incorporate the recent in-situ measurements. References (future revisions): CRWMS M&O 2000bm. *Analysis of Hydrologic Properties Data.* ANL-NBS-HS-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0519. CRWMS M&O 2000bn. *Calibrated Properties Model.* MDL-NBS-HS-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0520. CRWMS M&O 2000bj. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0527.

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UZ2: Flow Paths in the Unsaturated Zone			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Houseworth Wu Sonnenthal	UZ2.5.1	(CRWMS M&O 2000aq, page 143). A discussion is provided of perched water bodies. Information is needed on what the model is producing with respect to perched water bodies for example (How do the modeled perched water body ages compare to the dated ages of observed perched water bodies? Would perched water bodies be expected to have the same ages for future climate conditions as they do now? Do perched water bodies drain and what is the impact on dose?). Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Treatment of perched water for the flow model is discussed in Unsaturated Zone Flow Models and Submodels Analysis/Model Report (CRWMS M&O 2000bj). The perched water conceptual model and calibration are discussed in sections 6.2.2 and 6.2.3. See pages 65, 66, and 67 for flow results. The Analysis of Base-Case Particle Tracking Results of the Base-Case Flow Fields Analysis/Model Report (CRWMS M&O 2000bo,Section 6.2.2) discusses the effects of different perched water models on unsaturated zone transport. Water does drain through, as well as along, perched water bodies in the unsaturated zone flow model. Therefore, these effects are included in the TSPA dose calculations. Comparison of transport for alternative perched water models is documented in the Analysis of Base-Case Particle Tracking Results of the Base-Case Flow Fields Analysis/Model Report, (CRWMS M&O 2000bo, Section 6.2.2). The sensitivity study suggests that residence time for transport along more extensive perched water bodies is slower than vertical transport to the water table. However, the overall differences in transport times are not large. Flow models assumed steady state resident times for perched water bodies. Transients in the fracture system resulting from climate change are expected to propagate through the unsaturated zone in 100's of years (less than 1000 years). Climate change periods and the regulatory time period are long compared with the transient time period, therefore the neglect of transient flow due to climate change is reasonable.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

UZ2: Flow Paths in the Unsaturated Zone			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			References: CRWMS M&O 2000bj. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0527. CRWMS M&O 2000bo. *Analysis of Base-Case Particle Tracking Results of the Base-Case Flow Fields (ID: U0160).* ANL-NBS-HS-000024 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000207.0690.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

UZ2: Flow Paths in the Unsaturated Zone			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Francis Ho Houseworth	UZ2. TT.1	There is a lack of transparency pertaining to the presented parameter histories. Reference: CRWMS M&O 2000c. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000504.0296.	The parameter time-histories are given to specifically illustrate in the Near Field Abstraction Analysis/Model Report (CRWMS M&O 2000c) the potential thermohydrologic variability infiltration bin average thermohydrologic variability associated with the infiltration rate uncertainty (low, mean, and high infiltration flux cases) specified future climates repository design issues such as repository center and edge effects and other issues, such as different waste package types. The time-histories specifically indicate that for the thermohydrologic process-model assumptions, such as conceptual flow model, boundary conditions, etc (as described in the Multiscale Analysis/Model Report [CRWMS M&O 2000ag]), these are the thermohydrologic distributions for temperature, relative humidity, etc, that are made available for TSPA (and other downstream models). Furthermore, the actual thermohydrologic abstraction data passed to TSPA either for further abstraction and/or direct use is specifically given in Tables 3 and 4 in the Near Field Abstraction Analysis/Model Report. TSPA thermohydrologic data is used in direct process model results or infiltration rate bin averaged and is described in the downstream models that apply the abstracted thermohydrologic data as inputs. The illustrated time-histories shown in the Analysis/Model Report give an idea as to what is being passed/implemented into the downstream models including the TSPA model. References: CRWMS M&O 2000c. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC:

Subissue 3: Model Abstraction

UZ2: Flow Paths in the Unsaturated Zone			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			MOL.20000504.0296. CRWMS M&O 2000ag. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0062.
Francis Houseworth Ho Mackinnon	UZ2.TT.2	Water densities are used inconsistently to model evaporation. Reference: CRWMS M&O 2000ag. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0062.	The abstracted average invert evaporation rate used a constant water density of 1000 kg/m^3. Section 6.3.10 in the Multiscale Analysis/Model Report (CRWMS M&O 2000ag) utilized both a constant water density and a temperature dependent water density to compute the average evaporation rate at the top of the drip shield surface. The constant water density used in the drip shield calculation was 983.19 kg/m^3, not 1000 kg/m^3. However, Figure 53 in the Multiscale Analysis/Model Report indicates that the difference in evaporation rate at the drip shield surface was not very sensitive to the choice of water density temperature dependence (e.g., approximately 500 years after waste emplacement, both evaporation response curves, temperature dependent and constant density, are the same). In the drip shield calculations for evaporation rate, the water densities used in the calculations varied by about 4% (from 25°C to about 100°C) in accordance with Figure 53. No differences in the evaporation rates are noted after about 500 years. Subsequently, the difference between the invert water density and the drip shield water density was actually less than 2%, thus indicating that the choice in water densities (in this range 2-4% difference) will not affect the evaporation rates. Based on the above, the choice of water density used to calculate the evaporation rate is not dependent on the value selected in the 25°C to 100 °C range (CRWMS M&O 2000ag, Figure 53, for the drip shield evaporation rate.)

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Subissue 3: Model Abstraction

UZ2: Flow Paths in the Unsaturated Zone			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			Reference: CRWMS M&O 2000ag. *Multiscale Thermohydrologic Model.* ANL-EBS-MD-000049 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0062.
Houseworth Ho Sevougian Wilson	UZ2.TT.3	What is the water mass flux balance used above, at, and below the repository horizon in the TSPA? Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Mass balances are based on mass conservation equations in the flow calculations. The unsaturated zone flow fields are mass balanced. Any seepage that enters and then exits the drifts would be assumed to be a small perturbation that does not disturb the steady state flow fields. The conceptual model for water flow within the drift accounts for the various possible flow paths (e.g., some water flows around the drip shield, some flows through the drip shield and around the waste package, and some flow through the drip shield and through the drip shield). The effects of the drift in perturbing the water flow (for example, the "shadow zone" below the drift) are not taken into account, but the approximations made are conservative (i.e., account for increased flux because of thermally mobilized water above the drift, no credit for thermal dryout, no credit for drift shadow zone).

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Subissue 3: Model Abstraction

UZ3: Radionuclide Transport in the Unsaturated Zone			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Houseworth	UZ3.5.1	(CRWMS M&O 2000ar, page 3-30). Field observations suggest limited interaction between the fractures and matrix. A comparison is needed that the abstraction and implementation of matrix diffusion in the TSPA model is consistent with the field observations. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Existing field observations concerning fracture-matrix interaction do not provide much constraint on the range of potential behavior. Further field testing is being conducted in the Alcove 8/Niche 3 tests. The results of these tests will be analyzed and implemented in TSPA. Alcove 1 tracer tests indicate that matrix diffusion plays an important role in tracer transport behavior. The Alcove 1 tracer tests are in documented in Section 6.8.1 of the Unsaturated Zone Flow Models and Submodels Analysis/Model Report (CRWMS M&O 2000bj) and the following sections of the Unsaturated Zone Process Model Report Sections 2.2.2.2.3; 3.7.4.4; 3.11.11.1. Another observation in section 3.8.2 of the Unsaturated Zone Process Model Report (CRWMS M&O 2000aw) suggests matrix diffusion is important is the uniform geochemical signature in pore water of the TSw. References: CRWMS M&O 2000bj. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0527. CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

UZ3: Radionuclide Transport in the Unsaturated Zone			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Sevougian Houseworth	UZ3.TT.1	Page 433. An explanation is needed of what physical processes are causing the strong variation in the release curves from the UZ, such as for 239-Pu. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The variations are a numerical discretization issue caused by chain decay in the particle tracker, specifically the decay of discrete particles of the parent radionuclide Am-243. The code was optimized to minimize this discrete behavior for as many chains as possible, but some residual "discreteness" remained for a few radionuclides, such as Pu-239 and U-233. Since there was an upper limit on the number of particles that could be injected into the unsaturated Zone model based on process size and RAM availability, using a very, very large number of particles to resolve the variations was not possible. The maximum number was used while still remaining within these constraints.
Sevougian Houseworth Ho Viswanathan /Robinson	UZ3.TT.2	The AMR describes in general terms how FEHM and resulting data will be implemented, but does not include detail about implementation into GoldSim. Data resulting from this AMR will be used in the UZ Flow and Transport PMR and the TSPA-SR. Reference: CRWMS M&O 2000bp. *Abstraction of Flow Fields for RIP (ID:U0125).* ANL-NBS-HS-000023 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000127.0089.	Total System Performance Assessment Model for Site Recommendation (CRWMS M&O 2000aq, Section 6.3.6) describes the implementation FEHM is into GoldSim. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.
Houseworth Robinson Arnold	UZ3.TT.3	Matrix diffusion in the UZ has emerged, somewhat surprisingly, as a significant natural barrier for attenuation of potential radionuclide releases. This increased importance seems to have come after the incorporation of the active-fracture concept into the transport model. The integration of active fracture concept within the transport abstraction is not transparent. References: CRWMS M&O 2000bq. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000320.0400.	The active fracture model is a flow focusing model that results in reduced fracture-matrix area (and increased flowing fracture-spacing). The geometric interpretation of the Active Fracture Model is transferred directly to the matrix diffusion transport model. The Alcove 8 test results will be documented in the In-Situ Field Testing of Processes, Analysis/Model Report (CRWMS M&O 2000bl).

Subissue 3: Model Abstraction

UZ3: Radionuclide Transport in the Unsaturated Zone			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
		CRWMS M&O 2000ak. *Particle Tracking Model and Abstraction of Transport Processes.* ANL-NBS-HS-000026 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000502.0237.	The differences found in matrix diffusion in radionuclide transport calculations for the TSPA-Viability Assessment and TSPA-Site Recommendation models are primarily due to the differences in calibrated model parameters including the fracture-matrix interaction factors. In the TSPA-Viability Assessment, a constant fracture-matrix interaction factor was calibrated for each hydrogeologic model unit. For TSPA-Site Recommendation, the active fracture model was used in which the fracture-matrix interaction factor is a function of the effective fracture water saturation. The fracture-matrix interaction factors are different in the Site Recommendation model due to changes in other hydrologic parameters for TSPA-Viability Assessment versus TSPA-Site Recommendation such as permeability and van Genuchten alpha. This has lead to differences in the fracture-matrix reduction factors in TSPA-Site Recommendation compared with TSPA-Viability Assessment. A more complete description of how the active fracture model is integrated with the transport model will be given in an update to the Radionuclide Transport Models under Ambient Conditions Analysis/Model Report. References: (future revisions) CRWMS M&O 2000bl. *In Situ Field Testing of Processes.* ANL-NBS-HS-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000504.0304. CRWMS M&O 2000bk. *Radionuclide Transport Models Under Ambient Conditions.* MDL-NBS-HS-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0529.

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Subissue 3: Model Abstraction

Unsaturated Zone NRC Letter (June 20, 2001) Comments			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	1.b Subissue 4 Agreement 1	Attachment 3 has created some confusion as to what information the NRC needs DOE to provide. The clarified wording below requests some of the testing plans from Attachment 3 as originally intended by the NRC, as well as the results from several tests and model studies. The NRC believes that adding the request for testing and model study results to this agreement is more efficient than adding a number of new USFIC agreements. i. Consider a mass balance of water for the 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 the documentation of the test plan for the Alcove 7 teat. vii. 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 the Alcove 7 (determination whether the water comes from seepage or condensation). viii. Provide documentation of the test plan for the Niche 5 test.	Test plans and pre-test predictions will be made available as they are developed. Exceptions: (vi) Test plan for Alcove 7 is not needed since test is near completion. (xiii) This is a modeling issue that is not related to testing. An agreement on the comparison of continuum versus discrete fracture seepage models is not needed because this is ongoing work. (xiv) This is a modeling issue that is not related to testing. An agreement on the comparison of continuum versus discrete fracture seepage models is not needed because this is ongoing work.

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Subissue 3: Model Abstraction

Unsaturated Zone NRC Letter (June 20, 2001) Comments			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
		ix. Provide documentation of the results obtained and the analysis for the Niche 5 test. x. Provide documentation of the results obtained and the analysis for the Systematic Hydrologic Characterization test. xi. Provide documentation of the results obtained and the analysis for the Niche 4 test. xii. Provide documentation of the results obtained from the calcite filling test. Include interpretations of the observed calcite deposits found mostly at the bottom of the lithophysal cavities. xiii. 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. xiv. 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.	
Bodvarsson Houseworth	1.c Subissue 4 Agreement 4	Provide the analysis of geochemical and hydrological data (water content, water potential, and temperature) used for support of the flow field below the repository, particularly in the Calico Hills, Prow Pass and Bullfrog hydrostratigraphic layers. Demonstrate that potential bypassing of matrix flow pathways below the area of the proposed repository, as opposed to the entire site-scale model area, is adequately incorporated for performance assessment.	See UZ2.3.3 above

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Subissue 3: Model Abstraction

Unsaturated Zone NRC Letter (June 20, 2001) Comments			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	1.d Subissue 5 Agreement 4	The NRC staff does not believe that this agreement needs to be rewritten; however, it would like to confirm that the effects of water table rise on groundwater flux will be addressed in the two documents cited by DOE for this agreement.	The effects of water table rise on groundwater flux will be addressed in the Saturated Zone Flow and Transport Process Model Report (CRWMS M&O 2000an) and the Uncertainty Distribution for Stochastic Parameters Analysis/Model Report (CRWMS M&O 2000at) as part of Unsaturated and Saturated Flow under Isothermal Conditions agreement 5.4. References: (future revisions) CRWMS M&O 2000an. *Saturated Zone Flow and Transport Process Model Report.* TDR-NBS-HS-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0067. CRWMS M&O 2000at. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.
Bodvarsson Houseworth	3.a Subissue 3	The UZ AMR U0010, Simulation of Net Infiltration for Modern and Potential Future Climates (USGS 2000), notes that the simulation results using three synthetic meteorological data sets are averaged for the lower, mean and upper bound estimates of net infiltration. The NRC is interested in obtaining two of the three synthetic meteorological data sets; 4AJ.s01 and Area12.s01. Reference: USGS 2000. *Analysis/Model Report (AMR) U0010, "Simulation of Net Infiltration for Modern and Potential Future Climates".* Input Transmittal 00132.T. Las Vegas, Nevada: U.S. Geological Survey. ACC: MOL.20000330.0421.	See UZ1.3.2 above
Bodvarsson Houseworth	3.b Subissue 4	The NRC is interested in how the results of the Passive Cross Drift Hydrologic and Alcove 8 – Niche 3 Cross-over tests were used to validate or modify the values used for the flow focussing factor in the seepage model for performance assessment. In addition, the NRC is interested in the justification for the van Genuchten alpha for fracture continuum, ($\forall_f$) parameter.	See UZ2.3.4 above

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Subissue 3: Model Abstraction

Unsaturated Zone NRC Letter (June 20, 2001) Comments			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Bodvarsson Houseworth	3.c Subissue 4	The NRC is interested in additional justification on how fracture continuum properties (i.e., porosity, spacing, aperture) for the unsaturated transport model are calculated and how the active-fracture concept is integrated into these parameter values. The discussion should show that the matrix diffusion and active fracture models are properly integrated.	See UZ 3.TT.3 above
Bodvarsson Houseworth	3.d Subissue 4	The NRC is interested in an update to the calibrated unsaturated zone flow model using the most recent matrix saturation and water potential data that suggest the rock mass is wetter than previous core-sample saturation measurements have indicated.	See UZ2.3.5 above

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Subissue 3: Model Abstraction

SZ2: Radionuclide Transport in the Saturated Zone			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Robinson Arnold	SZ2.3.1	Calculation of the K_c parameter, used to simulate reversible colloid attachment during SZ transport by lowering the radioelement K_d, involves a term for colloid concentration in the water (CRWMS M&O 2000at). The concentration adopted-0.03 mg/L-is claimed to be "for conservatism, the highest observed or expected colloid concentration" (CRWMS M&O 2000aq). However, this concentration is well below the maximum values used in release models for waste form (5 mg/L) and iron (hydr) oxide (1 mg/L) colloids derived from the EBS (CRWMS M&O 2000ba). References: CRWMS M&O 2000at. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000526.0328. CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ba. *Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary.* ANL-WIS-MD-000012 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000525.0397.	Measurements of natural colloid concentrations in groundwater are more representative of colloid stability in equilibrium with far-field geochemical conditions than are estimates of colloid concentrations at the waste form. Sensitivity and uncertainty analyses for the Supplemental Science and Performance Analysis (BSC 2001e) include an evaluation of colloid facilitated transport that considers uncertainty in the colloid concentrations in groundwater. This analysis effectively evaluates the impact of a broader range of values (as high as 0.3 mg/L) for the colloid concentrations on the simulated dose rates in TSPA-Site Recommendation (CRWMS M&O 2000aq). References: BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062. CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20001226.0003.

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Subissue 3: Model Abstraction

SZ2: Radionuclide Transport in the Saturated Zone			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Robinson Arnold	SZ2.3.2	Five FEPs concerning possible chemical effects on radionuclide transport properties are stated to be included in TSPA to the extent that uncertainty ranges in K_d bound the effects (CRWMS M&O 2001m). These FEPs are: 2.2.08.01.00-Groundwater chemistry/composition in UZ and SZ; 2.2.08.02.00-Radionuclide transport in a carrier plume; 2.2.08.03.00-Geochemical interactions in the geosphere; 2.2.08.06.00-Complexation in the geosphere; 2.2.09.01.00-Microbial activity in geosphere. The issue common to these five included FEPs is that DOE has not adequately demonstrated that uncertainty distributions bound the possible variations in K_d in the saturated zone below Yucca Mountain (CRWMS M&O 2000at, 2000au). To support a licensing decision, documentation is necessary to determine how DOE developed the TSPA transport parameter distributions. References: CRWMS M&O 2001m. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. CRWMS M&O 2000at. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000526.0328. CRWMS M&O 2000au. *Unsaturated Zone and Saturated Zone Transport Properties.* ANL-NBS-HS-000019 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000829.0006.	Documentation of the justification for uncertainty distributions for radionuclide sorption coefficients will be revised. This comment is addressed in the existing Radionuclide Transport agreements 2.10 and 1.5.

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Subissue 3: Model Abstraction

SZ2: Radionuclide Transport in the Saturated Zone			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Robinson Arnold	SZ2.4.1	On page 3-174 (CRWMS M&O 2000ar), the transport times for 14-C range from 100 years to greater than 100,000 years. This result appears to be non-physical and brings into question the representation of variability/uncertainty. The proposed dose standard is based on peak of the mean dose. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	There is a misprint in the text of the TSPA-Site Recommendation REV 00 ICN01. The statement should be that transport times for C-14 vary from less than 100 years to greater than 10,000 years among the realizations. These results reflect a relatively large aggregate uncertainty in the transport of C-14 in the saturated zone, but are not "non-physical". Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Subissue 3: Model Abstraction

DIRECT 1: Volcanic Disruption of Waste Package			
AC1 - System description and model integration are adequate			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Valentine McGregor	Direct 1.1.1	DOE has not yet assembled the information relating to the potential for volcanic disruption of the waste package needed for a potential license application, and DOE does not yet have a reasonable approach to do so by the time of license application. Available information shows that variations in the amount of HLW disrupted during extrusive and intrusive igneous events can affect significantly the probability-weighted doses to the proposed critical group. References: CRWMS M&O 2000l. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0061. CRWMS M&O 2000ab. *Igneous Consequence Modeling for the TSPA-SR.* ANL-WIS-MD-000017 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001204.0022.	This item was discussed at the Igneous Activity Technical Exchange, June 21-22, 2001.
Valentine McGregor	Direct 1.1.2	While the text was updated to reflect the "backfill" to "no-backfill" design change, the model and analysis were not modified to account for this design change. References: CRWMS M&O 2000bh. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000523.0157. CRWMS M&O 2000l. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0061.	This item was discussed at the Igneous Activity Technical Exchange, June 21-22, 2001.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

DIRECT 1: Volcanic Disruption of Waste Package			
AC1 - System description and model integration are adequate			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Valentine McGregor	Direct 1.1.3	This AMR uses a pre-VA design to estimate thermal loads and implications on rock mechanics and the thermal-mechanical evolution of the stress states (CRWMS M&O 2000l, pp. 15-16, Figures 2 and 3, p. 49). The model should be consistent with design and thermal load assumptions used elsewhere in the TSPA. Reference: CRWMS M&O 2000l. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0061.	The Analysis/Model Report (CRWMS M&O 2000l) cites previous work, which was based on the pre-Viability Assessment design thermal loads, to provide support for the concept of principal stress rotation. The referenced calculation is used to make the point at issue, which is a change or rotation in the stress conditions during the thermal period. The conceptual finding from the cited work indicate that the rotation of principal stress direction remains valid even for thermal loads that differ from the pre-Viability Assessment design. The Analysis/Model Report (CRWMS M&O 2000l) uses the findings in a conceptual or qualitative sense in development of a decision tree (Figure 1). One of the decision points is whether a dike is intruding into an ambient or thermally perturbed stress environment. The findings are used quantitatively for the plots presented in Figures 2 and 3 to demonstrate the possible magnitude of the change. The magnitude of the stress rotation, the duration of the thermal period, and the distinction between thermal and non-thermal periods are not further considered within the igneous-related TSPA models. For these reasons, citation of the previous work is consistent with the findings presented in the TSPA-Site Recommendation (CRWMS M&O 2000ar). If the rotation of stress or drift stress conditions are quantitatively considered in future igneous consequence work, the magnitude and direction of the stress rotation with time will be reconsidered and based on the design and thermal load assumptions consistent with the inputs developed for use in the corresponding TSPA. References: CRWMS M&O 2000l. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0061.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

DIRECT 1: Volcanic Disruption of Waste Package			
AC1 - System description and model integration are adequate			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

DIRECT 1: Volcanic Disruption of Waste Package			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Valentine McGregor	DIRECT 1.TT.1	This AMR uses a 600 C drift wall temperature (CRWMS M&O 2000l, p. 36) to calculate a sample magma solidification time. What is the basis for this value? Is it dependent on thermal load? Reference: CRWMS M&O 2000l. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0061.	The drift wall temperature was assumed to be 600 degrees C to be consistent with the conduction calculation for cooling of the pyroclastic material in the previous section of the Analysis/Model Report (CRWMS M&O 2000l, "Pyroclastic Flow"). This calculation indicated the drift wall temperature, based on the thermal power available and conducted away into the rock. The assumed value is also consistent with the available literature as cited and described in Section 5.2 of the Analysis/Model Report. Thermal loading effects from emplaced waste were considered secondary with respect to this assumption. Note that the calculated duration leads to the bounding assumption for the models that packages in contact with the magma are significantly damaged and provide no further protection. Therefore, changes in the exact value of the wall temperature, unless they were sufficient to reduce the "hot soak" duration to a few hours or days (which is not a credible condition), would not lead to a different assumption. Reference: CRWMS M&O 2000l. *Dike Propagation Near Drifts.* ANL-WIS-MD-000015 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001213.0061.

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Subissue 3: Model Abstraction

DIRECT2: Airborne Transport of Radionuclides			
AC2 – Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Valentine McGregor	Direct 2.2.1	The TSPA model abstraction for incorporation of waste particles into erupting magma makes use of unsupported assumptions related to the size distribution of particles. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	This item was discussed at the Igneous Activity Technical Exchange, June 21-22, 2001.

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Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

DIRECT2: Airborne Transport of Radionuclides			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Valentine McGregor	Direct 2.TT.1	The dose pathways for direct release scenario are discussed on p. 3-206 in TSPA-SR (CRWMS M&O 2000ar). Inhalation and ingestion have been considered, but external exposure from contaminated ash on the ground surface was not listed. DOE should clarify in TSPA-SR whether ground surface exposure was considered. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	This item was discussed at the Igneous Activity Technical Exchange, June 21-22, 2001.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

Importance to System Performance - This subissue focuses on the information and technical needs related to the development of abstracted models for TSPA. Specifically, the following aspects of model abstraction are addressed under this subissue: (i) data used in development of conceptual approaches or process-level models that are the basis for abstraction in a TSPA, (ii) resulting abstracted models used to perform the TSPA, and (iii) overall performance of the repository system as estimated in a TSPA. In particular, this subissue addresses the need to incorporate numerous features, events, and processes (FEPs) into the PA and the integration of those factors to ensure a comprehensive analysis of the total system.

DOSE1: Dilution of Radionuclides in Groundwater due to Well Pumping

AC1 - System description and model integration are adequate

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith)	DOSE 1.1.1	Climate change is considered in other model abstractions to assess repository performance, but DOE does not consider the impact of climate change on projected well pumping withdrawals. Climate change could reduce groundwater withdrawals without impacting the lifestyle of the critical group. A wetter, cooler climate could reduce groundwater extraction and therefore reduce the volume of water available for dilution. Reduced dilution could result in an increased effective dose. References: CRWMS M&O 2000w. *Groundwater Usage by the Proposed Farming Community.* ANL-NBS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000407.0785. CRWMS M&O 2000an. *Saturated Zone Flow and Transport Process Model Report.* TDR-NBS-HS-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0067.	An evaluation has been performed that takes into account the annual estimate of precipitation (during the growing and irrigation season) both at the present and in future climate conditions and uses these data to predict groundwater usage from alfalfa evapotranspiration estimates. The evaluation is documented in Section 13.3.5 in the Supplemental Science and Performance Analysis, Volume 1. Reference: BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.

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Subissue 3: Model Abstraction

DOSE1: Dilution of Radionuclides in Groundwater due to Well Pumping			
AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 1.2.1	The analysis of groundwater usage by the proposed farming community is based on 1990 census data which may not reflect current conditions in the YM region. References: CRWMS M&O 2000w. *Groundwater Usage by the Proposed Farming Community.* ANL-NBS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000407.0785. CRWMS M&O 2000an. *Saturated Zone Flow and Transport Process Model Report.* TDR-NBS-HS-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0067.	The annual groundwater usage distribution cited in the Groundwater Usage Analysis/Model Report (CRWMS M&O 2000w) was based on State published data of land use and irrigation in Amargosa Valley (Attachment II to cited Analysis/Model Report) and not census data. The agricultural groundwater users in Amargosa Valley were used to represent the parent distribution from which the 15 to 25 farms based on the preamble to the proposed 10CFR 63. Annual water usage used in the TSPA-Site Recommendation was not based on any census data. The 1990 census data were used in an alternate water usage model based on per population usage rather than per farm usage. The calculations substantiate/support the conservative water usage estimates, but did not use the census data. Reference: CRWMS M&O 2000w. *Groundwater Usage by the Proposed Farming Community.* ANL-NBS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000407.0785.
Smith	DOSE 1.2.2	DOE addresses conservatism and identifies those parameters to which its model are sensitive. However, the data used to develop model parameters are limited and appear insufficient. For example, the agricultural water usage data used to support the model are based on one year of data (State of Nevada 1997). Although these data represented the most recent data available at the time the analyses were performed, the DOE has not demonstrated that agricultural water usage data for this year are representative of annual water usage in the region. Furthermore, DOE has not presented any basis for the nominal distribution used to select	The annual groundwater usage was based on a single year of state published data and is therefore subject to some uncertainty due to temporal variation. DOE will consider including the assessment of multiple year data. There is likely to be a high correlation of usage from one year to the next, so it may be difficult to obtain statistically independent annual usage estimates on which to base unbiased estimates. The annual groundwater usage distribution in the Groundwater Usage Analysis/Model Report (CRWMS M&O 2000w) was

Subissue 3: Model Abstraction

DOSE1: Dilution of Radionuclides in Groundwater due to Well Pumping			
AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
		parameter values for their model. References: CRWMS M&O 2000w. *Groundwater Usage by the Proposed Farming Community.* ANL-NBS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000407.0785. CRWMS M&O 2000an. *Saturated Zone Flow and Transport Process Model Report.* TDR-NBS-HS-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0067.	based on State published data of land use and irrigation in Amargosa Valley (CRWMS M&O 2000w, Attachment II). The agricultural groundwater users in Amargosa Valley were used to represent the parent distribution from which the 15 to 25 farms based on the preamble to the proposed 10CFR 63. Reference: CRWMS M&O 2000w. *Groundwater Usage by the Proposed Farming Community.* ANL-NBS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000407.0785.

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Subissue 3: Model Abstraction

DOSE1: Dilution of Radionuclides in Groundwater due to Well Pumping			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 1.TT.1	Improved transparency required to determine if DCFs are consistently used in TSPA and preclosure calculations. Section 6.4 of this AMR states: "Worst case solubility values, provided as part of the code, representing the most conservative conditions for radionuclides under consideration, were used for this analysis" (CRWMS M&O 1999a). The comparison was clearly made with the worst case DCFs, but it was unclear if the worst case DCFs are consistent with the DCFs used in the TSPA and preclosure dose calculations. Reference: CRWMS M&O 1999a. *Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods.* ANL-MGR-MD-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991207.0215.	The dose conversion factors are consistent. The dose conversion factors for some radionuclides are available as a function of solubility class. Because of the possibility of complex chemistry with the attendant difficulties of defining the species as a function of time in the biosphere, the most conservative values for the dose conversion factors were used. In the case of pre-closure releases, there is a possibility that the chemical species of the release are better known. In this case it may be possible to justify the use of smaller and more realistic dose conversion factors. Reference: CRWMS M&O 1999a. *Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods.* ANL-MGR-MD-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991207.0215.

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Subissue 3: Model Abstraction

DOSE2: Dilution of Radionuclides in Soil			
AC1 - System description and model integration are adequate			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.1.1	Scenarios in which high concentrations of radionuclides may be found on the ground surface should include a check to ensure the concentration of radionuclides leaching out of the surface soil does not exceed the solubility limit of the radionuclide. Reference: CRWMS M&O 2000r. *Evaluate Soil/Radionuclide Removal by Erosion and Leaching.* ANL-NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.	In the case of contaminated groundwater, the TSPA-Site Recommendation predicted radionuclide concentrations calculations in soils even after build-up due to continuing irrigation are many orders of magnitude below solubility limits. This may not be the case for contaminated ash deposition (i.e., significant amounts of relatively insoluble species e.g., oxides may be present). In this scenario, the major pathway is inhalation, primarily arising from resuspension of contaminated ash from locations remote from irrigated areas. For this release scenario, credit for leaching should not be taken. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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DOSE2: Dilution of Radionuclides in Soil			
AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.2.1	The analysis would be strengthened by the use of site-specific Kd values instead of generic values from Sheppard and Thibault (1990) because these values can vary significantly due to variations in soil pH and other soil characteristics. Reference: Sheppard, M.I. and Thibault, D.H. 1990. "Default Soil Solid/Liquid Partition Coefficients, Kds, for Four Major Soil Types: A Compendium." *Health Physics, 59,* (4), 471-482. New York, New York: Pergamon Press. TIC: 249329. CRWMS M&O 2000r. *Evaluate Soil/Radionuclide Removal by Erosion and Leaching.* ANL-NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.	Kd values appropriate for the soil at Amargosa Valley were used. A sensitivity study was performed and documented in Section 13.3.3 in the Supplemental Science and Performance Analysis (BSC 2001e) that evaluated the effect on Biosphere Dose Conversion Factors of using a distribution of partition coefficients, for several radionuclides identified in the TSPA analyses as important dose contributors. The range of Kds was taken from International Atomic Energy Agency Technical Report No. 364 (IAEA 1994). Estimated increases in the mean value of the Biosphere Dose Conversion Factors distributions, as the result of sampling over the possible variations in the Kd values, were by a factor of 1.4 and 1.3 for iodine and neptunium, respectively, and by a factor of 4.9 for technetium (Table 13.3-9). For the high Kd value Pu has such a protracted build-up time (24,000 years) that the limit is determined by the erosion rate (several hundred years). References: IAEA 1994. *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments.* Technical Report Series No. 364. Vienna, Austria: International Atomic Energy Agency. TIC: 232035 BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.

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DOSE2: Dilution of Radionuclides in Soil			
AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.2.2	Additional data are needed to support the assumption that the concentration of resuspended particles returns to background values within 10 years of the cessation of an igneous event. This concern is focused on the sustainability of elevated mass loadings over thicker tephra deposits. Reference: CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.	This item was discussed at the Igneous Activity Technical Exchange meeting (21/22 Jun 01).

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Subissue 3: Model Abstraction

DOSE2: Dilution of Radionuclides in Soil			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.3.1	The mixing of temporal variability and parameter uncertainty in the development of the mass loading above a tephra deposit is confusing and will only provide correct results if other time-dependent processes do not result in a significant change in the concentration of radionuclides in the soil over the 10-year period over which the temporal averaging is being performed. Reference: CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.	This item was discussed at the Igneous Activity Technical Exchange meeting (21/22 Jun 01).
Smith	DOSE 2.3.2	Sampling from a loguniform distribution between the nominal mass load representing a thin deposit and the average mass load for a thick deposit assumes that the average mass load over the first 10 years following an event is directly proportional to the thickness of the deposit. Reference: CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.	This item was discussed at the Igneous Activity Technical Exchange meeting (21/22 Jun 01).

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DOSE2: Dilution of Radionuclides in Soil

AC4 - Model uncertainty is characterized and propagated through the model abstraction

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.4.1	The particle transport model of radionuclide leaching out of the surface soil has not been investigated for its effect on TSPA results Reference: CRWMS M&O 2000r. *Evaluate Soil/Radionuclide Removal by Erosion and Leaching.* ANL-NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.	The current approach does not include radionuclide removal from soil by colloidal transport. The model uses the partition coefficient (K_d) to quantify radionuclide removal from top soil by leaching from over watering to avoid salt build up that would affect production efficiency. This approach assumes that only soluble contaminants can be removed by leaching. Suspended solids (colloids) are assumed to remain in the soil where they are available for plant uptake and resuspension and subsequent inhalation. The neglect of an additional loss mechanism is conservative.

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DOSE2: Dilution of Radionuclides in Soil			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.5.1	DOE has not provided support to justify that the mass loading model does not underestimate the concentration of radionuclides in the air. Reference: CRWMS M&O 2000r. *Evaluate Soil/Radionuclide Removal by Erosion and Leaching.* ANL-NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.	This item was discussed at the Igneous Activity Technical Exchange meeting (21/22 Jun 01).

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DOSE2: Dilution of Radionuclides in Soil			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.TT.1	It is not clear whether these long irrigation periods are realistic, since consideration of factors such as build up of salts, plant toxicity levels, and effect of periods of no irrigation are not documented. Reference: CRWMS M&O 2000a. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000517.0257.	As noted in responses to DOSE 3.1.4 and 3.2.6, the prior irrigation periods are used as a calculational tool, to ensure that the equilibrium radionuclide concentration in soil is achieved. The saturated radionuclide concentration in soil is a conservative approach to calculate dose after mitigation erosion (CRWMS M&O 2001q). The method of derivation of irrigation periods is described in detail in the Nominal Performance Biosphere Dose Conversion Factor Analysis Analysis/Model Report (CRWMS M&O 2001h). References: CRWMS M&O 2001q. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010201.0027. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.
Smith	DOSE 2.TT.2	Leaching values for carbon and cesium used in the AMR are inconsistent with the AMR *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* REV00B. The reviewed AMR cites a calculation package instead of the noted AMR. Reference: CRWMS M&O 2000m. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216. CRWMS M&O 2000r. *Evaluate Soil/Radionuclide Removal by Erosion*	Disruptive Event Biosphere Dose Conversion Factor Analysis Analysis/Model Report (CRWMS M&O 2000m) used preliminary leaching factors received via input transmittal (DTN SN9912T0512299.001), as noted in Section 4.1 of the report. These values were subsequently revised. Revision 01 of the Disruptive Event Biosphere Dose Conversion Factor Analysis (CRWMS M&O 2001n) uses leaching factors documented in the Evaluate Soil/Radionuclide Removal by Erosion and Leaching Analysis/Model Report (CRWMS

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DOSE2: Dilution of Radionuclides in Soil			
Transparency and Traceability			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
		and Leaching. ANL-NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.	M&O 2000r). References: CRWMS M&O 2000m. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216. CRWMS M&O 2001n. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233. CRWMS M&O 2000r. *Evaluate Soil/Radionuclide Removal by Erosion and Leaching.* ANL-NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.
Smith	DOSE 2.TT.3	The dose pathways for direct release scenario are discussed on p. 3-206 in TSPA-SR (CRWMS M&O 2000ar). Inhalation and ingestion have been considered, but external exposure from contaminated ash on the ground surface was not listed. TSPA-SR should clearly state whether ground surface exposure was considered. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Prior irrigation periods are used as a calculational tool to ensure that the equilibrium radionuclide concentration in soil is achieved. The saturated radionuclide concentration in soil is a conservative approach to calculate dose after mitigation erosion (CRWMS M&O 2001q). The method of derivation of irrigation periods is described in detail in the *Nominal Performance Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2001h). External exposure was not considered in the eruption phase dose factors, which are described on page 3-206 (CRWMS M&O 2000ar). These dose factors were not used to calculate doses in the TSPA-Site Recommendation. Instead they were only used in sensitivity studies. Biosphere Dose Conversion Factors for the transition phase used in the TSPA-Site

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DOSE2: Dilution of Radionuclides in Soil

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
			Recommendation analysis for a volcanic eruption included inhalation, ingestion and external exposure. During the volcanic eruption, only inhalation pathway was considered because for all radionuclides, except ^{137}Cs, external exposure from the ground is insignificant when compared with the inhalation pathway, as can be verified by examining the results of pathway analysis (CRWMS M&O 2001n, Tables 16-20). For the overall external exposure from volcanic eruption, the exposure during the eruption phase (which, on the average, lasts only 8 days) is negligible compared with the exposure during the transition phase. The Biosphere Dose Conversion Factors for the transition phase were calculated for one-year exposure because of the relative duration of these phases. In addition, during the transition phase, 100% of the available activity is already deposited on the ground resulting in the highest external exposure, as opposed to the eruption phase when the deposition is in progress. The reason that ingestion was included was based on the assumption that the intake of two thirds of the activity (large particles) is through the ingestion pathway. The recent model considers that the intake of all airborne particles occurs through the inhalation. Per Igneous Activity 2-15, DOE will clarify that external exposure from high level waste contaminated ash, in addition to inhalation and ingestion was considered in TSPA. DOE will include in the clarification the consideration of external exposure during indoor occupancy times, or provide a basis

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DOSE2: Dilution of Radionuclides in Soil

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
			for dwelling shielding from outdoor gamma emitters in a subsequent revision to the Input Parameter Values for External and Inhalation Radiation Exposure Analysis/Model Report (CRWMS M&O 2000ad) or equivalent document. References: CRWMS M&O 2001q. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010201.0027. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2001n. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233. CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.

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DOSE2: Dilution of Radionuclides in Soil

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 2.TT.4	No reference was provided on p. 3-210 in TSPA-SR to the basis for the assumption that the total suspended particle is 3 times higher than the mass load. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.	The assumption is documented in scoping calculation for the Biosphere Dose Conversion Factors. However, this assumption was not used in the recent version, as explained in DIRECT2.TT.1 Reference: CRWMS M&O 2000av. *Scoping Calculation for Volcanic Eruption Biosphere Dose Conversion Factors.* CAL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000809.0358.

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DOSE3: Lifestyle of Critical Group			
AC1 - System description and model integration are adequate			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Valentine Smith	DOSE 3.1.1	The AMR does not discuss how the analysis of disruptive event BDCFs would be affected by climate change. Climate change was included in the revised FEP analysis only for the nominal case. Reference: CRWMS M&O 2000m. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216.	This item was discussed at the Igneous Activity Technical Exchange meeting (21/22 Jun 01).
Smith	DOSE 3.1.2	In Figure 1 of the *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* AMR (CRWMS M&O 2000aj), the food transfer factors presented for the reasonable representation are not the same as those used in other reports (CRWMS M&O 2000ai; CRWMS M&O 2000k). Differences up to a factor of 540 were found. References: CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074. CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383. CRWMS M&O 2000k. *Design Basis Event Frequency and Dose Calculation for Site Recommendation.* CAL-WHS-SE-000001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000627.0214.	The difference by a factor of 540 is for carbon, for which an incorrect leaching coefficient was initially developed. This value was used in the Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis (CRWMS M&O 2000aj). Subsequently, the leaching coefficients were revised, which resulted in the change of the value for carbon and other radionuclides. The later reports (e.g., Non-Disruptive Event Biosphere Dose Conversion Factors, Analysis Model Report [CRWMS M&O 2000ai]) used the corrected values, hence the difference. References: CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074. CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.

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Stockman Rechard	DOSE 3.1.3	In the *Inventory Abstraction* AMR (CRWMS M&O 2000ae), the screening arguments for exclusion of a couple of radionuclides in the human intrusion analyses were insufficient. Example 1: Insufficient basis was provided to exclude ^{241}Pu. To account for human intrusion as early as 100 yr after the placement of waste, ^{137}Cs, ^{90}Sr, and ^{63}Ni were added to the radionuclides considered for the nominal TSPA'SR analysis. For 10-yr-old, average-pressurized water reactor SNF after 100 yr in the repository (i.e., a total decay time of 110 yr), ^{137}Cs and ^{90}Sr account for the majority of the activity. Although ^{241}Pu can be present in SNF with more activity than the "included" ^{63}Ni, ^{241}Pu was excluded from the human intrusion scenario. Example 2: Insufficient basis was provided to exclude ^{151}Sm. For longer times (~500-1,000 yr), the inventories of ^{151}Sm and ^{63}Ni become more important and their activities remain nearly equal. The inhalation DCF for ^{151}Sm is more than two orders of magnitude larger than for ^{63}Ni, and the ingestion DCF for ^{151}Sm is only slightly less (less than a factor of 1.5 smaller) than that for ^{63}Ni (Eckerman et al. 1988). Because the inventories of ^{63}Ni and ^{151}Sm tend to be similar during a 1,000-yr period, there appears to be insufficient basis provided to screen out ^{151}Sm and yet consider ^{63}Ni for the human intrusion scenario. Example 3: Insufficient basis was provided to exclude the long-lived radionuclide ^{59}Ni. Even for a hypothetical human intrusion event at 100 y after repository closure, the technical bases for radionuclide screening must be valid for much longer times, associated with the radionuclide travel times to the critical group. References: CRWMS M&O 2000ae. *Inventory Abstraction.* ANL-WIS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC:	The NRC claims insufficient basis for screening ^{241}Pu, ^{151}Sm, and ^{59}Ni. For ^{241}Pu and ^{151}Sm, the NRC points out that these radioisotopes are potentially more important than ^{63}Ni, which was screened in. However, ^{63}Ni was only mistakenly included in the first iteration of the *Inventory Abstraction* Analysis/Model Report (CRWMS M&O 2000ae). In ICN 01, ^{63}Ni was correctly screened out (CRWMS M&O 2000bs). Hence, ^{63}Ni cannot be used to argue that other radioisotopes with potentially larger Biosphere Dose Conversion Factors should be included as well. The Inventory Abstraction Analysis/Model Report, will be revised to take into account NRC's critique in the Container Life and Source Term IRSR Rev. 3 (NRC 2001); for example, screening factors that account for biological transport will be used for screening radioisotopes in future revisions of the Analysis/Model Report. With this and other modifications, perhaps ^{241}Pu, ^{151}Sm, and ^{59}Ni will be found to be important; however, if past analysis can be used as a guide, ^{241}Pu, ^{151}Sm, and ^{59}Ni were included in TSPA-93 and TSPA-95 (Leigh and Rechard 2001) and found to be unimportant. References: CRWMS M&O 2000ae. *Inventory Abstraction.* ANL-WIS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0643. CRWMS M&O 2000bs. *Inventory Abstraction.* ANL-WIS-MD-000006 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001130.0002. BSC 2001i. *Inventory Abstraction.* ANL-WIS-MD-000006

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
		MOL.20000414.0643. Eckerman, K.F.; Wolbarst, A.B.; and Richardson, A.C.B. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion.* EPA 520/1-88-020. Federal Guidance Report No. 11. Washington, D.C.: U.S. Environmental Protection Agency. TIC: 203350.	REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010416.0088. NRC 2001. *Issue Resolution Status Report Key Technical Issue: Container Life and Source Term.* Rev. 3. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20010418.0048. Leigh, C. and Rechard, R.P.. "Radioisotope Inventory for TSPA-SR", Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), April 29-May 3, 2001, Alexis Park Resort, Las Vegas, Nevada. La Grange, Illinois: American Nuclear Society. ACC: MOL.20010313.0012.
Smith	DOSE 3.1.4	The prior irrigation times contained within the referenced document (CRWMS M&O 1999d) were inconsistent with those used in the *Non-Disruptive Event Biosphere Dose Conversion Factors* AMR (CRWMS M&O 2000ai). For both the reasonable and bounding representations, the Input Request for Biosphere Dose Conversion Factors (BDCFs) to be Used in the TSPA-SR listed prior irrigation times for elements (Cs, Ni, Sr, and Mo) not contained within the AMR, and the AMR analyzed elements (Am, Ac, and Th) not contained within the referenced document. For those elements contained within both documents, the prior irrigation times for the reasonable representation did not agree for ^{240}Pu, and the prior irrigation times for the bounding representation did not agree for ^{14}C, ^{232}U, ^{238}Pu, ^{239}Pu, and ^{240}Pu. References: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.	The prior irrigation times from the Dose Conversion Factors used in the TSPA-Site Recommendation input transmittal were calculated based on leaching coefficients only, while those used in the Non-Disruptive Event Biosphere Dose Conversion Factors Analysis/Model Report (CRWMS M&O 2000ai) included radionuclide decay. Although prior irrigation periods are not site nor receptor specific inputs, they are parametric tools used in the Biosphere Dose Conversion Factor abstraction to incorporate soil removal by erosion (with a characteristic time of a few hundred years). The final Biosphere Dose Conversion Factor abstraction does not depend on which specific irrigation periods were used, as long as the trend in the Biosphere Dose Conversion Factor behavior with the duration of the prior irrigation can be observed. Therefore, the lack of agreement

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		CRWMS M&O 1999d. *Input Request for Biosphere Dose Conversion Factors (BDCFs) to be Used in the Total System Performance Assessment for Site Recommendation.* Input Request PA-R&E-99251.R. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990819.0070.	pointed out by the reviewer has no effect on the Biosphere Dose Conversion Factor values. The revised Section 6.3.2 in the Nominal Performance Biosphere Dose Conversion Factor Analysis (CRWMS M&O 2001h) addresses the derivation of the prior irrigation periods. References: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383. CRWMS M&O 2001q. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010201.0027. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123. CRWMS M&O 1999d. *Input Request for Biosphere Dose Conversion Factors (BDCFs) to be Used in the Total System Performance Assessment for Site Recommendation.* Input Request PA-R&E-99251.R. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990819.0070.

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Smith	DOSE 3.1.5	In the example pathway contribution for ^{243}Am on page II-8 of the *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* AMR (CRWMS M&O 2000aj, Figure 3 of Attachment II) were substantially different to those for ^{243}Am contained in the Attachment I compact disc file, /Ndesden_5/Pathway/Ndepat_6.xls. Reference: CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074.	The purpose of the example presented in Attachment II (CRWMS M&O 2000aj) was to show the mechanics of the pathway calculations using a spreadsheet routine. This specific example used the data from Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis (CRWMS M&O 2000bt), hence the difference. Although DOE agrees that the data from the report in question could have been used, the purpose of the attachment was not compromised by using some other numerical values. References: CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074. CRWMS M&O 2000bt. *Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000004 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000418.0826.

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AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.2.1	DOE selection criteria for parameters include selection based on the appearance of a parameter in more than half of the documents reviewed. DOE interprets this to represent consensus among the scientific community that the parameter is the best available data. This selection criterion is subject to manipulation and/or bias based on the initial selection and number of reviewed reports. The approach has no technical basis when the reason for frequent selection/use by the referenced reports is not known or provided. References: CRWMS M&O 1999b. *Environmental Transport Parameters Analysis.* ANL-MGR-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991115.0238. CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.	The selection criteria include several items, not just one "more than half" as indicated in the comments. Due to lack of site-specific data, generic data were used. All data were initially selected to be applicable to the Yucca Mountain biosphere model. The cited data were all from reputable sources, including NRC Guidance (Regulatory Guide, and NUREG/CR), National Labs' reports (Oak Ridge, PNL, Sandia, Argonne, and EPRI), and international sources (IAEA and AECL). The documents provide the comprehensive reviews of related parameters and/or completed radiation dose assessment. To refine the initially selected data, the selection criteria were created and used. The bases for parameter selections were included in the referenced documents. Because the parameter values were selected using compilations of data produced by reputable organizations, the original technical reports were not evaluated from the perspective of their technical merits. Instead, data selection was invoked based on the premise that the technical evaluation had been performed by the data compilers. Where possible, the parameter values were selected such that they were applicable to the environmental conditions at Yucca Mountain region, such as the soil type and pH. If such specific values were unavailable, generic ones were used. References: CRWMS M&O 1999b. *Environmental Transport Parameters Analysis.* ANL-MGR-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC:

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AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			MOL.19991115.0238. CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.
Smith	DOSE 3.2.2	Rationale for not using site specific studies for transfer coefficients that data have not been collected and is expensive/time consuming appears to ignore EPA research on the Nevada Test Site and possibility to show relevance of the few important coefficients using available information. Reference: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.	The Environmental Protection Agency research on the Nevada Test Site was not available to the author when the report was written. Procedurally, cited literature must be publicly available, as these documents may be in the public reading room. However, the applicability of the research will be reviewed in future and will be documented in a subsequent revision of the Analysis Model Report -- *Transfer Coefficient Analysis* (CRWMS MYO 1999e). Reference: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.
Smith	DOSE 3.2.3	AMR incorrectly states an NRC contractor report reflects the NRC position. Example Justification for use of GENII-S code inappropriately includes CNWRA use. The depth and types of analyses conducted to prepare for review of a license application (e.g., CNWRA use) are different than what may be required to support a license application. References: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O.	The incorrect statements have been removed from the latest revisions to these documents, and will not be used in the future. References: CRWMS M&O 2000bu. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001016.0005. CRWMS M&O 2001r. *Environmental Transport Parameter Analysis.* ANL-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC:

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
		ACC: MOL.20000413.0692. CRWMS M&O 1999b. *Environmental Transport Parameters Analysis.* ANL-MGR-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991115.0238.	MOL.20010208.0001.
Smith	DOSE 3.2.4	The selected value for inhalation exposure time is based on average value for U. S. citizens age 18 to 64. No rationale is provided for excluding adults over age 64. It also appears possible that the average member of a farming community would spend more time outdoors than the average American. Reference: CRWMS M&O 1999c. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990923.0235.	Inhalation exposure time was based primarily on the assumed occupation (farming) of the critical group members. Their work-related inhalation exposure time amounted to 2000 - 3,120 hours per year and was unrelated to age. The recreational component of the inhalation exposure time (827 hours per year) was based on the results of a nation-wide survey for adults 18-64 years old. Recreational exposure time for people older than 64 years is about 3% higher than that for those in the 18-64 years age bracket. Considering that people 18-64 years old account for 61.8 % of the US population, while people older than 64 years old constitute 12.7% of the population (KiplingersForecasts.com), inclusion of people over 64 would only result in the 0.6% increase in the recreational exposure time. Considering that the recreational exposure time accounts for less than 25% of the total time spent outdoors, the effect of including recreational exposure time of people over 64 years old would result in a negligible increase (about 0.04%) in the mean inhalation exposure time for the critical group. The critical group is composed of farmers, who because of the nature of their work, spend more time outdoors (CRWMS M&O 2000ad, Sections 6.2 and 6.4) than an average American and more than the average Amargosa Valley resident.

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
			Reference: CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.
Smith	DOSE 3.2.5	Applicability of beryllium data for determination of crop interception fraction for all radionuclides was not sufficiently discussed in the *Identification of Ingestion Exposure Parameters* AMR (CRWMS M&O. 2000y). Although based on beryllium, a single distribution for the crop interception fraction would be applied for all radionuclides. The analysis included a comparison between the interception fractions of iodine and beryllium, but further justification is needed to ensure that the interception fractions for beryllium will not likely be exceeded for other radionuclides. The crop interception fraction has been shown to be a significant parameter for most of the radionuclides considered in the sensitivity analyses for non-disruptive events (CRWMS M&O 2000aj). References: CRWMS M&O 2000y. *Identification of Ingestion Exposure Parameters.* ANL-MGR-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000216.0104. CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074.	The crop interception fraction was derived based on a series of studies done by the Hoffman et al. The experiment was conducted using two radionuclides, Be-7 and I-131. However, the type of radionuclide used in this study, was less significant than the ionization of the atoms. In this study beryllium was in form of cations (positive ions, +2) while iodine was in form of anions (negative ions, -1). The study established the empirical equation to estimate the crop interception fraction, which depends on crop type, crop yield, irrigation methods, irrigation rate, and the type of ions present in the water. The study showed that interception is higher for cations than anions, due to the mainly negative charge on leaf surface. Most radionuclides in groundwater form various complexes and their molecules are either positively (cations) or negatively (anions) charged. Because of the negative charge on the leaves, the interception fraction for the negative beryllium ion is assumed to serve as a conservative estimate of the interception fraction for other radionuclides of interest. In addition, small molecules, like those of beryllium, will tend to stick better to leaf surfaces than large molecules, such as NpO_2^+. References: Hoffman, F.O.; Frank, M.L.; Blaylock, B.G.; von Bernuth, R.D.; Deming, E.J.; Graham, R.V.; Mohrbacher,

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AC2 - Data are sufficient for model justification			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
			D.A.; and Waters, A.E. 1989. *Pasture Grass Interception and Retention of (131) I, (7)BE, and Insoluble Microspheres Deposited in Rain.* ORNL-6542. Oak Ridge, Tennessee: Oak Ridge National Laboratory. TIC: 237241. Hoffman, F.O.; Thiessen, K.M.; and Rael, R.M. 1995. "Comparison of Interception and Initial Retention of Wet-Deposited Contaminants on Leaves of Different Vegetation Types." *Atmospheric Environment, 29,* (15), 1771-1775. New York, New York: Pergamon Press. TIC: 243593. Hoffman, F.O.; Thiessen, K.M.; Frank, M.L.; and Blaylock, B.G. 1992. "Quantification of the Interception and Initial Retention of Radioactive Contaminants Deposited on Pasture Grass by Simulated Rain." *Atmospheric Environment, 26A,* (18), 3313-3321. New York, New York: Pergamon Press. TIC: 243594.
Smith	DOSE 3.2.6	While other parameters are assigned distributions that are sampled or fixed values, the prior irrigation time parameter has been grouped into six periods in the *Non-Disruptive Event Biosphere Dose Conversion Factors* AMR (CRWMS M&O 2000ai). For a given period (except for period 1 where a prior irrigation time of 0 yr was assigned for all radionuclides), different values of prior irrigation time were assigned to individual radionuclides. Reference: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.	As noted in the DOSE 3.1.4 response, the prior irrigation time periods are used as a calculational tool to determine the equilibrium Biosphere Dose Conversion Factor values (CRWMS M&O 2001q; CRWMS M&O 2001s). The exact numerical value is not required as long as they cover most of the period during which activity in soil builds up until the equilibrium conditions (steady-state) are reached. The time periods necessary for the equilibrium in soil to be achieved are different for different radionuclides. It is about a single year for mobile radionuclides such as technetium-99, and on the order of thousands of years, for the isotopes of thorium, if soil erosion is not considered. In the build-up analysis (CRWMS M&O 2001q) erosion has been considered.

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AC2 - Data are sufficient for model justification			
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			Section 6.3.2 of the Nominal Performance Biosphere Dose Conversion Factor Analysis (CRWMS M&O 2001h) addresses the derivation of the prior irrigation periods. References: CRWMS M&O 2001q. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010201.0027. CRWMS M&O 2001s. *Distribution Fitting to the Stochastic BDCF Data.* ANL-NBS-MD-000008 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010221.0148. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.
Smith	DOSE 3.2.7	The *Non-Disruptive Event Biosphere Dose Conversion Factors* AMR (CRWMS M&O 2000ai) provides the supporting data for the *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* AMR (CRWMS M&O 2000aj). However, the *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* AMR included two radionuclides, ^{90}Sr and ^{137}Cs, which were not included in the *Non-Disruptive Event Biosphere Dose Conversion Factors* AMR. Reference: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383. CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose*	The two radionuclides cited were identified too late to be included in the referenced Analysis/Model Report. REV 00 of the Analysis/Model Report (CRWMS M&O 2000ai) concerned the nominal scenario, while the two additional radionuclides were considered for human intrusion. The Biosphere Dose Conversion Factors were generated in a calculation but were available for the sensitivity study as documented in the *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* Analysis/Model Report (CRWMS M&O 2000aj). These two relatively short-lived radionuclides were added after the Non-Disruptive Event Biosphere Dose Conversion

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AC2 - Data are sufficient for model justification			
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		Conversion Factor Sensitivity Analysis. ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074.	Factors Analysis/Model Report (CRWMS M&O 2000ai) was completed. Calculation of the Biosphere Dose Conversion Factors for ^{90}Sr and ^{137}Cs is documented in the calculation report (CRWMS M&O 2000bv). The Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis Analysis/Model Report (CRWMS M&O 2000aj) applies the Biosphere Dose Conversion Factors developed in both reports. References: CRWMS M&O 2000aj. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074. CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383. CRWMS M&O 2000bv. *Biosphere Dose Conversion Factors for Reasonably Maximally Exposed Individual and Average Member of Critical Group.* CAL-MGR-MD-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000306.0251.

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DOSE3: Lifestyle of Critical Group			
AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.3.1	Uncertainty in Soil leaching factors supplied to GENII-S code is accounted for by running a reasonable case (probabilistic) and a bounding case (deterministic). The AMR is unclear as to how the uncertainty is accounted for in the TSPA modeling to fully account for data uncertainty. Reference: CRWMS M&O 2000m. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216.	Uncertainty in soil leaching has not been accounted for in the TSPA-Site Recommendation analyses. Additional evaluation of the uncertainty resulting from using a fixed value of leaching coefficient is presented in Section 13.3.4 in the Supplemental Science and Performance Analysis, Vol.1 (BSC 2001e). The bounding case was not used as compounded conservatism assumptions provided unrealistically large Biosphere Dose Conversion Factors. Volume 1 contains a sensitivity study of this parametric uncertainty in leaching. GENII-S cannot sample from the leaching parameter. A more integrated model that will allow stochastic sampling from the available K_d distributions is being proposed for any potential License Application. Reference: BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.

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DOSE3: Lifestyle of Critical Group			
AC4 - Model uncertainty is characterized and propagated through the model abstraction			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.4.1	The approach used to propagate uncertainty in BDCFs for the biosphere abstraction in the TSPA SR model (CRWMS M&O 2000aq) introduces unnatural correlation (e.g., samples from radionuclide-specific BDCF distributions are correlated to the NP-237 BDCF distribution and no justification for this approach is provided). Biosphere factors that influence the magnitude of BDCFs vary by radionuclide and the justification for the selected approach is not self evident. Failure to maintain vectors from initial GENII-S BDCF modeling leads to inconsistencies in sampled biosphere/critical group parameters across radionuclides when resampling in TSPA SR model. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00, p. 439. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	GENII-S is unable to consider the correlation between the equivalent parameters for multiple radionuclides. It also cannot track the results of such correlation. Most of the time, there is only one dominant radionuclide in which case correlation has no effect. For the limited time where there are two or more radionuclides contributing to dose, the Biosphere Dose Conversion Factor correlation is assumed to be unity (Rn#1 to Np to Rn#2). A distribution of dose with the correct mean value is obtained. The distribution is wider than it would have been if the correlation had been less than unity.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

DOSE3: Lifestyle of Critical Group			
AC5 - Model abstraction output is supported by objective comparisons			
Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.5.1	It is unclear how DOE will show that GENII-S is a valid model for the Yucca Mountain system. The AMR includes a comprehensive description of other AMRs that rely on the GENII-S code and also identifies AMRs that provided input to the validation analysis. The validation of GENII-S focuses on investigation the bases for the conceptual model and verifying that the mathematical model is performing as intended, but no discussion is provided of the scientific bases for the mathematical model. References: CRWMS M&O 2000a. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000517.0257. CRWMS M&O 2000s. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0075.	Biosphere model validation is presented as attachments to *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2001n) and *Nominal Performance Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2001h). Additional model validation is in progress in accordance with the model validation corrective action report.. References: CRWMS M&O 2001n. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.

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DOSE3: Lifestyle of Critical Group

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.TT.1	The AMR references supporting AMRs. The AMR does not identify where generated data will be used, but does indicate that the output will be used to develop BDCFs. Reference: CRWMS M&O 2000z. *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water).* ANL-MGR-MD-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000224.0399.	Procedurally, Analysis/Model Reports must cite the source of all data used. The Data Tracking Number of the data generated is identified. Any user requiring the data generated can get the data from the Technical Data Management System by the Data Tracking Number. Regarding the biosphere modeling, the Biosphere Process Model Report (CRWMS M&O 2000bw) described relationship between the Analysis/Model Reports contributing to the final output of the model. Note that the Process Model Report shows the interrelationship of input and outputs of applicable Analysis/Model Reports. Reference: CRWMS M&O 2000bw. *Biosphere Process Model Report.* TDR-MGR-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000620.0341.
Smith	DOSE 3.TT.2	More references should be made to other documents that contain related analyses. Irrigation with contaminated ground water is the only deposition process considered in this AMR (CRWMS M&O 2000y). The ingestion analyses within this AMR did not include root uptake. Neither deposition from airborne releases or effluents from preclosure operations nor ash deposition and remobilization were addressed in this AMR. It would be helpful if the appropriate documents that account for these processes and factors be referenced within this AMR. In addition, it appears that food washing and crop retention fraction after food washing has not been sufficiently discussed in this AMR. Reference: CRWMS M&O 2000y. *Identification of Ingestion Exposure Parameters.* ANL-MGR-MD-000006 REV 00. Las Vegas, Nevada:	The Identification of Ingestion Exposure Parameters Analysis/Model Report has a very limited scope. This Analysis/Model Report is one of many that develop input parameters for the biosphere model implementing code, GENII-S. It does not, in itself document any analyses of radionuclide transport to plants. Parameters for the root uptake were developed in another model input, Transfer Coefficient Analysis. Input parameters related to retention fraction for various crops are documented in another the Environmental Transport Analysis. The model uses many different parameters, which are documented in several input Analysis/Model Reports.

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DOSE3: Lifestyle of Critical Group

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
		CRWMS M&O. ACC: MOL.20000216.0104.	Food processing, which results in removal of radionuclides from edible parts of crops, was not included in the biosphere model. This is a conservative approach. GENII-S does not allow the user to include food processing. Biosphere Process Model Report (CRWMS M&O 2000bw) explains the relationship between and scope of work for each Analysis/Model Report. Deposition of radionuclides from the preclosure operations is outside the scope of the postclosure analysis. The issues of ash deposition and remobilization were addressed at the Igneous Activity Technical Exchange 21/22 June 2001. References: CRWMS M&O 2000bw. *Biosphere Process Model Report.* TDR-MGR-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000620.0341. CRWMS M&O 2000y. *Identification of Ingestion Exposure Parameters.* ANL-MGR-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000216.0104. CRWMS M&O 2000bu. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001016.0005. CRWMS M&O 2001r. *Environmental Transport Parameter Analysis.* ANL-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010208.0001.

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DOSE3: Lifestyle of Critical Group

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.TT.3	This AMR concludes with a summary tabulation consisting of BDCFs for each radionuclide and prior irrigation time, but it is unclear how the information from the six prior irrigation periods will be used in the total system performance analyses. Reference: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.	Information developed in the *Non-Disruptive Event Biosphere Dose Conversion Factors* Analysis/Model Report (CRWMS M&O 2000ai) was not used directly in the TSPA. The Biosphere Dose Conversion Factors used in TSPA are documented in the *Distribution Fitting to the Stochastic BDCF Data* (CRWMS M&O 2001s) and the *Abstraction of BDCF Distributions for Irrigation Periods* (CRWMS M&O 2001q). References: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383. CRWMS M&O 2001s. *Distribution Fitting to the Stochastic BDCF Data.* ANL-NBS-MD-000008 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010221.0148. CRWMS M&O 2001q. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010201.0027.
Smith	DOSE 3.TT.4	Improvements should be made in the documentation of data acquisition and traceability. Reference: CRWMS M&O 2000a. *Abstraction of BDCF Distributions for Irrigation Periods.* ANL-NBS-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000517.0257.	Biosphere Process Model Report (CRWMS M&O 2000bw) explains the relationship between Analysis/Model Reports, and scope of work for each Analysis/Model Report in which a well-defined analysis or model is presented. It is redundant to explain them in each individual supporting Analysis/Model Report.

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DOSE3: Lifestyle of Critical Group

Transparency and Traceability

Resp. Org	Item #	NRC Comment	DOE Proposed Response
			Reference: CRWMS M&O 2000bw. *Biosphere Process Model Report.* TDR-MGR-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000620.0341.
Smith	DOSE 3.TT.5	The AMR (CRWMS M&O 1999b) states that no assumptions were used for the analysis, yet numerous assumptions, implicit or otherwise, are made throughout the report. Some example assumptions include: (i) that parameter value selections made from literature sources or GENII-S default values are appropriate for the Yucca Mountain region, (ii) that fraction of roots in upper soil is one, and (iii) that 1/2 of forage is stored and 1/2 of forage is fresh for beef and dairy cattle consumption. Reference: CRWMS M&O 1999b. *Environmental Transport Parameters Analysis.* ANL-MGR-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991115.0238.	In a subsequent revision of the Analysis/Model Report, *Environmental Transport Analysis,* DOE will ensure that all major assumptions are listed in the Assumption section In addition, DOE will cite where the assumptions are documented and used. Reference: CRWMS M&O 1999b. *Environmental Transport Parameters Analysis.* ANL-MGR-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991115.0238.
Smith	DOSE 3.TT.6	AMR is unclear how soil to plant transfer factors were combined when a food group value was needed yet the source data applied to a number of specific crops (e.g., arithmetic or geometric mean etc). AMR is also unclear how it was determined which plants were most likely to be planted in a farmers garden. The AMR states fish is not an important pathway w/ no justification or reference to support. Reference: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.	The initially selected transfer coefficients were based on the reputable sources, including NRC Guidance (Regulatory Guide, and NUREG/CR), National Lab's reports (Oak Ridge, PNL, Sandia, Argonne, and EPRI), and international sources (IAEA and AECL). The documents provide the comprehensive reviews of related parameters and/or completed radiation dose assessment. There were no specific crops for each group data, and no specific information on crop grown in the farmer garden. The process of the transfer factor selection, and grouping is documented in *Transfer Coefficient Analysis* (CRWMS M&O 1999e, 2000bu).

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
			Ingestion of fish was included in REV 01 of the *Nominal Performance Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2001h) and it turned out to be a significant pathway for carbon-14. References: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692. CRWMS M&O 2000bu. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001016.0005. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.
Smith	DOSE 3.TT.7	AMR ambiguously defines conservatism as "...a value that would lead to a higher dose". Reference: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.	The Analysis/Model Report definition of conservatism will be clarified in the next. Reference: CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692.
Smith	DOSE 3.TT.8	Some areas in this AMR were unclear. Example 1 AMR is unclear how "period of prior irrigation" values were derived for the analysis. The AMR states that the parameters were based on the soil	For Example 1 in cited the Analysis/Model Report (CRWMS M&O 2000n), these values are simply input data. The Analysis/Model Report Rev 01 (CRWMS M&O 2001h) documenting Biosphere Dose Conversion Factor generation, discusses this period selection. The prior irrigation time was

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
		leaching factor and half-life but provides no additional information. No explanation is provided why this parameter varies by radionuclide. Example 2 AMR includes an assumption that model, mathematical model, numerical solution, and computer model uncertainty is negligible and cites a code validation exercise in another AMR (Non-disruptive Event BDCF [CRWMS M&O 2000ai) as the basis. The cited AMR does not contain the referenced model validation analysis results nor provides any indication on where to find it. References: CRWMS M&O 2000n. *Distribution Fitting to the Stochastic BDCF Data.* ANL-NBS-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000517.0258; MOL.20000601.0753. CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.	calculated in Biosphere Dose Conversion Factor Analysis/Model Report (CRWMS M&O 2000ai). The data provided as input for each radionuclide consisted of a set of 150 stochastic realization. The distribution of the data was assumed to capture uncertainties in the data generation process. The *Nominal Performance Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2001h, Section 6.3.2) addresses the derivation of the prior irrigation periods. For Example 2, biosphere model validation is presented as attachments to ANL-MGR-MD-000003 Rev 01 and ANL-MGR-MD-000009 Rev 01. Additional model validation is in progress. Code validation is an ongoing activity, and status of the validation activity was reported in the Analysis/Model Report. References: CRWMS M&O 2000n. *Distribution Fitting to the Stochastic BDCF Data.* ANL-NBS-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000517.0258; MOL.20000601.0753. CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123. CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
			CRWMS M&O 2001n. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233.
Smith	DOSE 3.TT.9	Transfer factors used in the AMR (CRWMS M&O 2000m, Table 3) do not match values in the cited source report (Analysis Model Report -- *Transfer Coefficient Analysis*, CRWMS M&O 1999g). References: CRWMS M&O 2000m. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216. CRWMS M&O 1999g. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991115.0237.	It was verified that transfer factors used in the *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000m) match the values in Rev 00 of the *Transfer Coefficient Analysis* (CRWMS M&O 1999g). Transfer factors used in Table 3 of the Analysis/Model Report (CRWMS M&O 2000m) are the same as the source report (CRWMS M&O 1999g) and were changed when the document was updated. Updated data was used in the Analysis Model Report, *Disruptive Event Biosphere Dose Conversion Factor Analysis.* (CRWMS M&O 2001n). References: CRWMS M&O 2000m. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216. CRWMS M&O 1999g. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991115.0237. CRWMS M&O 1999e. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000413.0692. CRWMS M&O 2001n. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233.

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DOSE3: Lifestyle of Critical Group

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.TT.10	1. In section 6.12.(5), Radionuclides Present (CRWMS M&O 2000y), discusses the dependency of interception fraction on the particle charge (e.g., for cations and anions), but it was unclear how this information was included in the analysis. 2. It appears that the determination of yield and growing time for hay and forage are inconsistent. The estimated effective yield for hay and forage was based on alfalfa and "other hay" production, while the growing time for hay and forage was based only on alfalfa. An explanation for why this approach was taken should be added. 3. The basis for applying a single distribution to the crop irrigation time for all of the leafy vegetables should be enhanced. Reference: CRWMS M&O 2000y. *Identification of Ingestion Exposure Parameters.* ANL-MGR-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000216.0104.	For comment No. 1, please see response to DOSE 3.2.5. Regarding comment No. 2, the discrepancy has been corrected in REV 01 of the *Nominal Performance Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2001h, Attachment III). Regarding comment No. 3, it is not possible in GENII-S to use more than one distribution for the crop irrigation time for leafy vegetables. A subsequent revision of the Analysis/Model Report will directly address the NRC comments. Reference: CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.
Smith	DOSE 3.TT.11	The AMR (CRWMS M&O 2000ai) contains a table of input parameters for BDCF calculations. This is a very useful table, however, it uses data tracking numbers rather than AMRs to link to source data. A link to AMRs would facilitate NRC review since we could easily locate the reports where the parameters are discussed. The present AMR approach has segmented the BDCF input into a large number of separate AMRs which increases difficulty/time to find the bases for specific parameter values. Reference: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.	Revision 01 of this report (CRWMS M&O 2001h, Table 1) links input data to individual Analysis/Model Reports. Procedurally, input data refer to Reference Information Base item or Data Tracking Number, instead of Analysis/Model Report. The cross-link could be found from Reference Information Base item or Data Tracking Number. Reference: CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.TT.12	The selected value for soil exposure time is based on the assumption the individual is not exposed when indoors. This is true for many radionuclides due to shielding provided by the house. However, this is not true for high energy gamma emitters (the only radionuclides where direct exposure is significant pathway). This is particularly true for the direct release scenario where the house would be surrounded by deposited ash. Staff were unable to locate the argument for exclusion of this exposure pathway. Reference: CRWMS M&O 1999c. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990923.0235.	This item was discussed at the Igneous Activity Technical Exchange, June 21-22, 2001. The parameter value has been updated in the revision of AMR (CRWMS M&O 2000ad). External exposure was not considered in indoors in a direct way. Most radionuclides considered in the postclosure assessment are not strong gamma emitters, therefore do not contribute significantly to the exposure indoors. Strong gamma emitters like cesium-137 are relatively short lived and will not contribute to the dose at times greater than a few hundred years. In addition, for groundwater release scenario, external exposure during the period of time spent outdoors was calculated using home (lawn) irrigation rate of, on the average, 74 inches, which is about twice the average irrigation rate for the crops. This results in the higher radionuclide concentration in the lawn soil than that for agricultural land, and, consequently, higher external exposure. This approach is conservative, because the receptor does not spend all of his outdoor time on the lawn, and more than compensates for not considering external exposure while indoors. Reference: CRWMS M&O 2000ad. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01 ICN 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.

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Resp. Org	Item #	NRC Comment	DOE Proposed Response
Smith	DOSE 3.TT.13	In addition to the data sets, the corresponding AMRs that include discussions of the parameter value selections should be referenced within the *Non-Disruptive Event Biosphere Dose Conversion Factors* AMR (CRWMS M&O 2000ai). For example, the animal product consumption rates for the Reasonable Representation and Bounding calculations were presented in Tables 1 and 2, respectively, with their data sources. However, no connection was made from the data sources to the AMRs that provide the justification for the parameter value selection. Reference: CRWMS M&O 2000ai. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.	Revision 01 of this report (CRWMS M&O 2001h, Table 1) links input data to individual Analysis/Model Reports. Procedurally, input data refer to Reference Information Base item or Data Tracking Number, instead of Analysis/Model Report. The cross-link could be found from Reference Information Base item or Data Tracking Number. Revision 1 considers only the reasonable representation cases. Reference: CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.

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General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA001	There are a number of positive examples in the documentation related to transparency and traceability. However, there are some areas that need improvement. In particular, there are numerous examples where the discussion in a summary section or an individual abstraction section is inconsistent with other sections or the actual TSPA-model. In particular, there are contradictory statements about the role of environmental variables in the corrosion models. The summation of the inconsistencies makes it difficult for the reviewers to identify what is being done in some parts of the TSPA-model. Two specific areas where transparency and traceability were lacking were (1) the abstraction of colloid modeling and (2) The use of WAPDEG in modeling the failure of the engineered barrier system. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE agrees that improvement on transparency and traceability of the documents can be made. Activities to improve transparency and traceability include: a. Update review procedures with emphasis on vertical slice, e.g., by chapter and between documents to improve consistency. b. Improve/update the documents as mentioned in the specific examples noted by the NRC c. Conduct vertical slice review for consistency. (currently ongoing) d. Develop additional transparency tools, such as – flow chart of model – data source flow to model – additional graphics e. Provide for additional reviews – International Peer Review Panel – internal review teams – technical editors DOE also will revisit the (1) the abstraction of colloid modeling and (2) the use of Waste Package Degradation Model in modeling the failure of the engineered barrier system. The following TSPA examples are categorized as follows: 1. Clarification required primarily in terms of rewording text. Limited additional work required. 2. Clarification and additional analysis required. Additional analyses or plots required to fully clarify the point.

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General and Applicable to all Integrated Subissues			
ACI – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
			3. Not the scope of the document. Some of the comments ask for more than the model document is intended to serve. For example, additional TSPA analyses in the model document that indicates the significance of the component to long term dose. These should be referred to the other documents. 4. Not used. 5. Correction required to the text. 6. Provide abstraction defensibility of the abstraction utilized. 7. No change required. Suggestions for transparency/traceability may not require any changes. 8. NRC points out a few instances where we have obtained transparency, or provided abstraction defensibility.
McNeish	TSPA001 Example	Model – Table 4.1, Page 40, is a good table for the reader but it also may be a source of confusion as to what is used/important in the TSPA-SR model and what is simply a capability of the TSPA-SR model but is never really activated (chemistry and waste package/drip shield corrosion). Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify Table 4-1 (CAT 1)
McNeish	TSPA001 Example	Model - Page 104, Reference to Figure 6-21. Figure 6-21 is somewhat misleading because WAPDEG is run up front and only passes information to GoldSim, so it should be in the first group of codes. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-	DOE will clarify Figure 6-21 (CAT 1)

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General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
		WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	
Kuzio	TSPA001 Example	Model - Page 109. It is unclear if any strongly sorbing radionuclides were modeled through the saturated zone and how they would contribute to very long time doses. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The Analysis/Model Report (CRWMS M&O 2000at, Section 6.10) discusses the sorption coefficients that are modeled in the saturated zone site scale model. Analysis/Model Report (CRWMS M&O 2000bx) discusses the simulated radionuclide mass breakthrough curves, Section 6.3.2. (CAT 3) References: CRWMS M&O 2000at. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328. CRWMS M&O 2000bx. *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA.* ANL-NBS-HS-000030 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0330.
Sevougian	TSPA001 Example	Model - Page 113, It would be helpful if each of the items described as key attributes to the repository system could be better quantified in terms of their significance to risk. In order for the NRC to perform a risk-informed review, it is necessary to have a clear and convincing identification of those components that are risk-significant. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Analyses quantifying the contribution of particular attributes to overall risk have not yet been conducted. We believe that it is not part of the scope of Total-System Performance Assessment Model for the Site Recommendation. (CAT 3) Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
Rickertson	TSPA001 Example	Model - Page 128 It would be useful to prepare a plot of the release rate of the gap and bulk-fuel radionuclides versus the flow-focusing factor for all realizations to determine if the maximum risk occurs at an intermediate value. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	This evaluation has not yet been conducted; however, it will be considered for the future work. The measure of risk is the mean annual dose. In the current calculational model, sensitivity of the mean annual dose to the flow focusing factor could be evaluated in a straightforward way. (CAT 3)
Mon Nowak	TSPA001 Example	Model - Page 148. The paragraph should clearly identify that the near-field environment outputs are being used by other models. As currently stated, there is a discrepancy with other statements made about model implementation. NRC Clarification: As will be elaborated upon in subsequent sections of this document, how the drift thermodynamic and chemical environment changes with time is important to repository performance in that the changes help determine degradation rates of the engineered barrier components,....' In the current model, the degradation rates of the engineered barrier components are not dependent on the changes to the chemical environment. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	It is agreed that the corrosion model abstractions do not have degradation rates that depend on environmental conditions. It should be noted that the general corrosion initiation criteria is based on the temperature-dependent deliquescence points of an assumed always present surface layer of a sodium nitrate salt film. The localized corrosion initiation criteria are based on in-drift chemical conditions (the pH). The general corrosion rates used are derived from weight-loss measurements in several solutions with compositions that are considered bounding. The chemical modeling done in support of TSPA provides some of the bases for the assumption that the solution compositions used are bounding. In addition, chemical conditions are used in GoldSim to calculate upper caps on radionuclide concentrations in the invert. Wording can be clarified in revisions to document. (CAT 1)
McNeish	TSPA001 Example	Model - Page 183 - A statement to the effect that "The resulting pH and concentration of dissolved solids are key parameters in determining the waste package and drip shield..." does not accurately reflect how the corrosion model is actually implemented in TSPA. The pH values are used only to examine	DOE will clarify the statement. (CAT 1)

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
		whether or not localized corrosion occurs, which is never the case. Please clarify this statement. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	
McNeish	TSPA001 Example	Model - Page 198 - The top paragraph is misleading. It implies that chemistry information at 400 locations is abstracted when in fact little chemistry information is abstracted to the corrosion models. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the text. (CAT 1)
Rob Rechard	TSPA001 Example	Model - Page 237- Talks about 1600 different histories for thermodynamic variables (temperature, RH, etc.), which is different from what is mentioned elsewhere. NRC Clarification: This statement can be removed. The 1600 different histories were generated with the multiscale TH model. Something like 588 histories were developed in the TH abstraction process. The commenter confused the two sets of output which should of course not be the same. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Per NRC Clarification, this comment does not need to be addressed.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA001 Example	Model - Page 250, We understand the need for an overview, but the current one is misleading. Many factors are listed, but only some of them are actually connected to one another (e.g. chemistry variables). Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the text (CAT 1)
McNeish	TSPA001 Example	Model - Page 252 – "The actual waste package corrosion rate is randomly sampled from the range bounded by these high and low values." This statement implies that there is a dependence of waste package corrosion rate on pH. We are not aware that the data demonstrate this conclusion. Maybe just a language clarification needed. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the text. (CAT 1)
McNeish	TSPA001 Example	Model - Page 350 - The flux-splitting algorithm was not used for the drip-shield as implied in the documentation. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the text. (CAT 1)

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
Kuzio	TSPA001 Example	Model - Page 406 -It would be useful to show a plot comparing the results for the three-dimensional model to those for the pipe model. This information would help give NRC assurance that the models were operating correctly. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Analysis/Model Report (CRWMS M&O 2000bx) Figure 25 compares results from the 3-D and 1-D models (CAT 2) Reference: CRWMS M&O 2000bx. *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA.* ANL-NBS-HS-000030 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0330.
McNeish	TSPA001 Example	Model - Page 555, The arrows for the curves in Figure 6-245 and 6-247 are backwards. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will correct the Figures. (CAT 1)
Kalinich	TSPA001 Example	Model - Page II-21, Equations II-2a, II-2b, II-4, and II-5 are all incorrect in the document. NRC Clarification: Rearrangement of equations II-2a and II-2b as shown in the document do not result in the constants listed (A,B,C). The correct constants can be found in the listing of the subroutine. Likewise the algebra for rearranging equations II-4 and II-5 is not correct. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will correct the text. (CAT 5)

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
Rickertson	TSPA001 Example	Page 1-32, It is stated that the iterative process of performance assessment reduces uncertainty in the forecasted performance of the potential repository. A historical comparison of past performance assessments would be useful to support this assertion. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The treatment of uncertainty in earlier assessments is not the same as the treatment today. For example, initial performance assessments (TSPA-91 and TSPA-93) were deterministic. Therefore, a comparison of quantified uncertainties has not been performed. (CAT 2)
McNeish	TSPA001 Example	Page 1-46, "use engineered components to tailor the environmental variables (i.e., temperature, relative humidity, seepage flux to be as benign as possible." This is a good concept but it is unclear how it has been done. If the drift spacing is called an engineered component then maybe this would be true, but typically engineered components are referring to waste packages, drip shields, tunnel support, etc. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text. (CAT 1)
McNeish	TSPA001 Example	Page 2-20, "The Alloy-22 layer degrades only in the presence of liquid water, i.e. when water drips directly on the waste package." If this statement were correct, then only 13% of the waste packages should fail in the TSPA-SR model. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will correct the text. (CAT 5)

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA001 Example	Page 2-20, There is a lengthy discussion of items that can cause variability in the corrosion rates. Later in the document (pages 3-82, 4-7, 5-12), it is stated that the degradation rates are insensitive to environmental conditions except when relative humidity increases above a threshold value. A clarification of which statements are accurate is needed and the inaccurate statements removed. If the environmental parameters influence the general corrosion rates, it would be useful to provide plots to illustrate the effects. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will correct the text. (CAT 1)
McNeish	TSPA001 Example	Page F2-20, The figure shows temperature, RH, drip/no-drip, and chemical conditions supplying input to the waste package degradation model. Based on the later descriptions, only temperature/RH are used and they only define the initial conditions. A clarification is needed. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the inputs to the Figure. (CAT 1)
Wilson	TSPA001 Example	Page 3-34 - The water travel time for the fraction of flow that in faults would be a useful addition to the results. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	No change is required. (CAT 7)

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
Mon	TSPA001 Example	Page 3-43, "The environments are important to the potential repository performance to the extent that they help determine degradation rates of the engineered barrier components ..." This statement does not appear to describe the corrosion model abstraction accurately. NRC Clarification: The corrosion model abstraction does not have degradation rates that depend on environmental conditions. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	It is agreed that the corrosion model abstractions do not have degradation rates that depend on environmental conditions. It should be noted that the general corrosion initiation criteria is based on the temperature-dependent deliquescence points of an assumed always present surface layer of a sodium nitrate salt film. The localized corrosion initiation criteria are based on in-drift chemical conditions (the pH). The general corrosion rates used are derived from weight-loss measurements in several solutions with compositions that are considered bounding. The chemical modeling done in support of TSPA provides some of the basis for the assumption that the solution compositions used is bounding. (CAT 1)
McNeish	TSPA001 Example	Page 3-65, From the paragraph at the top of the page, it is difficult to tell what is in the model and what is not in the model. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text. (CAT 1)
McNeish	TSPA001 Example	Page 3-66, 3.3.4.2.2, "Knowledge of water compositions on the drip shield is required to predict drip shield corrosion." While in theory this is correct, the current drip shield corrosion values are abstracted independently of chemistry. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text (CAT 1)

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA001 Example	Page 3-81, The last sentence of the second paragraph under 3.4.1.1 implies that in-package chemistry is an input to the waste package degradation model. Considering that WAPDEG is run up front it is unclear how this is done. It is also unclear what information is passed to TSPA. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text (CAT 1)
Mon	TSPA001 Example	Page 3-84, The reader would benefit from identification of the fraction of cracks that start and then stop. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	In the Waste Degradation Model, once stress corrosion cracking initiates cracks continue to grow to failure. No cracks start and then stop in the Waste Degradation Model. The statement quoted refers to a general description of the slip-dissolution model. (CAT 2) Reference: CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.
McNeish	TSPA001 Example	Page 3-93, The level of detail provided about the coupling of the in-package chemistry model to the degradation rates is excellent. This allows the reviewer to understand what was done. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	No response required (CAT 1)

Analysis of Resolution Status
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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
Schenker	TSPA001 Example	Page 3-100, The term "coupling" is used at the bottom of 3.5.2 to mean linkage or something else. Coupling implies a more complex solution than what is done. NRC Clarification: Coupling typically refers to the solution of a set of equations. The text is discussing a feedback link, which is different. Suggest the use of different terminology or provide DOE definition of coupling. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text by changing "coupling" to "linkage". (CAT 1)
Schenker	TSPA001 Example	Page 3-101, A comparison of the output values generated with the stochastic model, such as water flux into the failed containers, with the values selected to develop the conceptual model (3.5.2.1), would be useful to help judge the adequacy of the approach. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The comparison between assumed flux based on TSPA-Viability Assessment and values calculated in TSPA-Site Recommendation was performed. The much lower range of flux values calculated in TSPA-Site Recommendation into the waste package where used in the second iteration of the TSPA-Site Recommendation. See In-Package Chemistry for Waste Forms (BSC 2001g) for more discussion on flux values. (CAT 2) References: DOE (U.S. Department of Energy) 1998. *Total System Performance Assessment.* Volume 3 of *Viability Assessment of a Repository at Yucca Mountain.* DOE/RW-0508. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981007.0030. BSC 2001g. *In-Package Chemistry for Waste Forms.* ANL-EBS-MD-000056 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010322.0490. CRWMS M&O 2000aq. *Total System Performance Assessment*

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General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
			(TSPA) Model for Site Recommendation. MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Stockman Schenker	TSPA001 Example	Page 3-104, Third paragraph. The discussion is very good and an appropriate amount of detail to put here. However, more information showing the comparison would be very useful to the reader. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE believes the text provided is sufficient for this report since this report is not intended to fully justify the models used. Rather the Analysis/Model Reports provide this justification. DOE plans to provide more figures comparing the model with data in the Analysis/Model Reports which should provide adequate support for the statements. (CAT 2)
Schenker	TSPA001 Example	Page 3-123, Second paragraph under 3.5.5.4. The explanation for why ^{237}Np solubility does not appear to have a significant influence on the uncertainty of the dose needs further clarification. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The importance of a parameter is primarily a function of the range of uncertainty of the parameter. While the overall potential variation is greater for TSPA-Site Recommendation than used before, this potential variation of ^{237}Np solubility is a combination of the range that occurs in commercial spent nuclear fuel and codisposed packages and the range before and after 1000 yr after breach of the packages. (See Figure 2. in Y. Chen and R.P. Rechard). The dose in the TSPA-Site Recommendation is dominated by the ^{237}Np released from the commercial spent nuclear fuel 1000 years after breach of the package. This particular range in uncertainty of ^{237}Np is much narrower than the range used for TSPA-95 and TSPA-Viability Assessment. Hence, the importance of ^{237}Np is less in TSPA-Site Recommendation. (CAT 2)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
			Note: DOE has not "settled" on the "best" uncertainty to use for ^{237}Np. For the PA work accomplished to support the Supplemental Science and Performance Analysis, the uncertainty for ^{237}Np solubility was again greatly increased. Reference: Chen, Y. and Rechard, R.P. 2001. "Dissolved Concentration Component of Waste Form Degradation Model in TSPA-SR." *Proceedings of the 2001 International High-Level Radioactive Waste Management Conference, April 29 -May 3, 2001, Las Vegas, Nevada.* La Grange, IL: American Nuclear Society.
Kuzio	TSPA001 Example	Page 3-173, The presentation of curves using median values may be misleading for overall system performance. The stochastic behavior of the saturated zone should be represented in order to appropriately risk-inform. Probability density functions of travel times for important radionuclides developed considering the full stochastic behavior of the saturated zone would be appropriate. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Analysis/Model Report (CRWMS M&O 2000bx) presents simulated unit breakthrough curves from 100 stochastic realizations, for the radionuclides considered, Figures 12 – 19. (CAT 2) Reference: CRWMS M&O 2000bx. *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA.* ANL-NBS-HS-000030 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0330.
McNeish	TSPA001 Example	Page 4-8, An excellent discussion of how things are working is provided on this page. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	No response required (CAT 1)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
Sevougian	TSPA001 Example	Page 4-40, The second paragraph provides a qualitative example that corrosion doesn't depend at all on water. NRC Clarification: This comment does not require any response. It is an example that the corrosion models do not depend on thermohydrology so the corrosion models shouldn't be described/implied (as some other comments mention) as being dependent. It highlights the inconsistency between the text of the documents and the behavior of the models, in some instances. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Per NRC Clarification, this comment does not require a response.
McNeish	TSPA001 Example	Page 5-11, The last statement on the page is inaccurate or inconsistent with the description of flux-splitting provided earlier in the document. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text. (CAT 1)
Al Schenker	TSPA001 Example	Page F5-12 (Figure 5.1-12), It would be useful to present a plot of the probability density function of the dissolution rate for commercial spent nuclear fuel along with this figure. This would clarify why dissolution rate was identified as a sensitive parameter. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will add a probability distribution function plot to the figure. (CAT 2)

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General and Applicable to all Integrated Subissues			
AC1 – Transparency and Traceability of Documents is Inadequate			
Resp. Org	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA001 Example	Page EF-5 on. Many of these figures have puzzling connections that need to be explained, such as the connection of *General Corrosion and Localized Corrosion of the Waste Package Outer Barrier* to the AMR for Environments on the Surfaces of those engineered systems. Without identification of the information passed, transparency and traceability is more hindered than improved. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the Figures. (CAT 1)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues

AC1 – System description and model integration are adequate

AC2 – Data are sufficient for model justification

AC3 – Data uncertainty is characterized and propagated through the model abstraction

AC4 – Model uncertainty is characterized and propagated through the model abstraction

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA002	An appropriately rigorous methodology has not been utilized for model abstraction simplifications and selection of "conservative" parameter distributions, conceptual models, or modeling approaches. In addition to integration of various abstractions into the TSPA, DOE needs an integrated and consistent approach in other areas of the performance assessment. The system-model, or even individual abstractions, rapidly become too complex. Human intuition cannot be relied on to make accurate decisions consistently. For complex, nonlinear models embodied into the TSPA, it may be impossible to determine the effect of a parameter a priori. Because of the interactions at the system-level, some intermediate outputs may have a maximum impact on risk for some intermediate value rather than at its bounds. For example, if ionic strength affected both colloid stability and cladding corrosion, it is possible that minimizing ionic strength in order to maximize colloid stability may not result in maximizing risk (due to lessor cladding corrosion). References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Several activities will support improvement in this area. Additional documentation and training will be provided a. Systematize/characterize abstraction process. b. Systematize/characterize selection of conservatism in components. c. Provide more guidance for abstractions in procedures, such as in AP3.10Q. DOE will evaluate and define approaches to deal with: a. Evaluating non-linear models as to what is their most conservative settings b. Dealing with the "complexity" issue in the TSPA model c. Including some "basis" slides from the Analysis/Model Reports as Appendix. The following TSPA examples are categorized as follows: 1. Clarification required primarily in terms of rewording text. Limited additional work required. 2. Clarification and additional analysis required. Additional analyses or plots required to fully clarify the point. 3. Not the scope of the document. Some of the comments ask for more than the model document is intended to serve. For example, additional TSPA analyses in the model document

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues

AC1 – System description and model integration are adequate
AC2 – Data are sufficient for model justification
AC3 – Data uncertainty is characterized and propagated through the model abstraction
AC4 – Model uncertainty is characterized and propagated through the model abstraction

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	that indicates the significance of the component to long term dose. These should be referred to the other documents. 4. Not used. 5. Correction required to the text. 6. Provide abstraction defensibility of the abstraction utilized. 7. No change required. Suggestions for transparency/traceability may not require any changes. 8. NRC points out a few instances where we have obtained transparency, or provided abstraction defensibility.
Schenker	TSPA002 Example	Model - Page 251, It is unclear how a "conservative" abstraction is selected when the chemistry model outputs can impact so many system components. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	For degradation of cladding, commercial spent nuclear fuel. High level waste, solubility, and colloids generation are all greater at low pH values; (only colloid solubility decreases as pH decreases). Hence, for the time period where pH was low, a bounding low value was chosen. (CAT 2)
McNeish	TSPA002 Example	Page 1-5, DOE stated that some abstractions have very little detail eliminated, while others are simplified greatly. NRC staff were unable to determine where guidance is provided to project staff to ensure a consistent approach is taken for the abstraction process (much simplification vs. little). The criteria to be applied to determine the amount of simplification are likely subjective. Reference: CRWMS M&O 2000ar. *Total System Performance*	DOE will clarify the text. (CAT 1)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues

AC1 – System description and model integration are adequate
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AC4 – Model uncertainty is characterized and propagated through the model abstraction

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		Assessment for the Site Recommendation. TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	
Nowak Francis	TSPA002 Example	Page 3-57, It is unclear that the neglect of the dry-out effect is conservative with respect to near-field chemistry or temperatures. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Dryout (by ventilation) during the preclosure period is neglected. This ultimately results in lower near-field/engineered barrier system temperatures since the thermal conductivity in the rock is effectively the wet thermal conductivity (higher than dry), thus resulting in higher heat transfer rates away from the repository horizon. It is true that neglecting dryout may or may not result in a conservative condition for temperature. However, it can be argued that this effect on final dose, either conservative or nonconservative, does not matter. Two cases can be considered. In the case of lower early time temperatures being adverse to dose, this is the current method of calculation and, if it occurs, this influence would be captured within the limitations of modeling assumptions and/or conceptual model usage (particularly associated with the corrosion models). In the case of higher early time temperatures, it can be argued that high early time temperatures have been applied in the current analysis. It is noted that the much higher rock temperatures associated with full power heating (e.g., initial postclosure period) and rock dryout did not adversely affect the corrosion models. Therefore, even if preclosure ventilation host rock dryout would have been included (and hence caused engineered barrier system/near-field temperatures to be higher due to a lower host

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – System description and model integration are adequate *AC2 – Data are sufficient for model justification* *AC3 – Data uncertainty is characterized and propagated through the model abstraction* *AC4 – Model uncertainty is characterized and propagated through the model abstraction*			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			rock thermal conductivity), it is unlikely that the (higher) temperatures during this short time period (50 years) would be any greater than those being used immediately after repository closure. The high temperatures immediately after closure don't adversely affect the corrosion models (and hence dose). Therefore, an assumed condition of lower temperatures for the first 50 years does not impact dose. More moisture left in the model is expected to result in earlier appearance of water with dissolved constituents on engineered barrier system materials such as the drip shield or waste, resulting in potential for earlier radionuclide release. (CAT 2)
Nowak Francis	TSPA002 Example	Page 3-59, It is unclear that forcing seepage is conservative with respect to near-field chemistry or temperatures. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Earlier appearance of water in the drift, although all effects are less clear in this case. There is currently not a direct process-level link between emplacement drift seepage and predicted engineered barrier system temperatures. The multiscale thermo-hydrological process-level model treats the emplacement drift as a capillary barrier that does not allow seepage moisture to enter the drift during the simulation. Some preliminary studies have been performed using selected submodels of the multiscale thermo-hydrological model to determine the influence of seepage water on the in-drift temperatures and relative humilities. (CAT 2)

Analysis of Resolution Status
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Subissue 3: Model Abstraction

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Nowak Francis	TSPA002 Example	Page 3-60, It is unclear that setting preclosure RH artificially high is conservative with respect to near-field chemistry or temperatures. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	High relative humidity promotes earlier appearance of water with dissolved constituents on engineered barrier system materials such as the drip shield or waste, resulting in potential for earlier radionuclide release. Since rock dryout during preclosure is not included in the models, the in-drift relative humidity is made artificially high during the 50 year preclosure period. Temperatures and relative humidity are dynamically calculated by the multiscale thermo-hydrological model. Therefore, if moisture removal would have been modeled during the preclosure period, the resultant temperatures would be higher (see above), relative humidity lower. However, an assumed high relative humidity (results from not removing moisture during preclosure) during this 50 year period was deemed to be a more conservative response for potential corrosion since it requires higher relative humidity values to initiate. (CAT 2)
McNeish	TSPA002 Example	Page 3-86, It is unclear that DOE considered combined effects such as chemistry+radiolysis+coupled electrochemical processes when evaluating whether a process can cause a shift in potential large enough to initiate localized corrosion. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text. (CAT 1)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Mishra	TSPA002 Example	Page 5-32, Using the 5th or 95th values might not capture the highest dose or sensitivity, because for some processes the worst case might be somewhere in the middle of the distribution rather than at its bounds. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The use of 5th and 95th percentile values in the one-off sensitivity analysis implicitly assumes a monotonic relationship between the uncertain input and the model output. For most processes, this is indeed the case, i.e., the worst outcome can be traced to extreme values of the underlying parameters. As part of the screening for the one-off analyses, the TSPA-Site Recommendation analysts examined the nature of the input-output relationship. When it was felt that extreme behavior may not be reflected by 5th and 95th percentile parameter values (e.g., solubility of secondary mineral phases), alternative conceptual/parametric models were used to stress the system. Such analyses have been documented in Section 5.2 of the TSPA-Site Recommendation report. (CAT 2) Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA003 Example	Inadequate basis is provided for the simplifications utilized for some model abstractions. We recognize that it is intractable to represent all of the spatial and temporal uncertainty and variability, as well as conceptual model uncertainty in the overall TSPA-model. The abstraction process is typically a simplification of process-model results into a form that represents an appropriate amount of uncertainty/variability, while allowing a computationally efficient solution. A number of instances have been identified where inadequate justification has been provided for the amount of information retained by the abstraction. In particular, DOE needs to justify the simplifications used with consideration of all affected subsystems or models. The risk-significance of the models or subsystems will determine the degree of support needed for the simplifications. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	As NRC has recognized, it is intractable to represent all of the spatial and temporal uncertainty and variability, as well as conceptual model uncertainty in the overall TSPA-model. DOE acknowledges the comment. We believe that adequate technical basis has been provided for the simplification utilized for model abstractions. Please see our responses to all of the specific examples identified by NRC as inadequate justification. In TSPA-License Application, documentation of the simplifications will be updated per TSPA002 activities. The justification will be provided to show that the simplification appropriately represents the necessary processes. The following TSPA examples are categorized as follows: 1. Clarification required primarily in terms of rewording text. Limited additional work required. 2. Clarification and additional analysis required. Additional analyses or plots required to fully clarify the point. 3. Not the scope of the document. Some of the comments ask for more than the model document is intended to serve. For example, additional TSPA analyses in the model document that indicates the significance of the component to long term dose. These should be referred to the other documents. 4. Not used. 5. Correction required to the text. 6. Provide abstraction defensibility of the abstraction utilized. 7. No change required. Suggestions for transparency/traceability may not require any changes. 8. NRC points out a few instances where we have obtained transparency, or provided abstraction defensibility.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Jim Nowak	TSPA003 Example	Model - Page 107, Engineered barrier system environment section. TSPA uses an equilibrium batch reactor in simulation of the engineered barrier system environments. There is inadequate technical basis provided that the simplification is appropriate to represent the dynamic processes. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The statement that an equilibrium batch reaction calculations were used is an oversimplification. As stated in the In Drift Precipitates/Salts Analysis (CRWMS M&O 2000bz), "The conceptual model is that boiling and evaporation of water within the drift will cause dissolved solids in the water to concentrate and precipitate. The degree of vaporization of H_2O and precipitation of salts and minerals may change with time as conditions change. The precipitates that form will depend on the temperature, gas fugacities, vaporization rate, seepage rate, and seepage composition."..."The Precipitates/Salts model was developed to simulate the conceptual model." The precipitates/Salts model consists of a low relative humidity model and a high relative humidity model. Those two models are linked at 85% relative humidity. "In the low relative humidity salts model, seepage water enters a specified location within the drift where it is subjected to evaporation processes. This location is called a "reactor" in this document. "The EQ3/6 high relative humidity model is used in two modes, a simple evaporation mode and a mode that simulates both flow-through and evaporation simultaneously. The first mode is used to predict the simple evolution of a given solution as water evaporates. The second mode is used to predict the evaporative evolution of a constant incoming seepage." (CAT 6) Reference: CRWMS M&O 2000bz. *In-Drift Precipitates/Salts Analysis.* ANL-EBS-MD-000045 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000512.0062.

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Wilson Houseworth	TSPA003 Example	Model - Page 118, There is inadequate technical basis provided that it is unimportant to represent uncertainty in the infiltration map at each climate state. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Performing an uncertainty analysis of infiltration for the other climate states is included in the Unsaturated and Saturated Flow under Isothermal Conditions agreement 3.1. The resolution for representing uncertainty is described in the response to the second NRC Comment for Model-Page118. (CAT 6)
Wilson Houseworth	TSPA003 Example	Model - Page 118, There is inadequate justification that representing seepage threshold by three levels (low, medium, and high) captures the contribution from the tails of the distribution, especially on the upper side. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	To resolve this issue, we propose to use the 90th percentile infiltration case identified in the Monte-Carlo analysis for the upper-bound infiltration map of the glacial transition climate. Parameters from this case will be used in the infiltration model to calculate the upper-bound infiltration map. Using this in the infiltration weighting scheme the weights for lower bound, mean and upper bound infiltration cases will be recalculated. The upper bound infiltration cases for the monsoon and modern climates will be computed by the ratio of the spatial average infiltration for the upper bound infiltration map to the mean infiltration map for the glacial transition climate multiplied by the mean infiltration map for the monsoon and modern climates. These new infiltration maps will be incorporated into the process model calculations that are used to support TSPA and the new weighting factors will be used directly for TSPA sampling. (CAT 6)
McNeish	TSPA003 Example	Model - Page 129, The seepage uncertainty parameter is randomly sampled from 0 to 1 and is not considered data. It seems that if it is representing uncertainty but *no data exists* to support its selection, then DOE should favor the value that produces the largest risk. Reference: CRWMS M&O 2000aq. *Total System Performance*	The random number from 0 to 1 is only necessary because the parent triangular distributions for seepage uncertainty are evaluated in the seepage dynamically linked library (DLL - a subroutine external to GoldSim) rather than in GoldSim itself. These parent distributions are based on data (see Table 6-4, p. 125). If the triangular distributions were in GoldSim itself, then GoldSim

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
ACI – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		Assessment (TSPA) Model for Site Recommendation. MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	would utilize exactly the same method of using a uniform random number surrogate for sampling the seepage uncertainty distributions. (CAT 7)
McNeish	TSPA003 Example	Model - Pages 167 - It is unclear whether inputs for the thermo-hydro-chemical model came from the TSPA or from the process model. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the text. (CAT 1)
Rickertson	TSPA003 Example	Model - Pages 167 and 170, DOE should provide further clarification of the temporal variability of the thermohydrology parameters and the significance of the variation considering the large time-step used in the TSPA model. It is unclear how the model is constructed so that processes operating at faster time constants than the model time steps are captured. Figure 6-41 illustrates the point; it shows that the temperature responds very dynamically in the first 500 years. If a 500-year timestep was used in the TSPA simulation, it is unclear how the dynamic response of this process would be captured. We suggest at least a few test cases using smaller time steps to demonstrate sensitivity. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Efforts are made to ensure time steps are not too long to prevent resolution of system dynamics. The time step is generally tested as a part of model implementation. For example, such testing helped identify appropriate times steps for the early period when temperatures are changing and for the periods when the climate transitions occur. (CAT 2)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA003 Example	Model - Page 182, On the electronic figure (6-65), it looks like that even for median value simulations, there is significant underprediction of peak temperatures. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the Figure. (CAT 1)
Nowak	TSPA003 Example	Model - Page 183, "...abstracted to representative constant values..." We are not aware of the criteria used to interpret whether the process model was an appropriate abstraction. Also, we do not know what you mean by a "representative constant value", and whether simplification you employed eliminates significant amounts of uncertainty and variability. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Discussion of the appropriateness of the abstraction and uncertainty are in Abstraction of Drift-Scale Coupled Processes (CRWMS M&O 2000b). As stated in that document, "Section 6.1 provides the details of the thermal-hydrologic-chemical abstraction of water chemistry and gas-phase composition adjacent to the drift wall. It provides a tabulation of the abstracted time-histories of the aqueous species concentrations, pH, and CO_2 component concentration in the gas phase. In addition, Section 6.1 contains a discussion of the uncertainty in these values based on the differences in the thermal-hydrologic-chemical results from the other infiltration flux cases." (CAT 6) Reference: CRWMS M&O 2000b. *Abstraction of Drift-Scale Coupled Processes.* ANL-NBS-HS-000029 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0371.
Nowak	TSPA003 Example	Model - Page 184, Technical basis is needed for the "subset of combinations" that were used in the chemistry modeling. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The "subset of combinations" used for the lookup tables that constitute the response surface span the entire range used in the TSPA. Interpolation was used to obtain values between the values in the tables. (CAT 6)

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Gross	TSPA003 Example	Model - Page 360, Because of the strong dependence of diffusivity in the invert on liquid saturation, you should provide the technical basis that it is appropriate to represent the invert as one mixing cell and to not consider heterogeneities in the engineered materials. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The representation of the invert as one mixing cell is a reasonable simplification for two reasons. First, the saturation in the invert is essentially uniform, as explained below, so there is no need to represent this heterogeneity. Second, a one cell representation for the invert provides a conservative calculation of diffusive transport through the invert in comparison to multiple cells through the invert. An analysis was performed with the NUFT computer code to evaluate the saturation gradients in the invert during the recent evaluation of unquantified uncertainties for the Nuclear Waste Technical Review Board. The new analysis is documented in Section 10.3.3.3.3 of Volume I of the Supplemental Science and Performance Analysis (BSC 2001e). This analysis considers a low-temperature operating mode for the latest engineered barrier system design. The grid for the simulation is finer than that used for typical calculations with the multiscale thermal-hydrologic model in order to provide more resolution in the invert. The NUFT calculation predicts essentially constant saturation in the invert underneath the drip shield, demonstrating that the saturation beneath the waste package is essentially constant (uniform). In this case, the use of a volume-averaged saturation for the invert provides acceptable accuracy for calculating the effect of saturation on the diffusion coefficient. (CAT 6) Reference: BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
ACI – System Description and Model Integration are Adequate			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Kuzio	TSPA003 Example	Model - Page 372, DOE needs to demonstrate that heterogeneities in the flow paths are adequately captured by the abstraction; i.e., releasing from the unsaturated zone to four random points in the saturated zone. It is unclear whether the peak mean dose will be larger if the releases are distributed over the total flow area to the saturated zone or to four discrete points. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The horizontal placement of the point source in each of the four source regions is varied stochastically from realization to realization, reflecting uncertainty in the location of leaking waste packages and transport pathways in the unsaturated zone. This is described in more detail in the Section 6.2.2 of the Analysis/Model Report (CRWMS M&O 2000bx) (CAT 6) Reference: CRWMS M&O 2000bx. *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA.* ANL-NBS-HS-000030 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0330.

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Model Abstraction Output is Supportive by Objective Comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA004	Process model support is inadequate. As part of the model development process it is necessary to verify that the model is calculating properly, validate that an appropriate model has been developed for the problem being examined, and complete analyses to explain the detailed functioning of the model. The DOE has provided information on all three of these topics in the TSPA-SR documentation. Support for the process model results abstracted in the TSPA was lacking. The DOE has issued a Corrective Action Report (CAR) BSC-01-C-001 dated 5/3/01 that found "the area of model validation is considered to be a significant condition adverse to quality". The CAR indicates that 18 of 24 Analysis Model Reports (AMR's) were inadequately validated, including eight that were not validated at all. In general, the DOE did not present comparisons of the process model output to the abstractions used in the TSPA. Also, as the CAR indicates, the other methods deemed acceptable to develop support for process models were not satisfied. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will provide comparisons of process model output to the abstractions used in the TSPA. A root cause analysis for Corrective Action Report (BSC-01-C-001) is being performed. This comment seems more applicable for Analysis/Model Report model and abstraction validation, not for TSPA model abstractions. The following TSPA examples are categorized as follows: 1. Clarification required primarily in terms of rewording text. Limited additional work required. 2. Clarification and additional analysis required. Additional analyses or plots required to fully clarify the point. 3. Not the scope of the document. Some of the comments ask for more than the model document is intended to serve. For example, additional TSPA analyses in the model document that indicates the significance of the component to long term dose. These should be referred to the other documents. 4. Not used. 5. Correction required to the text. 6. Provide abstraction defensibility of the abstraction utilized. 7. No change required. Suggestions for transparency/traceability may not require any changes. 8. NRC points out a few instances where we have obtained transparency, or provided abstraction defensibility.

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
ACI – Model Abstraction Output is Supportive by Objective Comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	TSPA004 Example	Model - Page 50, #7, It doesn't appear that points on which experts disagree have been discussed in the documentation, as implied by the comment. It is unclear how the DOE has handled these issues in the TSPA. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify the text. (CAT 1)
Sevougian	TSPA004 Example	Model - Page 120, The paragraph basically shows that the *Infiltration_Scenario* parameter was implemented correctly at the local, limited basis. The technical basis for evaluating the *Infiltration_Scenario* implementation on a limited basis was not provided. In particular, the *Infiltration_Scenario* is listed as being utilized by UZ flow fields, thermohydrology, and seepage and is described as being linked to 137 other parameters. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Verification that the correct value of *Infiltration_Scenario* is used in the various submodels is generally described in the subsection of the Model Document devoted to that submodel. These subsections are referred to on p. 120. For example, see Table 6-6 (CRWMS M&O 2000aq, Section 6.3.1.2) for the value of *Infiltration_Scenario* used in the seepage submodel. If additional proof is needed, the GoldSim model file can be opened and the external links for *Infiltration_Scenario* can be followed individually to each place that the parameter is used. (CAT 6) Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.
Rickertson	TSPA004 Example	Model - Page 191, pH and ionic strength should be checked at time periods between calculational switch points also. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The current model switches in-package water chemistry at times chosen to represent the dynamics of the chemistry evolution. It would be straightforward to provide finer resolution on these switches. However, the effect of doing so would not be very important in the calculational construct. The evolution of chemistry within each waste package is not tracked. Instead, an average chemistry is used to represent performance of groups of

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Model Abstraction Output is Supportive by Objective Comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			waste packages. Since the waste packages within a group fail at very different times, this averaging means that fine details of the changes in chemistry after the time of package failure are blurred over. Consequently, finer resolution on the chemistry changes is not likely to change the calculated dose rate very much. (CAT 2)
Kuzio	TSPA004 Example	Model - Page 421, We expect that the pipe model has an analytical solution that can be verified. We also believe that the more-complex models should be compared to simple models to provide model support. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The Analysis/Model Report (CRWMS M&O 2000bx), Section 6.5.2, discusses the 1-D model validation. (CAT 2) Reference: CRWMS M&O 2000bx. *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA.* ANL-NBS-HS-000030 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0330.
Kuzio	TSPA004 Example	Model - Page 424, "...it can be concluded that the SZ component model is verified." DOE should provide the technical basis that demonstrates the approach taken satisfies the requirements for model verification. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The intent of this statement is not to verify the sub-component model, but to show that the saturated zone site-scale model is correctly implemented in the TSPA model and working as intended. The specific Analysis/Model Reports (CRWMS M&O 2000ca, 2000cb), flow and transport respectively, discuss model verification. (CAT 6) References: CRWMS M&O 2000ca. *Calibration of the Site-Scale Saturated Zone Flow Model.* MDL-NBS-HS-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000825.0122. CRWMS M&O 2000cb. *Saturated Zone Transport Methodology and Transport Component Integration.* MDL-NBS-HS-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000824.0513.

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Subissue 3: Model Abstraction

General and Applicable to all Integrated Subissues			
AC1 – Model Abstraction Output is Supportive by Objective Comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Houseworth	TSPA004 Example	Page 3-37, The conceptual model for infiltration is based on field studies at Yucca Mountain under current climate conditions. Technical basis is needed that the same infiltration model will apply under future climate conditions, which is roughly 94% of the 10,000 year compliance period. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The infiltration model has been compared with alternative methods for estimating infiltration over a range of precipitation corresponding to wetter future climates. These comparisons include the Maxey-Eakin method and the chloride mass balance method. These comparisons support the conclusion that the net infiltration model is appropriate for estimating the spatial distribution of net infiltration at Yucca Mountain. (CAT 6)
McNeish	TSPA004 Example	Page 3-61, DOE needs to address more thoroughly the observation: "The use of the simplified THC model results for the abstraction is based on the fact that it reproduces more accurately the observed changes to water and gas compositions in the drift-scale heater test..." Specifically, we are concerned that the fact that the field data show better agreement with the abstraction than with the process model may be anecdotal rather than real. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The "simplified model" and the "complex model" are both process-level models (run with TOUGHREACT), not abstractions. The main difference is that the "complex model" has more trace constituents. In CRWMS M&O 2000cc, the simplified process-level model better matches the results of the drift-scale heater test, therefore, it was used as the basis for the thermal-hydrologic-chemical abstraction in TSPA, i.e., the "simplified" process-level model was further simplified (abstracted) for use in TSPA. (CAT 7) Reference: CRWMS M&O 2000cc. *Near Field Environment Process Model Report.* TDR-NBS-MD-000001 REV 00, ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001005.0001.
Nowak	TSPA004 Example	Page 3-73, Technical basis is needed for the pH values applied below 85% RH. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The EQ3/6 database and code are now being further developed to make pH predictions at far lower values of relative humidity. Extrapolation of values from 85% relative humidity to lower values was chosen in lieu of any other rational approach. The duration of relative humidity below 85% is relatively short compared with the period of performance. (CAT 6)

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General and Applicable to all Integrated Subissues			
AC1 – Model Abstraction Output is Supportive by Objective Comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Schenker	TSPA004 Example	Page 3-107, last paragraph under Basis for High-level Radioactive Waste Glass Degradation Model. The description is for a comparison of a model to other models. A comparison of models to models is a questionable method to develop model support. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The Analysis/Model Report on high level waste glass degradation explains that the model for glass degradation in humid air was based on drip tests on Savannah River glass. DOE will add sentence "The better model, in turn, was based on drip tests using results from high level waste glass." (CAT 6)
McNeish	TSPA004 Example	Page 3-114, Is the frequency of 1.1E-6/yr cladding failure due to severe seismic results a modeled result? If so, what is the model support for this result? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify the text. (CAT 1)
Schenker	TSPA004 Example	Page 3-117, In order for the reader to agree with the assertion that the corrosion of Zircalloy in boiling seawater and geothermal solutions provides adequate model support, a comparison of the corrosion rates of Zircalloy in those environments and a comparison of those environments to the ionic strength solutions of the other solutions would be appropriate. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE intends to document the technical basis for the assertion that the corrosion of Zircalloy in boiling seawater and geothermal solutions provides adequate model support in the Waste Form Degradation Process Model Report (CRWMS M&O 2000by) and Cladding Analysis/Model Report (CRWMS M&O 2001t). (CAT 2) Reference: CRWMS M&O 2000by. *Waste Form Degradation Process Model Report.* TDR-WIS-MD-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000713.0362. (future revision) CRWMS M&O 2001t. *Clad Degradation – Summary and Abstraction.* ANL-WIS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0229.

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AC1 – Model Abstraction Output is Supportive by Objective Comparisons			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Kuzio	TSPA004 Example	Page 3-149, A comparison of the unsaturated zone results from this abstraction with basic information about fractures and flow should be provided for adequate model support. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will consider providing in tabular form, a comparison between infiltration rates and water flow travel times. (CAT 6)
Wilson Houseworth	TSPA004 Example	Page F3-23, Model support is needed for the percolation flux modeling results, such as comparison to the ECRB observations or other natural systems. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE has quantitative support for the levels of percolation flux used in the unsaturated zone flow model from hydrological (water saturation and potential), geochemical (Cl and Sr), temperature, and mineralogical (calcite) measurements. For seepage, model predictions have been compared with seepage testing at Niche 3650 and seepage studies conducted during systematic characterization of the Enhanced Characterization of the Repository Block. (CAT 6)
Wilson Houseworth	TSPA004 Example	Page 4-6, Model support is needed for the glacial transition climate or monsoon climate ratios of infiltration to precipitation. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	See the response to NRC Comment for Page 3-37. If the technical basis is sufficient to support the model calculations of infiltration for future climates (NRC Comment for Page 3-37) then DOE considers it is sufficient to support the computed ratios of infiltration to precipitation for future climates. (CAT 6)

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General and Applicable to all Integrated Subissues			
AC1 – Transparency and traceability			
Resp.Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	General.TT.1	Table D.1-1 defines the subissues of the NRC Key Technical Issues (KTIs), when the NRC structure is shifting from KTIs to Integrated Subissues (ISIs). Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Table D.1-1 is a synopsis of the TSPAI Issue Resolution Status Report Key Technical Issue (NRC 2000) and their related Subissues. The relationship between NRC Integrated Subissues and Key Technical Issue subissues is in Table D.1-2. Table D.1-1 will be deleted in the next revision of TSPA-Site Recommendation. Reference: NRC 2000. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration.* Rev. 3. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 249045.
McNeish	General.TT.2	TSPA-SR lists the process model factors with a reference to the Repository Safety Strategy (CRWMS M&O 2000). However, the list of process model factors in Table D.1-3 is different from those in the Table B-1 of the Repository Safety Strategy (CRWMS M&O 2000). References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	DOE agrees that Table D.1-3 should be same with Table B-1 of Repository Safety Strategy Rev. 4 (CRWMS M&O 2001i). DOE will verify the accuracy of the information in Table D.1-3 and update it as necessary. Reference: CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.
McNeish	General.TT.3	It seems that it would be more helpful if the IRSR tracking database, described in Appendix D of TSPA-SR, included the content of the IRSR (i.e., the comments and how they have been addressed) in addition to listing the acceptance criteria from the TSPAI IRSR.	In the next revision to TSPA-Site Recommendation, references and content of the Issue Resolution Status Report database will be removed from Appendix D. Considering the impending release of the Yucca Mountain Review Plan, DOE does not believe that it is prudent to update Appendix D since the acceptance criteria may

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AC1 – Transparency and traceability			
Resp.Org.	Identifier	NRC Comment	DOE Proposed Response
		References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. NRC 2000. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration.* Rev. 3. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 249045.	change in the Review Plan.
McNeish	General.TT.4	The contents of Table E-1 seemed to have missed the intent implied by the title to Appendix E called "Analyses Model and Data Traceability". The reader likely will assume that the information in the table will provide a way to trace the source of input data through the TSPA system, however the poorly formatted and confusing information is more useful for tracking document contents through the system than data items. Consider the data input item of a geologic layer thickness in the unsaturated zone. The "Reference Document" column could be scanned to locate possible locations of the data. For example, "Abstraction of Flow Fields for RIP", Abstraction of Drift Seepage", and Draft of AMR Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux". With an educated guess one might select the "Abstraction of Flow Fields for RIP". But there is no verification in the Table that the data actually exists in this document or any other. Indeed, the data may not exist in any of the documents listed. Reference CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will consider updating Table E-1 to add another layer to identify the type of information that will be fed into the models.

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Subissue 4: Overall Performance

Importance to System Performance - This subissue focuses on the role of the PA to demonstrate that the overall performance objectives have been met with reasonable assurance. This subissue addresses calculation of the expected annual dose to the average member of the critical group and the consideration of parameter uncertainty, alternate conceptual models, and the results of scenario analysis.

Acceptance criterion 3: The Total System Performance Assessment Code provides a credible representation of repository performance

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Swift Wilson Arnold	J-O3.1	DOE appears to be weighting the results of alternative conceptual models without an appropriate technical basis for the weighing factor used. *Specific Examples* -Igneous dike propagation model identifies two alternatives - that the dike either centralizes above the repository due to flow into the drifts or the dike centralizes randomly along the drift length. Without any technical basis, each of these alternatives is weighted by 50%. - Seepage uncertainty parameter is randomly sampled from 0 to 1 without any justification for selecting a value less than 1. - Information on the correlation of Kds among different UZ units is limited, but the most conservative model is not identified or selected - The anisotropic and isotropic alternative conceptual models for saturated zone flow are weighted equally without a technical basis for this weighting factor (check SZ agreement)	DOE agrees that weighting for alternative conceptual models should be appropriately justified. Note that in some cases (e.g. seepage) the distribution has been chosen to capture uncertainty, and it is not always clear a priori which end of the distribution is more conservative. The DOE has therefore included the full uncertainty in the analysis to allow determination of sensitivity. -Seepage Uncertainty - The seepage uncertainty parameter does not represent alternative conceptual models, but rather the uncertainty in the hydrologic properties around the drifts. This uncertainty is discussed in detail in the seepage-abstraction Analysis/Model Report (CRWMS M&O 2001o) Unsaturated Zone Kds - The Kd measurements and abstraction are done in terms of rock type, not stratigraphic unit. This is appropriate because it is the rock chemistry (i.e., mineral abundances, etc.) that will determine the Kd. Saturated Zone Anistropy - Given the lack of any additional basis for assigning probability weights to alternative conceptual models of horizontal anisotropy, the least biased approach is to assign equal weights to the two alternatives. Reference: CRWMS M&O 2001o. *Abstraction of Drift Seepage.* ANL-NBS-MD-000005 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010309.0019.

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Swift Bodvarsson	J-O3.2	The treatment of alternative conceptual models in the DOE sensitivity and uncertainty analysis is not clear. DOE briefly mentions about alternative conceptual model only as an example in the TSPA-SR Technical Document (CRWMS M&O 2000ar, page 5-9): "An example of a parameter with this effect is neptunium solubility (see Section 5.2.4.2). An example of a conceptual model that might have this effect is the dual-porosity UZ transport model, which may result in faster transport than a dual continuum model. " Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Where a particular conceptual model is technically justified, there is no requirement to consider more conservative alternatives. DOE will clarify the incorporation of alternative conceptual models in the next revisions to the Analysis/Model Reports.
Swift Sevougian Arnold Lee	J-O3.3	Inappropriate characterization of data uncertainty may affect the results of calculated repository performance even if the mean of the distribution is reasonable. Selecting too wide of an uncertainty band may dilute the risk by spreading the peak dose in time, thereby reducing the peak value. Selecting too narrow of an uncertainty band may underestimate peak dose during the compliance period by delaying dose beyond the regulatory period of interest. DOE needs to discuss what, if any, analyses that they have used to provide confidence that their choice of parameter distributions is appropriate and will not lead to risk dilution by reducing the peak expected annual dose. *Specific Examples* - Use of uniform distributions for the Kd value for several radionuclides (Am, Pu, Ra, Pb, Pa, Sn) gives equal probability to all values, which is likely not appropriate. A more biased distribution	Parameter distributions utilized in the TSPA model are documented in the TSPA model report (CRWMS M&O 2000aq) or in the supporting Analysis/Model Reports. For the TSPA-License Application, the documentation of the selection of parameter distributions and associated impact on peak expected annual dose will be enhanced. Kd Distributions - Uncertainty distributions for Kd values are based on statistical analyses of data in most cases. Additional justification for uncertainty distributions will be included in revision of existing documentation, as covered by an existing Radionuclide Transport agreements 2.10, 1.5). Stress Intensity Factor - The stress intensity factor (K_I) could become negative depending on the stress state and crack geometry. Negative stress intensity factor values included in the uncertainty range do not have any impact on the waste package performance because no stress corrosion cracks grow with the stress intensity

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		could increase peak dose by reducing the spread in travel times. - Selection of non-zero lower value for distributions of Kds for Pu, Pb, Ra, and Sn without an appropriate technical basis may inappropriately delay doses beyond compliance period. - Lower values in uncertainty bands for the stress intensity factor (Ki) include values below 0, which have no risk significance. This may inappropriately dilute risk.	factor less than zero. As a result, DOE does not believe that this results in any dilution of risk. DOE will provide a plot of Pu Kd vs. distribution function. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.
Rickertsen Sevougian	J-O3.4	The 10,000-year water residence time in the WP does not appear to be consistent with the assumption that diffusion in the WP is instantaneous.	Diffusion out of the waste package is not instantaneous because of the relatively small area available for diffusion. Later on as the hole becomes larger, diffusion does increase.
Swift Smith (Bio)	J-O3.5	DOE has not demonstrated that the results of all of their analyses are stable with respect to the number of realizations performed in the simulations. *Specific Examples* - Submodels such as BDCFs and saturated zone transport transfer functions are developed from a limited number of realizations, which is not increased for tests of the stability of the results.	TSPA-Site Recommendation model results have been determined to be stable only with respect to their inputs. For postclosure, the analyses focussed on stability for the first 10,000 years. Multiple replicate TSPA runs are being considered to provide additional insight regarding stability of model results. Biosphere Dose Conversion Factors - Testing was not used to demonstrate Biosphere Dose Conversion Factors stability. This testing would be more appropriate post-Site Recommendation and DOE recognizes that additional work is required to demonstrate stability of the results in TSPA-License Application. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Sevougian Wilson	J-03.6	DOE has not presented justification that the model results appropriately address variability (e.g., from the level of discretization within the system). Specific Examples - Number of infiltration bins - Number of climate states - Number of thermohydrology bins - Time step size	Spatial and temporal variability and discretization apply at all scales of all of the process-level and abstraction models, and the TSPA model. The level of discretization/variability used in the models represents an optimization that strives to achieve the greatest amount of variability within the constraints of available scientific data and available computational resources. For example, the five thermo-hydrological/infiltration bins represent a discretization of the source term behavior that is a compromise between modeling the source term releases at each individual waste package environment (total of about 12,000) versus assuming an average behavior for the entire repository. The four saturated zone source regions represent a similar compromise. Studies indicate that little difference in repository behavior would be expected using either one source saturated zone region or four saturated zone source regions (CRWMS M&O 2000ar, Figure 4.1-18). Chapter 3 includes discussions of uncertainty and variability as implemented in the various TSPA submodels. Variability ranges used in the models represent a combination of scientific data and judgement, generally biased toward conservatism when specific data is lacking. Number of infiltration bins - The infiltration bins are used to divide the waste packages into groups for purposes of calculating radionuclide mobilization, release, and transport within the Engineered Barrier System. It is not possible to model all 11,770 waste packages individually. However, the following observations apply: (1) The infiltration bins used (0-3 mm/yr, 3-10 mm/yr, 10-20 mm/yr, 20-60 mm/yr, and 60+ mm/yr during the glacial-transition climate) cover a wide range of infiltration, and therefore do capture important aspects of the effects of

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			infiltration variability. (2) The TSPA results have been found not to be particularly sensitive to infiltration (see Section 5.2.1.1 of the TSPA-Site Recommendation technical report). Thus, including greater detail in its TSPA implementation would not be expected to have a great effect. Number of climate states - The climate states, including their number and properties (e.g., precipitation, temperature, etc.), are justified in detail in the future-climate Analysis/Model Report (USGS 2000b). Number of thermohydrology bins - The thermal-hydrology results are binned according to the infiltration bins that are discussed above. Timestep size - Timestep size in the total system model was conducted to optimize: (1) convergence (timestep size and substep size), (2) result file size and the amount of data that could be saved within the Windows NT 2GB limit, and (3) computational time. The first constraint forces smaller timesteps, while the latter two constraints force larger timesteps. The timestep sizes used in the TSPA-Site Recommendation model (CRWMS M&O 2000aq) are small enough to capture the key changes in the system (e.g., the climate oscillations), but large enough to allow storage of key data from a multiple-realization, million-year simulation using currently available computational resources. The internal substep used for convergence of the model allows the much larger timesteps (e.g., 500 years) to cycle as low as 1 month in order to attain convergence. Further internal substep reductions, e.g., on the order of hours, do not give noticeably different results. Sensitivity studies on timestep size and substep size in GoldSim will be

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			available for the TSPA-License Application. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. USGS 2000b. *Future Climate Analysis.* ANL-NBS-GS-000008 REV 00. Denver, Colorado: U.S. Geological Survey. ACC: MOL.20000629.0907. CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.
Sevougian	J-O3.7	The TSPA code is not properly verified, such that there is confidence that the code is modeling the physical processes in the repository system. The TSPA code needs to be verified by the time of a License Application (if one is submitted). See general comment 1. NRC Clarification: The proposed rule at 10 CFR 63.114(g) requires that the DOE provide the technical basis for the models used in the Total System Performance Assessment (TSPA). The technical basis includes appropriate efforts to ensure the quality of the code results, where verification and validation are integral to assuring the quality of code results. Verification ensures that software performs properly prior to its use for the intended purpose. The verification process should demonstrate that (i) the models used have been adequately tested for calculational correctness with all relevant data together with associated uncertainties; (ii) a well-defined and rational assessment procedure has been followed; and (iv) results have been fully disclosed and subjected	Code verification and model validation are accomplished through DOE's Quality Assurance procedures. AP-SI.1Q is used for code verification and AP-3.10Q is used for model validation. Examples of model verification and validation methods include: • Software verifications by the developer (Golder) • Input to TSPA model checked to ensure that the input is used for its intended purpose and is working appropriately • Intermediate and expected value results checked to ensure subsystem linkages and overall system performance are performing properly Corrective action reports have been initiated to assess recent discrepancies identified with software and model verification and validation. In addition, root cause analyses have been initiated to identify systemic causes of the discrepancies and programmatic improvements, if necessary. Periodic updates on the root cause

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		to QA and review procedures. The verification process encompasses (i) tests that provide evidence of correct and successful implementation of algorithms, as appropriate, and (ii) bench-marking or comparative testing against results from other software for cases where accuracy of the code or the correctness of the code cannot be judged otherwise, because there is no analytical method to use for the comparison. Verification must be clearly distinguished from model validation. Model validation (e.g., conceptual or mathematical) deals with the conceptual basis of the model used for representing the real system. Therefore, model validation is a demonstration of suitability of a model to accurately represent a stipulated component (e.g., waste package) or aspect (e.g., heat flow) of a real system. Whether the processes are properly formulated mathematically and parameterized following accepted theories (or if a new theory is used [e.g., the active fracture model] then is this new theory tested), numerical schemes used have acceptable convergence properties, dimensionality (space and time) is appropriate, etc. are part of model validation. The validation of the TSPA model, which is essentially an abstracted model or a combination of models, has a special requirement that the simplification introduced does not cause optimistic biases in the results.	findings and corrective actions are being reported in accordance with the DOE Management Plan for TSPA Quality Issues. References: AP-3.10Q, Rev. 2, ICN 4. *Analyses and Models.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010405.0009. AP-SI.1Q, Rev. 3, ICN 1, ECN 1. Software Management. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010705.0239. CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. Brocoum, S.J. Letter from S.J. Brocoum to W. Reamer, Total System Performance Assessment Quality Issues, dated July 6, 2001.
McNeish	J-O3.7 Example	DOE has the elements of verification in their TSPA-SR and supporting documents. However, rigorous verification of the modules and the full code is either not conducted, or has not been adequately reported, or is not yet available for review. The description of the verification in Section 6.5 (CRWMS M&O 2000aq) is not adequate. A specific verification plan was not found and the verification was not uniform across the document. Example findings from the review of the TSPA-SR verification efforts are listed below.	See above response to J-O3.7.

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		Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	
McNeish	J-O3.7 Example	Inputs and outputs to process-level models were verified with hand calculations. NRC review of several hand calculations have identified various errors.	See above response to J-O3.7. Specific concerns regarding use of hand calculations have been addressed in the DOE Management Plan.
McNeish	J-O3.7 Example	Although DOE states that no abstractions in the PA model operates outside of their intended ranges, the NRC review found models being utilized outside the range of conditions for which the abstractions were developed.	See above response to J-O3.7. Specific concerns regarding range of conditions for a given model have been addressed in the DOE Management Plan.
McNeish	J-O3.7 Example	An extensive GoldSim error log file was generated by execution of the "median value" file by the DOE. DOE documents do not discuss the significance of the warnings and errors logged in the GoldSim error log file.	The impact of run log error messages is assessed by the analysts to determine their effect on model results. The run log errors will be documented in future revisions of the TSPA model report. Specific concerns regarding GoldSim errors have been addressed in the DOE Management Plan. See also above response to J-O3.7.
McNeish	J-O3.7 Example	Sufficient rationale was not provided to describe why verification of the median value results is an appropriate verification for a model that relies on stochastic simulations. There is no indication that verification of the TSPA model behavior included stochastic simulation of the model, sensitivity analyses, or uncertainty importance analyses. These analyses provide insights into whether the code is computing properly near the extremes of the input values. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	TSPA-Site Recommendation model results have been determined to be stable only with respect to their inputs. For postclosure, the analyses focussed on stability for the first 10,000 years. Multiple replicate TSPA runs are being considered to provide additional insight regarding stability of model results. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.

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McNeish	J-O3.7 Example	In the TSPA-SR Technical Document (CRWMS M&O 2000ar), the DOE presented various levels of analyses to demonstrate the verification of selected aspects of the performance assessment model. However, the verification was not sufficiently comprehensive; carrying the calculations forward to step through different parts of the model in larger segments would provide a more robust verification of the TSPA code. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	In a future revision of the TSPA model report, DOE will provide additional documentation regarding the TSPA modules and their integration into the overall TSPA.
McNeish	J-O3.7 Example	There is no indication that DOE has conducted tests to systematically verify the operations of the TSPA-SR model (CRWMS M&O 2000aq) to ascertain that the code is functioning properly over the full range of conditions being modeled. Sufficient tests have not been conducted for the code to be relatively bug free. The verification of the TSPA model (as it is implemented using GoldSim and the associated codes called through dynamically linked libraries [DLLs]) does not appear to satisfy the intent behind systematic verification. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	In a future revision of the TSPA model report, DOE will provide additional documentation regarding the TSPA modules and their integration into the overall TSPA.
McNeish	J-O3.7 Example	NRC believes that to demonstrate model validation, DOE should present the validation of the conceptual basis for the model. This should include: (i) whether the processes are formulated properly mathematically and correctly parameterized following accepted theories (or if a new theory is used (e.g., the active fracture model)	Model validation is within the scope of Corrective Action Report BSC-01-C-001. Successful validation of conceptual as well as mathematical models will be ensured. See above response to J-O3.7.

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		then is this new theory tested), (ii) numerical schemes used have acceptable convergence properties, and (iii) dimensionality (space and time) is appropriate. DOE has the elements of model validation in their documents supporting the TSPA-SR Technical Document (CRWMS M&O 2000ar). However, a model validation plan does not appear to exist. Rigorous model validation at the system level has either not been conducted or has not been adequately reported. Example findings from the review of the TSPA-SR validation efforts are listed below. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	
McNeish	J-O3.7 Example	There appears to be some confusion in the understanding of validation and verification. Although Section 6.5 of the TSPA-SR Model Report (CRWMS M&O 2000aq) is titled "Model Validation," the discussion only pertains to software verification. From those parts of the report where validation is discussed in its proper sense, it appears that validation is only partially done. For example, DOE has performed validation of the conceptual model for the biosphere, but they have not applied the same validation procedures to the mathematical model of the biosphere (GENII-S). No attempts have been made to validate the model to show the mathematical model accurately represents the physical system. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	DOE will clarify Section 6.5 (CRWMS M&O 2000aq) to distinguish between model verification and model validation. Biosphere model validation (includes GENII-S) is presented in attachments to CRWMS M&O 2001n and CRWMS M&O 2001h. Additional model validation is in progress in accordance with the corrective action reports on software and model validation. References: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2001n. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233.

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			CRWMS M&O 2001h. *Nominal Performance Biosphere Dose Conversion Factor Analysis.* ANL-MGR-MD-000009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010123.0123.
McNeish	J-O3.7 Example	A peer review is not a substitute for objective confidence building measures such as comparison with field data, laboratory data, or natural analogs. Although field investigations and natural analogs may not present the whole spectrum of information needed to validate the TSPA model, comparisons against field investigations and natural analogs may be used to provide objective support that a large portion (i.e., multiple components of the TSPA model) is validated. If, however, a peer review is used to help validate the TSPA code, the peer review should be documented with an appropriate level of detail to allow an independent assessment of its value in the validation process. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	AP3.10Q allows validation by peer review. DOE understands that use of field investigations or natural analogs is preferred, if available. Reference: AP-3.10Q, Rev. 2, ICN 4. *Analyses and Models.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010405.0009.
McNeish	J-O3.7 Example	DOE has collected field and laboratory data to support detailed hydrologic calculations from which abstractions were made when representing the data in tabular form. Whether the data that support the original model also support the abstracted model (in the form of tabular data) has not been investigated consistently throughout the document. Also, objective comparisons have not been made for all the constituent models (validating parameters and/or the abstraction). Lack of validation (i.e., objective comparison) of the colloidal transport model with the C-wells Alluvium Testing Complex results (although the model is based on such data) is one example.	Model validation is within the scope of Corrective Action Report BSC-01-C-001. Process and abstracted models will be validated. DOE understands that abstracted models must honor process models and that process models must be representative.

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
McNeish	J-O3.7 Example	It is not clear that validating an abstracted model through the validation of the corresponding detailed model truly validates the abstracted model for the span over which the abstracted model has been applied (e.g., whether the simplified model is appropriate, including the treatment of coupled phenomena, over the full range of conditions for which the model is used).	Model validation is within the scope of Corrective Action Report BSC-01-C-001. Process and abstracted models will be validated. DOE understands that abstracted models must honor process models and that process models must be representative.
McNeish	J-O3.7 Example	DOE has issued a Corrective Action Request (CAR) BSC-01-C-001 on model validation. The condition described in the CAR is that the DOE requirements for model validation (AP-3.10Q) have not been consistently implemented, which places the validation status of the TSPA model in question. Reference: AP-3.10Q, Rev. 2, ICN 4. *Analyses and Models.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010405.0009.	Model validation and its impact on TSPA results is within the scope of Corrective Action Report BSC-01-C-001
McNeish	J-O3.7 Example	There are several instances where DOE has validated results by comparing with NRC calculations. While DOE may use NRC's published work in light of its technical merit, NRC's results do not necessarily reflect regulatory position. If DOE chooses to use NRC results to support their technical findings, it is the sole responsibility of the DOE to provide validation for such results.	DOE will not use NRC calculations as the sole line of evidence. Instead, NRC calculations will be used as corroborating evidence.
Swift	J-O3.8	Throughout Section 5 of the TSPA-SR Technical Document (CRWMS M&O 2000ar), the discussions on the method, data analyses, and model verification information appear to be mixed. Example: The general discussion on sensitivity and uncertainty analysis briefly touches on model sensitivity. But the section does not appear to have any treatment or analysis of model uncertainty. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC:	Section 5 (CRWMS M&O 2000ar) discusses uncertainty and sensitivity in model results, conditional on the distributions assigned to model inputs, rather than discussing uncertainty in those distributions, which may be the point of the comment. DOE will clarify Section 5 in the next revision of the document. Uncertainty in the model inputs for TSPA is captured in probability distributions. Discussion of the basis for these probability distributions is, in general, outside the scope of the TSPA technical report.

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		MOL.20001220.0045.	Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Swift	J-O3.9	Section 5 of the TSPA-SR Technical Document (CRWMS M&O 2000ar) gives an appearance that the section is more geared toward depicting the power of analysis the method(s) and has less emphasis on the analysis of results from sensitivity and uncertainty analysis. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify Section 5 (CRWMS M&O 2000ar) in the next revision of the document to emphasize results from sensitivity and uncertainty analyses. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Swift Mishra	J-O3.10	Sensitivity and uncertainty analysis emphasized only on one or two parameters, giving an appearance that only one or two parameters are important. It is not clear what quantitative cutoff value (e.g., R square loss etc.) was used to determine that not more than one or two parameters could be important. The influence of important parameters and models, identified through sensitivity and uncertainty analyses, on the performance assessment results should be described.	In Section 5 (CRWMS M&O 2000ar, F5-1 through F5-21), most of the uncertainty importance analyses included 3 or 4 important parameters, the only exception being Figure 5.1-19, which had 2 important parameters. The selection of these was based on an uncertainty importance factor cutoff of 0.10, which corresponds to an R-squared loss in the range between 0.07-0.09. Tables of uncertainty importance factors have been developed that show the clusters of unimportant parameters. These tables were not included for reasons of brevity in the current TSPA-SR report. DOE will include these tables in future revisions to better explain the uncertainty importance results. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Swift	J-O3.11	Section 5 of the TSPA-SR Technical Document (CRWMS M&O 2000ar, page 5-8) states, " In most cases, the sensitivity to individual parameters is examined by setting a parameter to its 5th and 95th percentile values. This choice keeps most of the range that is considered defensible. The 5th and 95th percentiles are used rather than the entire range (i.e., 0th and 100th percentiles) because in some cases there is a very long tail out to extremely unlikely parameter values. The 5th and 95th percentile values are at the level that they are unlikely, but not so unlikely as to be unreasonable." This does not explain why choice of 95th and 5th percentiles are more appropriate and reasonable than, say, 99.9th and 0.1th percentile. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The "one-off" sensitivity analyses are conducted to provide insight into model sensitivity to specific parameter values. They do not provide insight into the appropriate value of expected annual dose for regulatory decision making. The basis for the choice of the 5th and 95th percentiles is as stated, and there does not appear to be any need to choose alternative values for this type of analysis.
Swift	J-O3.12	Section 5 of the TSPA-SR Technical Document (CRWMS M&O 2000ar, page 5-9) states, "...uncertainty analyses based on dose rate as the metric necessarily deal only with those radionuclides that pass through the potential repository system. Those that are retained, for example the majority of the uranium, cannot influence these types of analyses. Thus, a case can be made that the relatively immobile waste form itself (comprised mostly of uranium) is the most important part of the system, rather than the waste package." Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will clarify Section 5 (CRWMS M&O 2000ar) in the next revision of the document. The discussion of important aspects of the overall system will be enhanced to incorporate this topic of the waste form, and it's own immobile characteristics, being an important aspect of the overall system performance. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Sevougian	J-O3.13T	Integration roadmap: While the object oriented approach of the Goldsim software provides connections among modules, it is still difficult to get a clear picture of how process models are working in an integrated fashion in the TSPA model. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	TSPA will continue to attempt to provide clearer descriptions of the modeling system. Appendix E describes the integration of the TSPA models, but will be clarified in the next revision of the document.
Itamura	J-O3.14T	Description of uncertainty: Uncertainty and variability does not appear to have been described adequately for all submodels. Although each TSPA sub-model has an associated description of uncertainty and variability, it is difficult to draw a clear picture of where uncertainty was considered or the rationale for not describing it. For example, description of uncertainty in thermal properties could not be found in any of the documents. The TSPA-SR Technical Document (CRWMS M&O 2000ar) only indicates, "information on thermal properties and processes has come from laboratory tests and from a series of *in situ* thermal tests in the ESF at Yucca Mountain (CRWMS M&O 2000cc, Section 3.6)". But any specific discussion of how uncertainty in thermal conductivity was handled in the TSPA, could not be found. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2000cc. *Near Field Environment Process Model Report.* TDR-NBS-MD-000001 REV 00, ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001005.0001.	The uncertainty in thermal conductivities was not considered in the TSPA- Site Recommendation thermohydrologic process level submodels. Only the mean thermal conductivities were used in the models that fed TSPA-Site Recommendation (CRWMS M&O 2000ar). Sensitivity studies are planned in the potential License Application time frame to investigate the sensitivity of thermohydrologic process model results to uncertainty of the thermal conductivities in the host units. To improve transparency and traceability, DOE will consider consolidating and providing additional detail regarding the treatment of uncertainty and variability in the next revision of the TSPA Technical Report. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Swift Sevougian	J-O3.15T	In the presentation TSPA-SR Technical Document (CRWMS M&O 2000ar), sometimes 1.E-6 and other times 1-E5 mrem/yr has been used as the smallest value for displaying dose as a function of time. In the sensitivity analysis, a value of 1.E-5 mrem/year is used as a cutoff below which the response is considered negligible. Has there been any analysis done to ensure that this cutoff value is not partly responsible for zero dose in various figures until much after 10,000 years? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Cut-off values on the y-axis of dose plots have been chosen for readability and clarity--scales of interest vary from plot to plot. DOE has verified in TSPA-Site Recommendation (CRWMS M&O 2000ar) that no nominal realizations showed waste package failure before 10,000 years. References: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Swift	J-O3.16T	The TSPA-SR Technical Document (CRWMS M&O 2000ar) specifies that it is difficult to quantify the bias introduced through the use of conservative assumptions. Since the developer knows what is conservative, he/she must, conversely, know what is non-conservative and therefore should be able to at least bound the bias. Page 4-3 of TSPA Rev. 0, TSPA results are biased toward higher dose but can't be quantified. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Bias introduced through the use of conservative assumptions has been addresses on a component-by-component basis in the Supplemental Science and Performance Analysis Volumes 1 and 2 (BSC 2001e, 2001f). Note, however, that the developer of inputs does not know, a priori, what the effect of bias will be on system-level performance because of coupled and nonlinear effects within the system model. References: BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062. BSC 2001f. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

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Mishra Swift	J-O3.17	Demonstrations of the convergence of the LHS methods as implemented in the TSPA should be more technically robust. Simple graphical demonstration of the increased "stability" of the expected annual dose versus time curve as more realizations are conducted should be bolstered by discussions of how the variance of the variance in the peak of the mean dose decreases as the number of realizations in increased.	DOE will use appropriate statistical approaches to investigating the stability of the mean in future revisions of the TSPA document. (Note that the approach suggested here, of examining changes in the variance in the peak of the mean with changing sample size, may not be the only approach considered.). TSPA-Site Recommendation Section 4.1.4 (CRWMS M&O 2000ar) shows the probability results for the mean, 5th and 95th percentiles. For 100, 300, and 500 realizations, the results appear to be stable. As an alternative approach consideration will be given to performing additional comparisons (e.g., T-tests) to demonstrate confidence in the limits. Additional calculations will be done as part of the next major update to TSPA-Site Recommendation to demonstrate stability of results. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Acceptance criterion 4: Comparison of alternative design features (Acceptance Criterion Withdrawn by NRC)			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Swift	J-O4.1	Two alternative designs are considered: Backfill and a low temperature operating mode -The minimal effect of backfill on dose for volcanism does not appear to completely capture the reduction in the number of waste packages contacted by magma -Basis for assumption for incorporating low temperature operating mode into TSPA are not adequately supported. -It is not apparent from the analysis of the low temperature mode how uncertainties in the thermal regime and thermal effects on performance are reduced.	The technical justification for the intrusive damage model was addressed at the Igneous Technical Exchange, June 2001. TSPA results appropriately capture effects consistent with that input. Low temperature operating mode uncertainties are being examined through Supplemental Science and Performance Analysis and will be addressed in more detail at the August 2001, Operating Range Technical Exchange.
Swift	J-O4.1	The Science and Engineering Report (DOE 2001) introduces DOE plans for additional low-temperature evaluations and DOE has indicated that the Supplemental Science and Performance Analyses (SSPA) (BSC 2001e, 2001f), with a planned release in summer 2000, will address and provide performance assessment results for different operating temperature modes. The NRC staff is aware of these DOE plans, but may have questions relating to the evaluation of major design features after reviewing these forthcoming documents. References: DOE 2001. *Yucca Mountain Science and Engineering Report.* DOE/RW-0539. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272. BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.	Withdrawn by the NRC.

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Acceptance criterion 4: Comparison of alternative design features (Acceptance Criterion Withdrawn by NRC)			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		BSC 2001f. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.	

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Acceptance criterion 1: Evaluation of an intrusion event demonstrates that the average annual dose to the average member of the critical group in any year during the compliance period is acceptable. The Total System Performance Assessment code provides a credible representation of the intrusion event.

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Freeze Swift	J-H2.1	Assumptions made in the analysis of the effects of human intrusion do not appear to be justified or appropriate based on draft Part 63. Specific Examples - Volume and chemistry of drilling fluids are ignored in analysis: Sufficient support is not provided for not considering the impact of these aspects of the human intrusion scenario analyses on the system. - Rate of infiltration is unaffected by presence of borehole: The technical basis for this assumption used for the human intrusion scenario analyses is not fully transparent and traceable. - Cladding in the penetrated WP is perforated due to the event, but not completely failed. The cladding still needs to be unzipped, which can take a very long time. The properties of the rubblized borehole (porosity, fluid saturation, and dispersivity) are represented by the matrix properties of a UZ fault.	The human intrusion analysis was formulated using the nominal case scenario. Unsaturated Zone and Engineered Barrier System components were replaced to produce a simplified representation of the human intrusion scenario as specified in the proposed !0 CFR Part 63 (64 FR 8640) and 40 CFR 197 (66 FR 32074). Human intrusion scenario inputs will be re-evaluated following promulgation of final Environmental Protection Agency, NRC, and DOE rules. References: 64 FR 8640. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada. Proposed rule 10 CFR Part 63. Readily available. 66 FR 32074. 40 CFR Part 197, Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV; Final Rule. Readily available.
Freeze Swift	J-H2.2	The results of the human intrusion analyses do not appear to be consistent with other models in the TSPA. *Examples* The peak expected dose resulting from human intrusion is shown to occur approximately 200 years after the single WP is breached by drilling. This result suggests that the travel time in the saturated zone is extraordinarily short. Elsewhere in the TSPA-SR Technical Document (CRWMS M&O 2000ar), it appears that the 3D SZ model	See above response to J-H2.1. For the specific example shown, this may be due to comparison of a mean peak dose form the TSPA HI calculation (Figure 4.4-11) to breakthrough curves calculated using median inputs to the 3D Saturated Zone model (Figure 3.8-18). Note that the mean HI dose is strongly dominated by the early breakthroughs. The TSPA median HI dose peaks after 10,000 years, consistent with retardation of Np and Pu. The probabilistic breakthrough curves

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Acceptance criterion 1: Evaluation of an intrusion event demonstrates that the average annual dose to the average member of the critical group in any year during the compliance period is acceptable. The Total System Performance Assessment code provides a credible representation of the intrusion event.

Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		predicts a median travel time for unretarded carbon-14 of about 600 years while for slightly retarded technetium-99, the median travel time is around 1000 to 1500 years. These finding seem inconsistent. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	shown in Figure 3.8-19 provides insight into the distribution of breakthrough curves that contribute to the distribution of dose curves. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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General TSPA Comments: Transparency and Traceability.			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Swift	J-TT1.1	Section 5 of the TSPA-SR Technical Document (CRWMS M&O 2000ar, page 5-19) states, "Figure 5.2-14 shows the mean dose rate from the base case compared to a case with no matrix diffusion in the UZ and also compared to a case where the UZ anion and cation matrix diffusion coefficients were set at 100 times the matrix diffusion coefficients in the base case. It should be noted that these parameter values are outside the range of base-case probability distributions, in contradistinction to most of the other analyses in Section 5.2. " Going outside the range appears to be inconsistent with the general philosophy of the 5th and 95th percentile values used in the sensitivity analysis. NRC would prefer that TSPA was more self-contained, i.e., more reference material contained within the document. Comment applies to all NRC transparency and traceability comments. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	For parameters/models whose base case model was either deterministic (because a conservative/bounding model was used or because the model was well-characterized with little or no uncertainty) or had a very narrow parameter range, a one-off sensitivity on the key stochastic parameters was performed. If an alternative model was available for such cases, it was insightful to substitute an alternative model sensitivity analysis for the one-off 5th/95th analysis. DOE plans to continue to use this approach going forward to License Application. DOE will consider adding clarifying words in the introduction to Section 5.0 (CRWMS M&O 2000ar) Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045..
Swift	J-TT1.2	Traceability of input parameters Input parameters for the DOE TSPA model is not easily traceable. Although Table E-1 of the TSPA-SR Technical Document (CRWMS M&O 2000ar) provides a general listing of inputs to the TSPA-SR model, for the parameter values (i.e., parameter range and distribution functions), the reader is pointed to AMRs, PMRs or similar other documents, or to a data tracking number. To obtain a complete picture of the parameters used in the TSPA, the reader has to refer to all AMRs, which makes the task of reviewing all parameters used in the TSPA difficult.	DOE will work to improve traceability and transparency for the potential License Application.

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General TSPA Comments: Transparency and Traceability.			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
		Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	
Sevougian	J-TT1.3	Page 4-8, last paragraph and Figure 4.1-11: It is not readily apparent why one would expect the "periodic structure" of WP failures to be preserved in an average WF release curve, unless WP failures occur at the same time(s) for all realizations. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The "structure" is a result of the numerical discretization of the temperature and relatively humidity curves at late times.
Swift Wilson	J-TT1.4	Page 4-24, first paragraph: The logic in the following sentence is difficult to follow. "Because it is assumed that the nominal models can be used in simulating the igneous disruption scenario, the annual dose for an igneous disruption, including all nominal processes, is approximated by D_n+D_i." Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Dn and Di in this section are used to denote the conditional dose, rather than the probability-weighted dose. This equation simply acknowledges that, if an igneous event occurs, a person may receive doses from both the igneous-related processes and also the nominal processes that have occurred prior to the event and will continue to occur after the event. As stated in the following the probability-weighted dose for the igneous scenario is therefore p (Dn+Di). The probability weighted dose for the nominal scenario is (1-p)(Dn), and the total probability-weighted dose, which is the expected annual dose the NRC requires, is the sum of these two terms, which can be rearranged to yield Dt = Dn + pDi. The approximation is based on the assumption that nominal release and transport processes are unaffected by the igneous event. If the nominal models are altered by the igneous event, then the conditional igneous dose should more rigorously be given by Dn (modified) + Di. Because Di is >>> Dn (without probability

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			weighting) and is assumed to also be much greater than the unquantified Dn(modified), changes in Dn due to igneous activity can be neglected without significant change to Dt.
Wilson	J-TT1.5	Page 5-10, Second paragraph (CRWMS M&O 2000ar): Part of the explanation for the one-off analyses producing a greater difference between base case infiltration and low infiltration than between base case infiltration and high infiltration is that low infiltration has a lower probability. Generally speaking, one would not expect probabilities to be included in a one-off analysis; however, further reading (CRWMS M&O 2000ar, Table 3.2-2 on Page 3-29) indicates that the so-called probabilities that are assigned to each entry in the infiltration vs. climate table are integral to the model. In the last sentence of this paragraph the statement that the low probability effect in the low infiltration one-off analysis results from the "low case [being] sampled less often than the others" implies that the base and high cases are also sampled in the low infiltration one-off analyses. The overall presentation is confusing. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The base-case curve includes contributions from the low, medium, and high cases, according to their probabilities. Because the low case has a low probability, the base-case curve includes only a small contribution from that case. Thus, the base-case curve can be very different from the low-infiltration curve.
Wilson Sevougian	J-TT1.6	Page 5-12, first paragraph (CRWMS M&O 2000ar) It is not readily apparent why the use of a deterministic as opposed to a stochastic approach for the EBS environment explains the one-off analyses for the EBS parameters not being "very enlightening." Is it the structure of the model that precludes one-off analyses or is it that the computer code prevents the parameters from being modified? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC:	There are very few parameters in the engineered barrier system environments that are stochastic and those that are stochastic have little effect on dose. Therefore, there were no "enlightening" or meaningful one-off 5th/95th analyses that could be done for the engineered barrier system environments submodel. Since most of the models are deterministic, it was not possible to carry out 5th/95th percentile analyses as was done with other submodels. However, the text does point the reader to some alternative engineered barrier system environment model studies carried out

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		MOL.20001220.0045.	for the robustness analyses of Section 5.3 (CRWMS M&O 2000ar). Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Swift Arnold	J-TT1.7	Page 5-21 (CRWMS M&O 2000ar). The finding that dose is relatively insensitive to the range of water usage volume seems to contradict the plot shown in Figure 5.1-11 for uncertainty-importance analysis. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	As shown in Figure 5.1-11 (CRWMS M&O 2000ar), water usage has an uncertainty importance factor of approximately 0.01 at 100,000 years. This is consistent with the conclusion stated on page 5-21, based on the interpretation of Figure 5.2-16, that dose is relatively insensitive to uncertainty in water usage volume. Although not stated in the text on page 5-21 or in the caption to Figure 5.2-16, the conclusion of relative insensitivity was intended to apply to the first 100,000 years, consistent with the analyses shown in Figure 5.2-16. Figure 5.1-11 shows that the relative importance of water usage rises somewhat after 100,000 years, but it remains a minor contributor, compared to the Alloy 22 general corrosion rate, until quite late in the simulation (900,000 years and beyond). As shown in Figure 5.1-11, relative importance of different components of the system change through time. In particular, importance of parameters affecting radionuclide concentrations in the natural barrier system (groundwater flux) and the biosphere (water usage) tends to increase as engineered barriers degrade. The relevant figures and text are correct in TSPA-Site Recommendation (CRWMS M&O 2000ar) (except for an editorial error in the last paragraph in Section 5.2.8.2, page 5-21, where "BDCFs" should be "water usage volume"). The conclusions in Section 5.2 are based on interpretation of analyses for 100,000 years only (or 20,000 years for igneous groundwater release cases).

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
			The million-year analyses are discussed in Section 5.1. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Wilson Sevougian	J-TT1.8	TSPA-SR Technical Document Figures 3.3-3 and 4.1-16 (CRWMS M&O 2000ar) The area covered by the infiltration bins do not appear to cover the entire repository waste emplacement area, It is not clear what infiltration rate is used for the areas not covered by the infiltration bins Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The waste-emplacement area does not cover the whole area inside the perimeter drift. The infiltration bins include the entire loaded area, as modeled.

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General TSPA Comments: Transparency and Traceability.			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Mishra Swift	General Issue #OPO-1	Stability of analyses and calculations has not been demonstrated There are many areas in the performance assessment where stochastic (Monte Carlo) calculations are performed. When performing Monte Carlo calculations it is important to verify that stability of the output has been attained. Stability verification applies to the final output (peak mean dose), sensitivity calculations, and process-level analyses where stochastic simulations are performed. Figure F4-23 was provided to address this issue. However, upon examining the data used to construct the figure the dose at 100,000 years is increasing almost linearly with increasing realizations. Other areas are identified below with possible stability problems. Examples/Comments: Unless otherwise noted, examples are from the following two references: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003. CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE will provide better justification of the stability of the expected annual dose and supporting analyses. Note that the figure referenced in the NRC comment is Figure 4.1-22 on page F4-23 of the TSPA-Site Recommendation (CRWMS M&O 2000ar). See also previous response to NRC Comment J-O3.17. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Sevougian	OPO-1 Example	Model - Page 58, Mountain-scale UZ, Item #3, Has a stability check been done related to this item? Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	The stability check has been performed and will be documented in the TSPA-License Application Model Report.

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General TSPA Comments: Transparency and Traceability.			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Sevougian Mishra	OPO-1 Example	Model - Page 109, Only 100 realizations worth of uncertain SZ results are produced and then replicated for simulations with more realizations. Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Multiple replicates of 100 realizations may not get carried forward because of lack of sensitivity of infiltration in the saturated zone. For future TSPA runs, the use of 300 realizations of the Saturated Zone model results is planned, even though the sensitivity of the overall model results to Saturated Zone parameters is relatively minor.
Sevougian	OPO-1 Example	Model - Page 516, Are human intrusion calculations stable with respect to realizations and time-stepping? Reference: CRWMS M&O 2000aq. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.	Human intrusion calculations for 300 realizations have been conducted. The calculations result in lower peak dose during the 10,000-year time frame. Both 300 and 100 realizations are well below the regulatory limit. The supporting basis the number of realizations will be documented in the TSPA-License Application Technical Report and the time-stepping in the TSPA-License Application Model Report.
Mon	OPO-1 Example	Page 3-89, The insensitivity of results to the number of drip-shield patches does not necessarily mean that a larger number of waste package patches will be sufficient. If the waste package functions differently it may still have significant stability problems at 1000 patches. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Analyses shown in the Waste Package Degradation Model (CRWMS M&O 2000az, Section 6.4.3) serve as sufficient evidence of the appropriateness of the number of drip shield patches, waste package patches, and number of drip shield waste package pairs selected for the analyses. Analogous analyses have been completed in analogous Analysis/Model Reports for other stochastic simulation models used within the TSPA. Reference: CRWMS M&O 2000az. *WAPDEG Analysis of Waste Package and Drip Shield Degradation.* ANL-EBS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001208.0063.

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General TSPA Comments: Transparency and Traceability.			
Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Sevougian	OPO-1 Example	Page 3-93, Where is the information provided regarding the stability of the results as a function of the size of the time-steps used in the PA? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Stability results will be documented in the TSPA-License Application Model Report.
Mishra	OPO-1 Example	Page 5-2, Was a test done for the stability of the regression analysis results to verify these important calculations aren't numerical aberrations? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	The statistical significance of regression coefficients was determined using the F-test.
Mishra Swift	OPO-1 Example	Page 5-9, It is likely the sensitivity results are unstable with only 100 realizations completed. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	DOE recognizes that sensitivity analyses that are used to support regulatory compliance (e.g., those that are used for multiple barrier analyses) will need to be done with sufficient sample size to be stable. In TSPA-SR Section 5.1, the calculations were performed with 300 realizations which seems to produce stable results. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.
Kicker	OPO-1 Example	Page 3-47, What are the biggest blocks and the stability or confidence in the Monte Carlo simulations of the biggest block size? Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC:	The verification that stability of the rockfall model output has been attained is provided in the Drift Degradation Analysis (CRWMS M&O 2000cd, Attachment IV). Additional sensitivity calculations for the rockfall model have been conducted as documented in the Supplemental Science and Performance Analysis Vol. 1 (BSC

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		MOL.20001220.0045.	2001e, Section 6.3.4), including a more detailed assessment of the stability of the output from the Monte Carlo simulations in the rockfall model. These supplemental analyses provided block size distributions for a range of Monte Carlo simulations up to 800, demonstrating that the rockfall model is stable at 400 simulations (i.e., the model produces a consistent maximum block and a consistent frequency of blocks). The largest blocks simulated in the rockfall model include 14.0 cubic meters in the Tptpmn unit, 1.3 cubic meters in the Tptpll unit, and 57.3 cubic meters in the Tptpln unit (Drift Degradation Analysis, Tables 23, 24, and 25). References: CRWMS M&O 2000cd. *Drift Degradation Analysis.* ANL-EBS-MD-000027 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001206.0006. BSC 2001e. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.
Sevougian	OPO-1 Example	Page F4-23, Even the mean base case results continue to increase with increasing number of realizations, with a 50% increase in the peak dose when increasing from 100 to 500 realizations at 100,000 years. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Page F4-23, Instability in mean base case results with increasing sample size: DOE acknowledge that the mean increases somewhat from 100 to 500 realizations. It increases from 62 to 72 or about 15%, not 50%. For any potential License Application DOE will conduct several replicate runs (with different random seeds) to show stability of the mean Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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Resp. Org.	Identifier	NRC Comment	DOE Proposed Response
Sevougian	OPO-1 Example	Page F4-33, 10,000 year igneous results seem to increase significantly with increasing number of realizations per simulation year. Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.	Note that the appropriate test is not whether or not the mean shifts from one sample size to the next, but rather whether or not the mean is stable at the largest sample size shown. Thus, the change from 1000 to 5000 is not unexpected. DOE intends to show that the mean is stable at 5000. For any potential License Application, several replicates will be conducted to show that the mean is stable Reference: CRWMS M&O 2000ar. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

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BSC 2001g. *In-Package Chemistry for Waste Forms.* ANL-EBS-MD-000056 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010322.0490.

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BSC 2001i. *Inventory Abstraction.* ANL-WIS-MD-000006 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010416.0088.

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