Significance of Hypothetical Sensitivity Evaluation Results

Introduction

NRC has questioned the EPRI team sources used for the W.S. Lee site. The NRC has suggested that the results of a sensitivity evaluation that varies the contribution of the Dames & Moore team should be considered in a way that could increase the seismic hazard curves at that site. For example, Figure 1 shows mean 10^{-4} UHRS, 10^{-5} UHRS, and GMRS for the Lee site under two assumptions. (1) The "Original" spectra are those calculated using the assumptions in the original EPRI (1989) study (Ref. 1), with updated ground motion models (Ref. 2 and 3) and with an updated Charleston seismic source. This analysis includes the original assumptions of the Dames & Moore team. (2) The "Modified" spectra are those calculated as a sensitivity evaluation using the same assumptions as in the "Original" spectra but hypothetically excluding the Dames & Moore team from the calculation and using only the remaining five teams to calculate mean spectra (Ref. 9). Under these hypothetical circumstances, there is about a 9% increase in the GMRS at 100 Hz, with smaller increases at lower spectral frequencies, for the GMRS with the sensitivity evaluation applied as compared to the original GMRS.

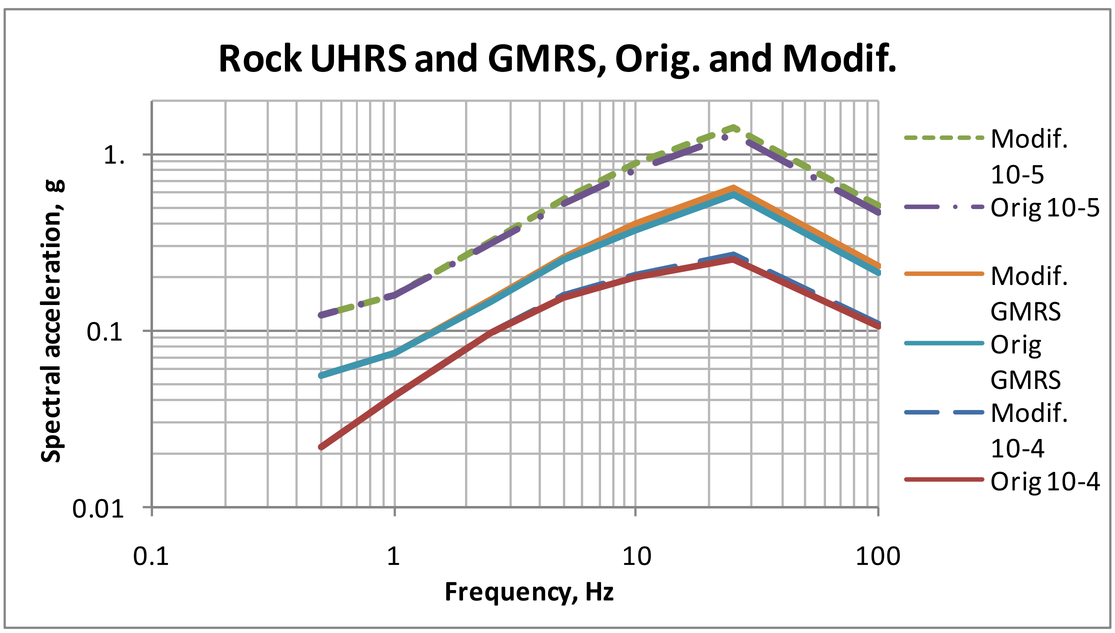

Figure 1: Mean 10^{-4} UHRS, 10^{-5} UHRS, and GMRS for Sensitivity Evaluation of Original And Modified Calculations Of Hazard At The Lee Site.

No definition or regulatory framework exists for characterizing the results of the hypothetical sensitivity study as "significant" or "not significant." It is therefore informative to determine the prospective change in seismic core damage frequency (SCDF) under the assumptions that (a) a generic plant is designed at the Lee site to the Original GMRS, and (b) the Sensitivity hazard calculation is assumed to be the correct definition of hazard. Guidance now in use for current plants could then be used to quantify the significance of such a difference.

<u>Calculation of seismic core damage frequency</u>

The annual seismic core damage frequency SCDF can be calculated as follows:

$$SCDF = \int H(a)\,[dP_{S|a}/da]\;da \qquad (1)$$

where $P_{S|a}$ is the probability of seismic core damage given ground motion amplitude a, $H(a)$ is the hazard (annual frequency of exceedence) at spectral acceleration a, and the integral over a goes from 0 to $+\infty$. This is the same equation derived in Ref. 6 and 7 for individual components, and this equation can be applied to generic plant-level seismic response. In Eqn. (1), $P_{S|a}$ represents a generic plant seismic fragility assuming a lognormal distribution with the following characteristics:

$HCLPF = F_S \times GMRS$, where $F_S = 1.67$

logarithmic uncertainty $\beta = 0.35$

The HCLPF (high-confidence of a low-probability of failure) point on the fragility curve is the value of the logarithmic distribution corresponding to a 1% probability of seismic core damage. The factor of safety F_S of 1.67 comes from the required seismic margin (as a multiplier of the design motion) that must be achieved in seismic design through the use of code factors on loads and stresses (see for example Ref. 4). The β value of 0.35 represents a typical β value that is characteristic of nuclear plant seismic response. For example, Ref. 5 uses β values of 0.3, 0.35, 0.4, and 0.45 to characterize plant-level seismic core damage fragilities. β values of 0.4 and 0.45 result in a slightly lower calculated SCDF, and a β value of 0.3 results in a slightly higher calculated SCDF. The changes in SCDF are not significantly affected by the choice of β or F_S value, as will be demonstrated below. Eqn. (1) is applied using seismic hazard curves at individual spectral frequencies, to span the range of frequency response of structures, systems, and components in a nuclear plant.

To achieve the goal of this evaluation, two applications of Eqn. (1) are made, one with the Original hazard curve (for each spectral frequency), and a second with the Sensitivity hazard curve (for each spectral frequency). This allows the SCDF values for the two analyses to be compared. A table will summarize the results of this calculation. For each spectral frequency the GMRS is listed (taken from the original hazard calculation), and the SCDF will be shown for the "Original" and "Sensitivity" hazard calculation, both using the same GMRS (which is taken from the Original hazard curve).

Table 1 Comparison Of SCDF Calculated For Original And Sensitivity Hazard Analyses
(Site-Specific Information LATER)

Freq, Hz	GMRS, g	SCDF-- Original Hazard	SCDF-- Sensitivity Hazard	ΔSCDF	% change in SCDF
100					
25					
10					
4					
2.5					
1					
0.5					

Table 1 will reflect the changes in SCDF for each spectral frequency along with the percentage change in SCDF.

Note that several alternative assumptions at the Lee site have been studied in various contexts. In the current sensitivity evaluation (Ref. 9), the Dames & Moore team is excluded from the analysis. In a previous sensitivity evaluation (Ref. 10), the probabilities of Dames & Moore sources were revised, and the revised source interpretations were substituted into the analysis. Both sensitivity studies indicate that, at the original GMRS level, the frequency of exceedence from the sensitivity analysis would increase by about 16% at high frequencies (100 Hz to 25 Hz). An alternative characterization of the evaluation is that, if one of the sensitivity analyses were adopted, the ground motion representing the GMRS at high frequencies would increase by 9% to 11%. These are equivalent characterizations of the sensitivity, the first quantifying the sensitivity in terms of annual frequency, and the second quantifying the sensitivity in terms of ground motion. For the purpose of the current evaluation, we quantify the sensitivity in terms of the change in SCDF (which is an annual frequency) for the hypothetical case in which the Dames & Moore team is excluded from the analysis. Results for the other sensitivity assumption would be similar.

Significance of change in SCDF

To evaluate the significance of changes in SCDF, it is instructive to examine guidelines contained in Regulatory Guide 1.174 (Ref. 8) regarding risk-informed decisions regarding changes to a nuclear plant's licensing basis. Reg. Guide 1.174, as written, is for existing plants, but it provides insights into what constitutes a significant change in assumptions, based on changes to the calculated risk associated with the plant, with two measures of risk being used: core damage frequency (CDF), and large early accidental release of radionuclides.

Figure 2 shows the acceptance guidelines for changes to the licensing basis for nuclear plants, based on changes to the calculated CDF. Acceptable changes depend on the absolute CDF and on the change in CDF (called ΔCDF in Figure 2). When ΔCDF is less than 1E-6 and the absolute CDF is less than 1E-4 (which would be expected for a nuclear plant with a modern design), the change falls into Region III, which is characterized as "very small changes, more flexible with respect to baseline CDF."

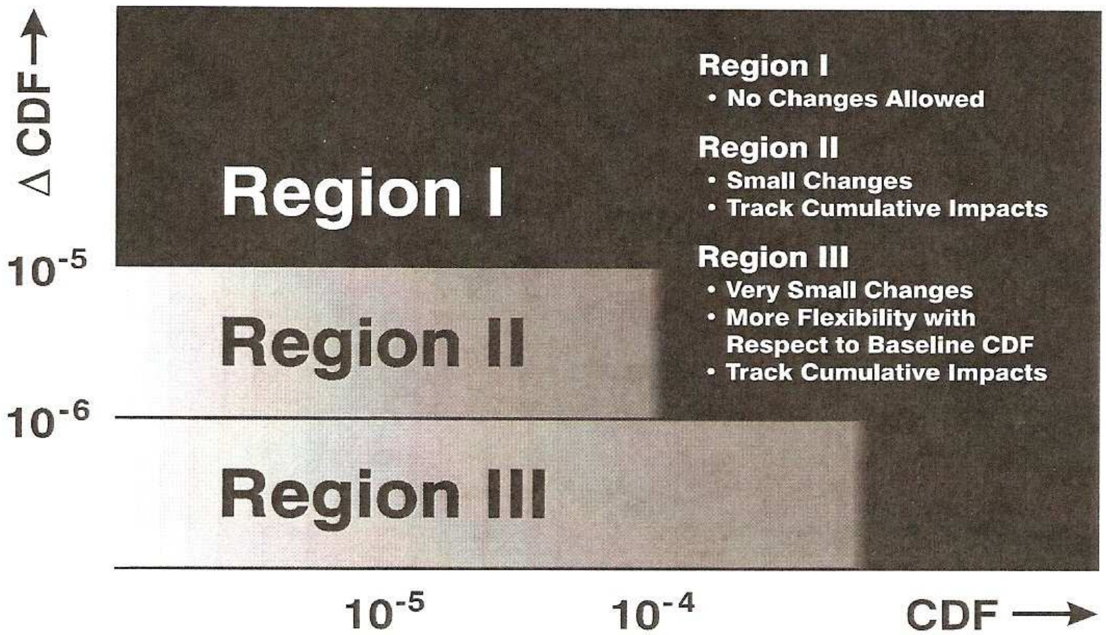

Figure 2: Acceptance Guidelines For Core Damage Frequency
(Reproduction of Figure 3 of Ref. 8)

Results will be tabulated to indicate the ΔSCDF associated with the Sensitivity seismic hazard curve for comparison with the guideline values above. Those results will be useful in inferring a basis for determining whether the sensitivity evaluation results should be considered "significant." Note that Ref. 8 also contains acceptance guidelines for change in large early release frequency, which are a factor of 10 lower than those for CDF. There is no generic fragility representation available for large early release, but it would be expected that a newly designed plant would achieve this factor of 10 reduction between CDF and large early release frequency.

<u>Sensitivity of results</u>

It is useful to examine how sensitive the ΔSCDF results are to alternative assumptions on several parameters. To determine these sensitivities, the ΔSCDF calculation will consider alternative β and F_S values. Particular attention will be focused on the spectral frequency with the peak

ΔSCDF, which will likely will bound the sensitivity of other spectral frequencies to changes in assumed parameter values.

Table 2 Sensitivity of ΔSCDF to Alternative Assumptions on β and F_S.
(Site-Specific Information LATER)

Freq, Hz	GMRS, g	β	F_S	SCDF w/ D&M	SCDF wo/ D&M	ΔSCDF

Conclusions

This evaluation is intended to examine the effects of sensitivity analyses and the resulting hypothetical alternative assumption in seismic hazard at the Lee site in the context of plant risk, calculated for a generic plant seismic design. The hypothetical assumption is to exclude one of the EPRI (1989) teams (Dames & Moore) from the analysis. The measure of plant risk is the change in seismic core damage frequency ΔSCDF, and the context is the guideline provided by Reg. Guide 1.174 on evaluating changes to a nuclear plant's licensing basis.

The analysis of ΔSCDF will reflect the change in seismically induced core-damage frequency for the alternative assumption (dropping the Dames & Moore team), compare those results with the significance criterion of Reg. Guide 1.174, and derive from that comparison a conclusion about the significance of the sensitivity evaluation results. It is anticipated that using the guidance of Reg. Guide 1.174, the results will be characterized as "Very small changes, more flexibility with respect to baseline CDF."

The anticipated conclusion is that, if a nuclear plant were to be designed at the Lee site using the Original spectra, any hypothetical change in seismic hazard at the Lee site caused by dropping the Dames & Moore team would have a very small impact on plant risk. Further, the hypothetical nature of these changes do not constitute a basis for departure from the approved regulatory position that the use of the EPRI/SOG ESTs and the associated diversity and range of interpretations of the scientific community are a valid basis for calculating seismic hazard in the central and eastern US.

References

1. EPRI (1989). *Probabilistic seismic hazard evaluations at nuclear plant sites in the central and eastern United States: resolution of the Charleston earthquake issue*, Elec. Power Res. Inst, Palo Alto, CA, Rept. NP-6395-D, Apr.
2. EPRI (2004). *CEUS ground motion project final report,* Elec. Power Res. Inst, Palo Alto, CA, Rept. 1009684, Dec.
3. Abrahamson, N.A., and J. Bommer (2006). *Program on technology innovation: truncation of the lognormal distribution and value of the standard deviation for ground motion models in the central and eastern United States,* Elec. Power Res. Inst, Palo Alto, CA, Rept. 1014381, Aug.
4. Chilk, S.J. (1993). Memorandum to J.M. Taylor on *SECY-93-087—Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs*, US Nuc. Reg. Comm. staff memorandum, July 21, USNRC Accession no. ML003798056.
5. Kennedy, R.P. (2007). "Recommended Modification to Performance-Goal Based (Risk Informed) Approaches for Establishing the SSE Site Specific Response Spectrum for Future Nuclear Power Plants," Appendix A in Risk Engineering, Inc. (2007), *Program on Technology innovations: Sensitivity of Performance-Based Approaches for Determining the Safe Shutdown Earthquake Ground Motion for New Plant Sites,* Elec. Power Res. Inst., Palo Alto, Rept. 1014379.
6. ASCE (2005). *Seismic design criteria for structures, systems, and components in nuclear facilities*, Amer. Soc. Civil Engrs, Rept. ASCE/SEI 43-05.
7. Risk Engineering,Inc. (2001). *Technical basis for revision of regulatory guidance on design ground motions: hazard- and risk-consistent ground motion spectra guidelines,* US Nuc. Reg. Comm. Rept. NUREG/CR-6728, Oct.
8. USNRC (2002). *Regulatory Guide 1.174, An approach for using probabilistic risk assessment in risk-informed decisions on plant-specific changes to the licensing basis,* US Nuc. Reg. Comm., Reg. Guide 1.174, Nov.
9. Dolan, Bryan J. (2008). Letter to USNRC, Duke Energy Carolinas, LLC., William States Lee III Nuclear Station - Docket Nos. 52-018 and 52-019, AP1000 Combined License Application for the William States Lee III Nuclear Station Units 1 and 2, Response to Request for Additional Information (RAI No. 1141), Ltr. no. WLG2008.11-21, November 20, 2008.
10. Risk Engineering, Inc. (2008). "White Paper on Influence of Dames & Moore Interpretations for Seismic Hazard Studies in the Southeastern US," Elec. Power Res. Inst., Palo Alto, CA, May 12, NRC accession no. ML081260215.