RAI: Volume 3, Chapter 2.2.1.3.1, Second Set, Number 11:

Provide additional information to demonstrate the significance of salt separation effects on the timing and magnitude of radionuclide release from the proposed repository system.

Basis: The salt separation aspects of localized corrosion initiation were not implemented in Revision 1 of the SAR (Sections 2.3.5.5 and 2.3.6.4.4). Therefore, DOE has not adequately described the relative significance of salt separation on the timing and magnitude of radiological release from the proposed repository system. This requested information is needed to assess the effects of salt separation on localized corrosion rates used in the performance assessment for the demonstration of compliance with 10 CFR 63.114(f).

1. RESPONSE

The estimates of repository performance presented in Revision 1 of the SAR do not include the results of the salt separation aspects of localized corrosion initiation. In fact, Revision 1 of the SAR (Table 2.2-8 and Sections 2.2.1.4.1.3.2.2, 2.3.5.3.3.3, 2.3.5.5, 2.3.5.5.1, 2.3.5.5.4.2.1, 2.3.5.5.4.3, 2.3.6.4.4.1, 2.4.2.3.1.4, and 2.4.2.3.2.1.5) includes text indicating that "Note, the salt separation aspects of localized corrosion initiation were not implemented." An analysis of the salt separation aspects of localized corrosion initiation has been performed and is included in updated Appendix O of *Total System Performance Assessment Model / Analysis for the License Application* (SNL 2008, Appendix O of ERD 05). DOE anticipates that the results will be included in a future SAR revision. The updated results that include salt separation and show the significance of that process to the TSPA results are provided in this response.

1.1 IMPLEMENTATION OF SALT SEPARATION

Salt separation and the subsequent formation of a "chloride-rich brine" on a waste package results from a specific sequence of conditions. The initial condition for salt separation is that seepage must come into contact with the waste package. The other necessary condition for salt separation to occur is that the relative humidity drops below a salt precipitation (i.e., halite or sylvite) threshold while seepage is occurring, and then rises back above this threshold. Once the relative humidity rises back above the threshold value, a chloride-rich brine is assumed to form and persist because as the salt dissolves back into the new seepage it maintains the chloride concentration at an elevated (nearly saturated) condition until all the salt has dissolved. The resulting increase in chloride is assumed to initiate localized corrosion of the waste package outer barrier wherever this precipitation and subsequent dissolution occurs.

Localized corrosion initiation as a result of salt separation has now been implemented in the localized corrosion initiation submodel, and the localized corrosion initiation uncertainty analysis has been updated as described in Appendix O of *Total System Performance Assessment Model / Analysis for the License Application* (SNL 2008, Appendix O of ERD 05). Briefly described, localized corrosion can be initiated by either salt separation and/or adverse electrochemical corrosion potential conditions. In the updated analysis, the conditions at each of the 3,264 thermal-hydrologic repository nodes are evaluated at each time step following drip shield failure. If conditions at a node allow either salt separation and/or an initiating electrochemical "corrosion potential" ($\Delta E = E_{critical} - E_{corr} \leq 0$) to occur at any time after drip shield failure, then localized corrosion at that node is assumed to initiate at the time of drip shield failure. The output of the localized corrosion initiation uncertainty analysis is the fraction of waste packages that have localized corrosion initiation (by either salt separation or by corrosion potential) as a function of drip shield failure time.

1.2 RESULTS OF LOCALIZED CORROSION INITIATION UNCERTAINTY ANALYSIS

The main results of the localized corrosion initiation uncertainty analysis are shown in Figure 1. The results show the mean fraction of repository locations with the potential for localized corrosion initiation (either by salt separation or corrosion potential) as a function of the drip shield failure time. Note that there are two differences between these results and the results from the original analyses shown in Figure 2. The original analysis did not include salt separation. In addition, the original analysis only showed the instantaneous fraction of nodes where localized corrosion would initiate, whereas the updated results show the final fraction of nodes that would initiate, either immediately or in the future after the drip shield failure time.

In Figure 1, the effects of salt separation and corrosion potential are combined. The maximum of the mean fraction of nodes with potential for localized corrosion initiation is about 0.34. In contrast, Figure 2 shows the fraction of locations with potential for localized corrosion due only to electrochemical corrosion potential conditions. Because the maximum mean fraction of locations shown on Figure 2 is about 0.1, the mean fraction of locations with potential for localized corrosion due only to salt separation is roughly 0.24. The increase in the total number of nodes at which localized corrosion could initiate from 10% to 34% is due to inclusion of the salt separation process. However, salt separation only contributes to the potential for localized corrosion initiation for about 1,000 years. Beyond 1,000 years, the relative humidity at the waste packages rises above the precipitation threshold, thus precluding future salt separation on the waste package surface. Consequently, after 1,000 years, Figure 1 and Figure 2 are quantitatively similar and show only the effect of the electrochemical corrosion potential because salt separation can no longer occur. The numbers in the two figures are slightly different, again, because Figure 2 shows only instantaneous values whereas Figure 1 also includes waste packages on which localized corrosion initiates at some time after drip shield failure.

As indicated by Figure 1, the conditions for any type of localized corrosion initiation do not occur beyond 12,000 years. If the drip shield remains intact for 12,000 years, localized corrosion of the waste package will not occur.

1.3 EFFECT OF INCLUDING SALT SEPARATION ON TSPA MODELING CASES

The effect of including salt separation in the localized corrosion initiation uncertainty analysis on the expected annual dose in each modeling case is summarized below.

For the nominal modeling case, drip shields degrade and fail only due to general corrosion of the drip shield materials. In this modeling case, the first drip shield failure occurs at about 230,000 years. As this is well past the initial 12,000-year period when localized corrosion could initiate, inclusion of salt separation in the localized corrosion initiation uncertainty analysis has no effect on this modeling case.

The two early failure modeling cases are not affected by the updated localized corrosion initiation uncertainty analysis. In the early failure waste package modeling case, the compromised waste packages are already assumed to be completely failed. In the early failure drip shield modeling case, the waste package under the early failed drip shield is conservatively assumed to be completely failed if any seepage is present at that location. The mechanism for this damage is assumed to be localized corrosion, regardless of whether or not conditions for localized corrosion initiation (due to salt separation or corrosion potential) are favorable at the waste package location. Thus, neither early failure modeling case is affected by inclusion of salt separation.

In the igneous intrusion modeling case, drip shield performance is the same as in the nominal modeling case until the time of an igneous event. Thus, inclusion of salt separation has no effect on the annual dose before the time of the igneous event. When an igneous event occurs, all of the drip shields and waste packages within the repository are conservatively considered to be damaged to the extent that they are assumed to no longer perform any water diversion function. Since the benefit provided by the waste package is essentially removed from the modeling case upon the occurrence of the igneous event, there can be no further consequence from any additional waste package degradation, and therefore inclusion of salt separation in the localized corrosion initiation uncertainty analysis does not affect this modeling case. In the volcanic eruption modeling case, the erupted waste packages are conservatively assumed to have remained intact (and thus contain all of the potential radionuclides that could leak) from the time of repository closure, and thus the results of this modeling case are not affected by the inclusion of salt separation in the localized corrosion initiation uncertainty analysis.

The effects of including salt separation on the results of the seismic ground motion modeling case are discussed separately for the 10,000-year and 1,000,000-year periods. For the first 10,000 years post-closure, the frequency of seismic events that result in drip shield failure is estimated to be less than 3.4×10^{-8} per year. However, if drip shield plate failure should occur, the waste packages could be subject to localized corrosion. Thus, inclusion of salt separation in the localized corrosion initiation uncertainty analysis could affect the timing and magnitude of radiological release from the proposed repository system. The potential contribution to expected annual dose to the reasonably maximally exposed individual (RMEI) from the combination of drip shield failure and localized corrosion of the waste package was presented in Section 7.3.2.6.1.3.2 of *Total System Performance Assessment Model /Analysis for the License Application* (SNL 2008). This estimate has been updated in ERD 05 of that report (SNL 2008) to account for the effects of salt separation.

Figures 3 and 4 show the 10,000-year distribution of expected annual dose from seismic ground motion events that result in drip shield plate failure, and compare the original results (without salt separation) to the updated results (with salt separation). The effect of including salt separation can be observed in several aspects: the earlier rise time of the expected annual dose (mean appearing just before 500 years instead of just after); a greater maximum in the mean annual dose by about a factor of three; and a narrower distribution of results due to increases in the lower range of the distribution.

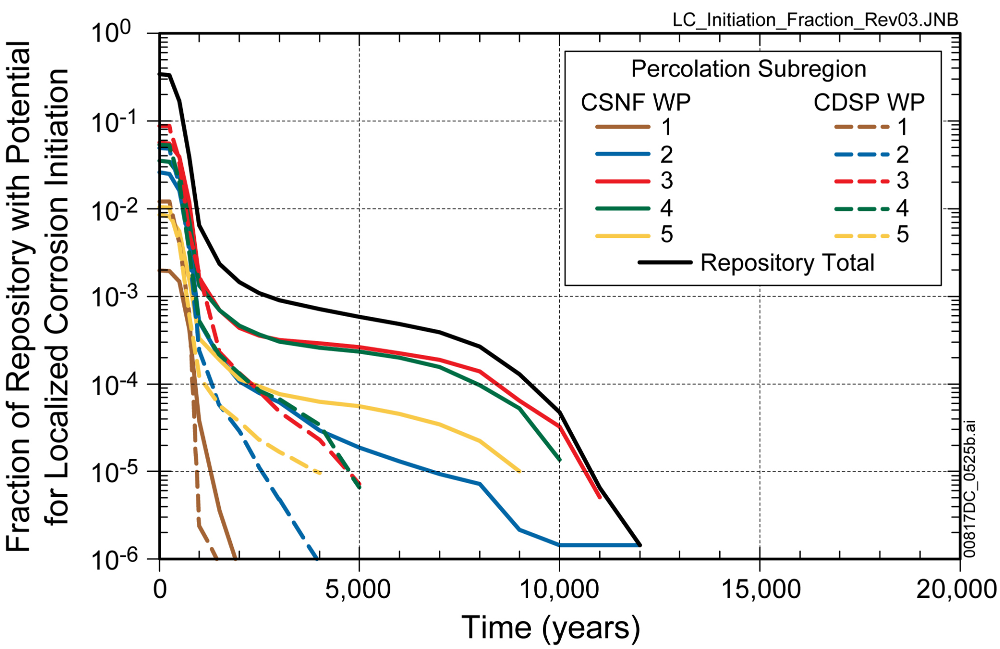
To determine whether the contribution to expected annual dose from the combination of drip shield failure and localized corrosion of the waste package is significant, the mean annual dose from Figure 3 is compared to the mean annual dose from the seismic ground motion modeling case for 10,000 years post-closure (SAR Figure 2.4-25a, reproduced here as Figure 5). The distribution of expected annual dose shown in Figure 5 results from considering only the annual dose resulting from seismically induced damage (i.e., stress-corrosion cracking) of co-disposal waste packages. The comparison between Figure 3 and Figure 5 shows that the mean annual dose considering drip shield failure and localized corrosion is substantially less than the mean annual dose calculated in the seismic ground motion modeling case, except just before 1,000 years post-closure. From about 800 to 1,000 years post-closure, the initial peak of the mean annual dose from the combination of drip shield failure and localized corrosion of the waste package rises to about 3×10^{-3} mrem, and is somewhat greater than the mean annual dose in the seismic ground motion modeling case. However, after 1,000 years post-closure the mean annual dose in the seismic ground motion modeling case significantly exceeds the mean annual dose from the combination of drip shield failure and localized corrosion of the waste package. Most importantly, the mean annual dose considering drip shield failures is less than 5×10^{-3} mrem during 10,000 years, which is not numerically significant compared to the maximum mean annual dose in the seismic ground motion modeling case for 10,000 years (about 0.2 mrem). Thus, inclusion of salt separation in the localized corrosion initiation uncertainty analysis has a negligible effect on the results of the seismic ground motion modeling case for 10,000 years post-closure.

The results shown in Figure 3 are also applicable when considering the potential effect of localized corrosion on the seismic ground motion modeling case for 1,000,000 years. The same qualitative conclusion is reached here as in the 10,000-year period (compare Figure 3 with SAR Figure 2.4-25b), in that the contribution to the mean annual dose from the combination of drip shield failure and localized corrosion is not significant during the first 10,000 years post-closure. The fully probabilistic seismic ground motion modeling case for 1,000,000 years considers the combined effects of general corrosion of drip shield materials and of seismic events (e.g., drift degradation) to determine the time of drip shield failure. The results of this modeling case show that no drip shield failures are estimated to occur before 12,000 years (SNL 2008, p. 8-66[a] and Figure 8.3-7[a]), and consequently inclusion of salt separation has no effect on the mean annual dose for this modeling case.

In the seismic fault displacement modeling case, accounting for localized corrosion of the waste packages would not significantly alter the radionuclide releases. When the fault displacement occurs, the drip shields at the affected waste packages are presumed to be failed. The waste package damage area opening is sampled uniformly from zero up to the waste package cross-sectional area. However, for opening areas greater than one-third of the cross-sectional area, radionuclide releases cease to change significantly as more damage area is applied. Since the dose result is insensitive to the damage area when more than one-third of the lid area is damaged, enlargement of the damage area by localized corrosion is not expected to affect the expected annual dose for this modeling case. Consequently, inclusion of salt separation has no effect on the mean annual dose for this modeling case.

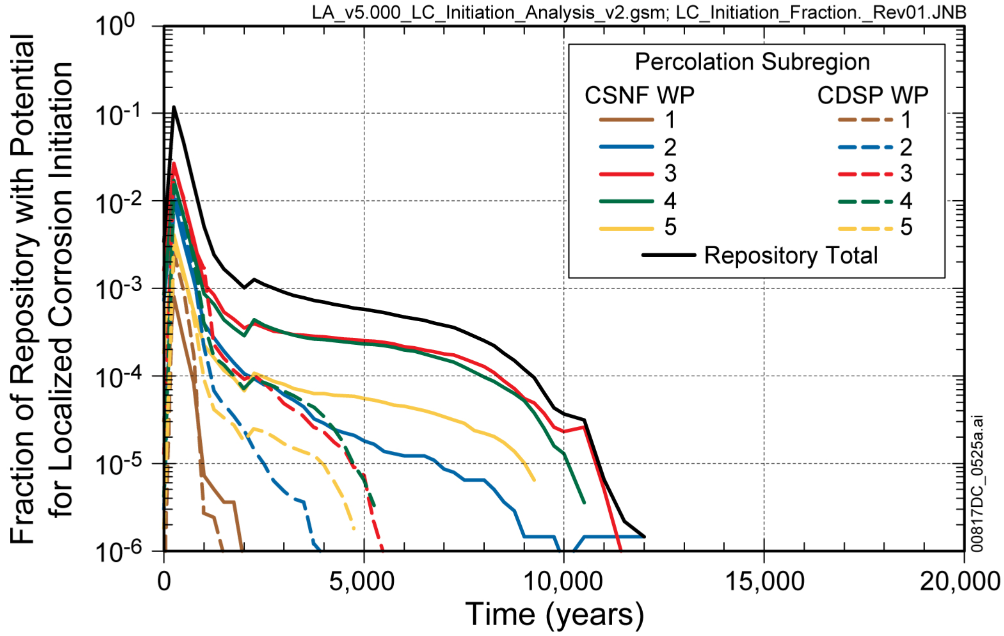
1.4 CONCLUSION

Without the drip shields in place, the localized corrosion initiation model shows that localized corrosion could potentially impact a mean of 34% of the waste packages within the first 1,000 years after closure, with salt separation accounting for roughly two-thirds of the potential for localized corrosion initiation. After 1,000 years, localized corrosion is unlikely and if initiated, a few waste packages could potentially be affected; by 12,000 years post-closure, no waste packages could be affected. Analyses considering each modeling case with drip shield failures in 10,000 years demonstrate that seepage-related localized corrosion is either accounted for (e.g., early failure drip shield modeling case) or that its inclusion would make little contribution to mean annual dose (e.g., seismic ground motion modeling case) due primarily to the low probability of drip shield failure. These analyses demonstrate that inclusion of salt separation in the localized corrosion initiation uncertainty analysis has no significant effect upon either the timing or magnitude of radionuclide release from the repository system described in Revision 1 of the SAR.



NOTE: WP = waste package.

Figure 1. Mean Fraction of Locations in Each Percolation Subregion That Will Experience Localized Corrosion Initiation after the Drip Shield Fails as a Function of Drip Shield Failure Time (SNL 2008, Figure O-2 of ERD05)



NOTE: WP = waste package.

Figure 2. Mean Fraction of Locations in Each Percolation Subregion Where Conditions Initiate Localized Corrosion (Due to Corrosion Potential Only) as a Function of Drip Shield Failure Time (SNL 2008, Figure O-2)

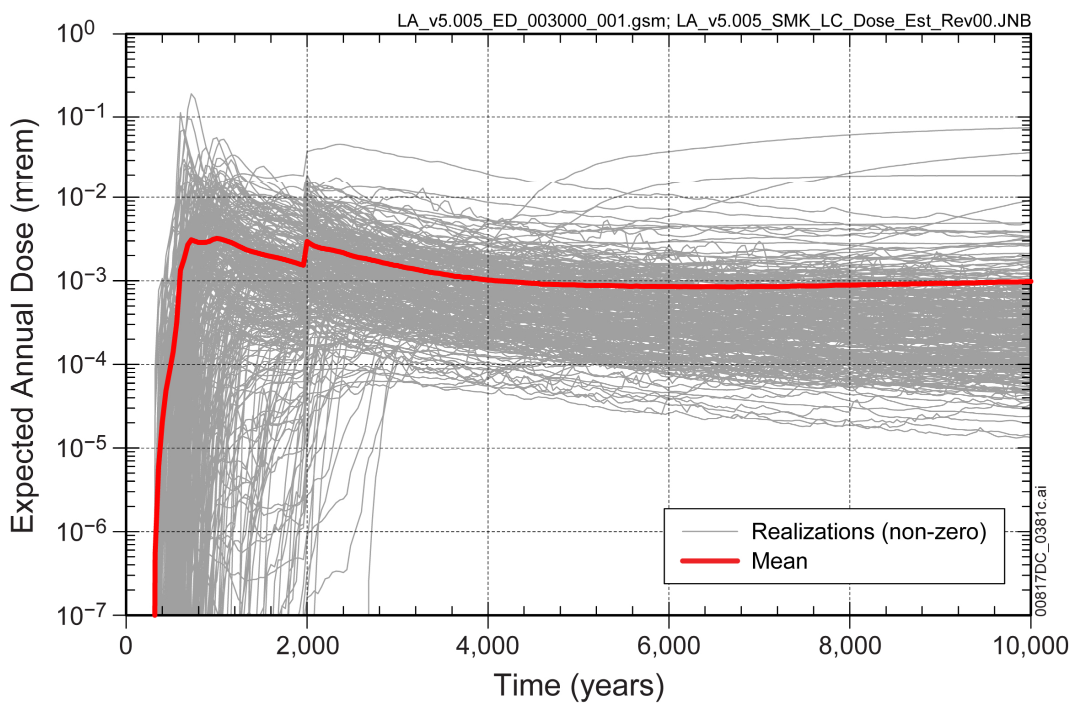


Figure 3. Expected Annual Dose over 10,000 Years from Seismic Ground Motion Events That Result in Drip Shield Plate Failure Including Salt Separation (SNL 2008, Attachment 2 of ERD 05)

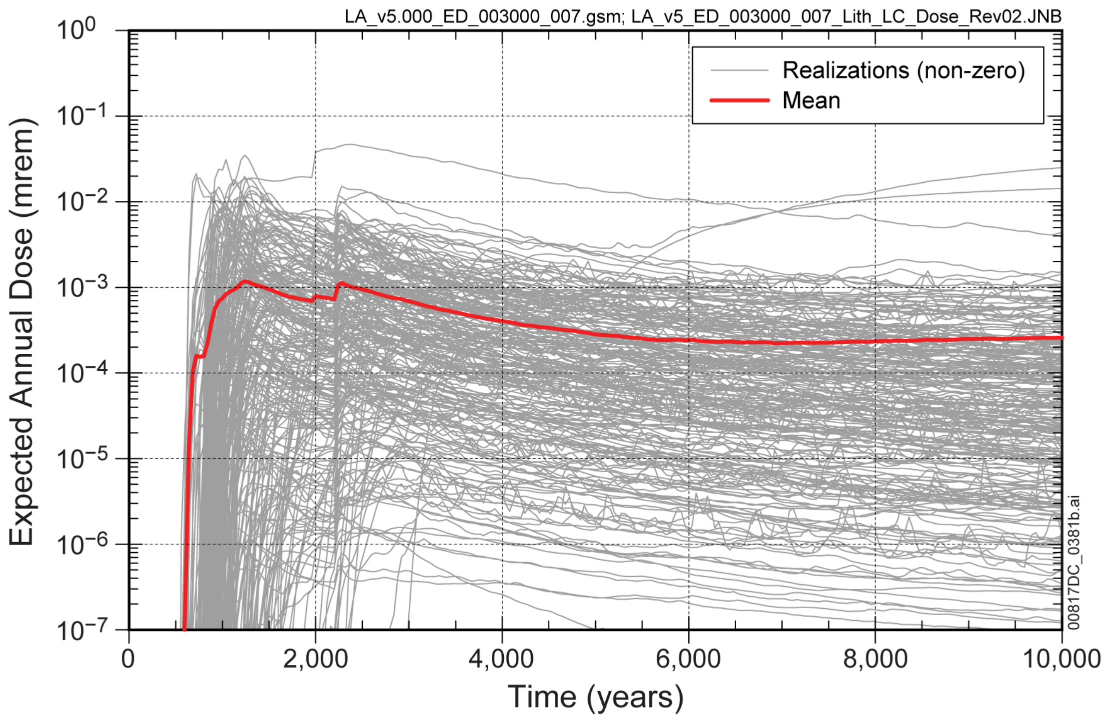


Figure 4. Expected Annual Dose over 10,000 Years from Seismic Ground Motion Events That Result in Drip Shield Plate Failure without Inclusion of Salt Separation (SNL 2008, Figure 7.3.2-17)

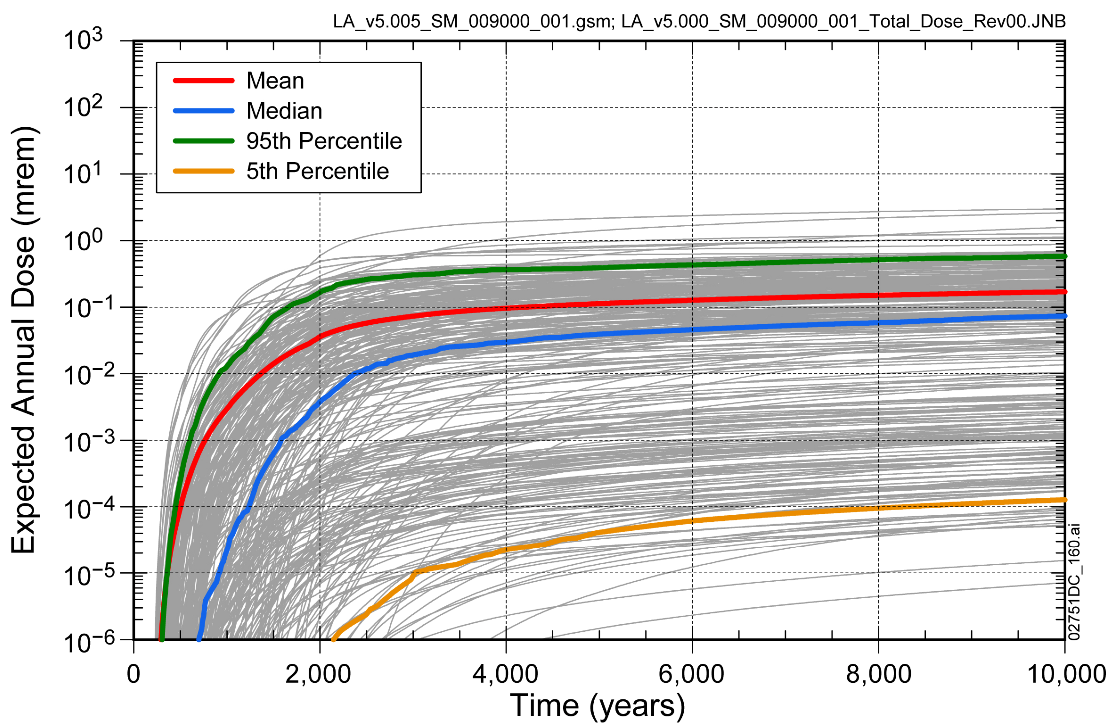


Figure 5. Distribution of Expected Annual Dose for the Seismic Ground Motion Modeling Case for 10,000 Years after Repository Closure (SNL 2008, Figure 8.2-11[a])

2. COMMITMENTS TO NRC

DOE commits to update the LA as described in Section 3 below. The change to be made to the LA will be included in a future LA update.

3. DESCRIPTION OF PROPOSED LA CHANGE

The notes that were added to Revision 1 of the SAR indicating that the salt separation aspects of localized corrosion initiation were not implemented will be removed in a future LA update.

4. REFERENCES

SNL 2008. *Total System Performance Assessment Model /Analysis for the License Application*. MDL-WIS-PA-000005 REV 00 AD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080312.0001; LLR.20080414.0037; LLR.20080507.0002; LLR.20080522.0113; DOC.20080724.0005; DOC.20090106.0001[a].

NOTE: [a] Provided as an enclosure to letter from Williams to Sulima dated 02/17/2009. "Yucca Mountain – Request for Additional Information Re: License Application (Safety Analysis Report Section 2.1), Safety Evaluation Report Volume 3 – Postclosure Chapters 2.2.1.1 and 2.2.1.3.7 – Submittal of Department of Energy Reference Citations."