White Paper on

Influence of Dames & Moore Interpretations for Seismic Hazard Studies in the Southeastern US

Prepared for

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May 12, 2008

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INTRODUCTION

The Electric Power Research Institute—Seismicity Owners Group (EPRI-SOG) study (Ref. 1) conducted in the 1980s developed seismic sources and calculated seismic hazard for nuclear plant sites located in the central and eastern US (CEUS). Six earth science teams provided inputs by delineating seismic sources and recommending seismic parameters for those sources. A large amount of effort went into defining these sources on the basis of geology, geophysics, tectonics, and historical earthquake occurrences, and bases for the source interpretations are well documented in separate EPRI reports written by each of the earth science teams.

This study examines the effect on seismic hazard of alternative assumptions regarding the probabilities of activity (P_a) for several seismic sources drawn by the Dames & Moore team for the EPRI-SOG study. The Dames & Moore team made the interpretation that certain parts of the eastern US have some probability of never producing earthquakes with m_b >5.0 in the current tectonic environment. This is consistent with the position that certain parts of the earth's crust are tectonically stable. No data have been observed (e.g. earthquake occurrences with m_b>5.0 in the sources drawn by Dames & Moore) that would invalidate the recommendations of the Dames & Moore team regarding P_a. (It is noted that the NCEER catalog of historical earthquakes in the CEUS assigned m_b=5.0 to a 1913 earthquake that occurred in South Carolina within Dames & Moore source DAM-41. The EPRI-SOG study assigned m_b=4.9 to this earthquake. Both estimates were based on intensity reports.) No new theories have been published that invalidate the recommendations of the Dames & Moore team regarding its seismic sources. This examination is conducted purely as a sensitivity study, to determine the effect of alternative values of P_a for two of the Dames & Moore sources. This effect is measured as the change in uniform hazard response spectra (UHRS) and ground motion response spectra (GMRS) resulting from alternative values of P_a. These results are presented as a "what-if" study and do not endorse the changes to P_a values.

The seismic hazard at two sites is examined here: the Shearon Harris nuclear plant site, and the William States Lee nuclear plant site. These sites have had seismic hazard analyses conducted (Ref. 2 and 3) as part of COL applications, so sensitivity studies are straightforward.

ALTERNATIVE DAMES & MOORE INTERPRETATIONS

Figure 1 shows Dames & Moore seismic sources in the southeastern US (taken from Ref. 1). Seismic sources DAM-41 and DAM-53 are examined for sensitivity, because the P_a is less than unity for these sources. The original Dames & Moore interpretation for these sources is as follows (these descriptions are taken from Ref. 4):

DAM-41 is the default source for the following sources:

DAM-42 (Newark G. Basis, P_a=0.40),
DAM-43 (Ramapo fault, P_a=0.20), and
DAM-46 (Dan R. Basin, P_a=0.28).

The activities of the above 3 sources are mutually exclusive, meaning that only one of them is the explanation of earthquakes with m_b>5.0 in the CEUS. The total P_a of these 3 sources is 0.88, and the remaining P_a of 0.12 is assigned to DAM-41 (the default source).

DAM-53 is the Southern Appalachian Mobile Belt, a default source for the following sources:

DAM-47 (Connecticut Basin, P_a=0.28),
DAM-48 (Buried Triassic Basis, P_a=0.28),
DAM-49 (Jonesboro Basis, P_a=0.28),
DAM-50 (Buried Triassic Basis, P_a=0.28),
DAM-51 (Florence Basis, P_a=0.28),
DAM-65 (Dunbarton Triassic Basis, P_a=0.28).

The activities of these 6 sources are perfectly dependent, meaning that all of them are either active (with P_a=0.28) or inactive (with probability 0.72). When they are inactive, either source DAM-52 (Charleston Mesozoic Rift) is active (with P_a=0.46), or DAM-53 is active (with the remaining P_a of 0.26).

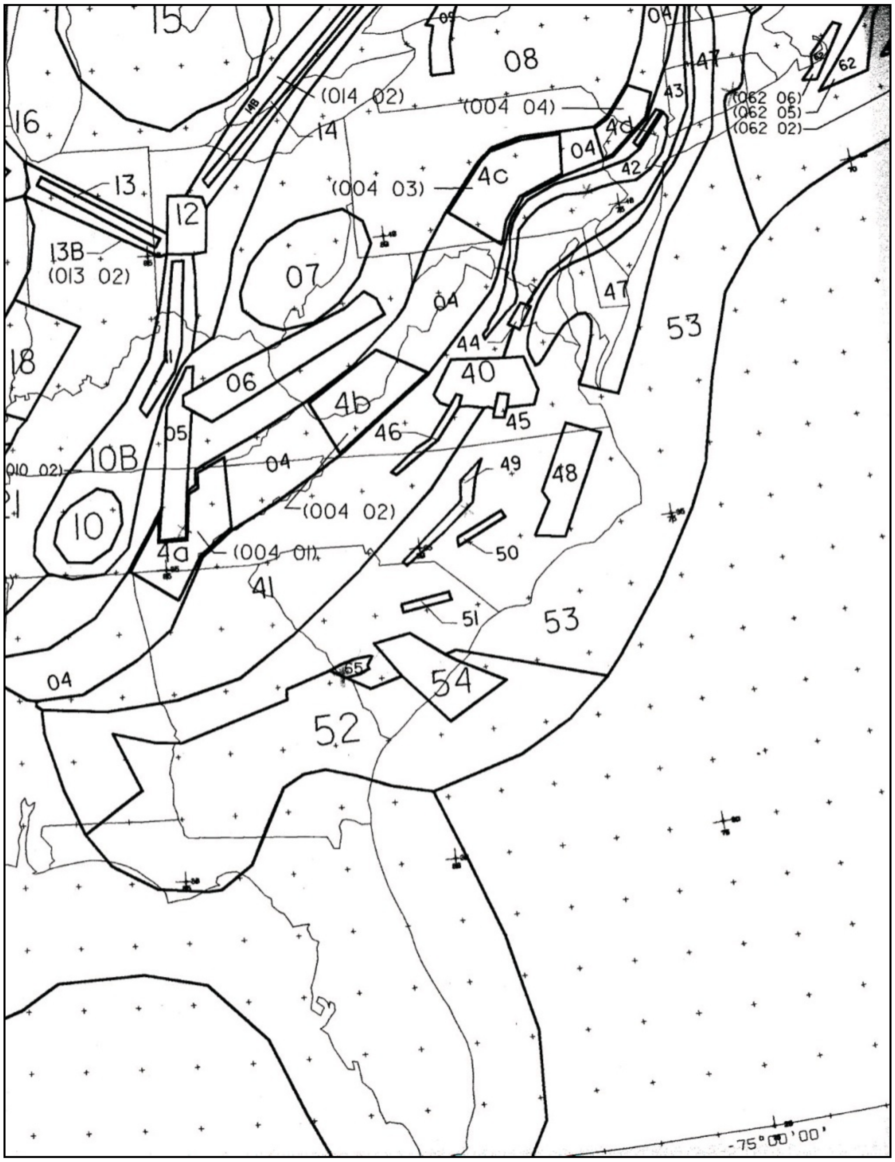

Figure 1. Dames & Moore seismic sources in the southeastern US (from Ref. 1).

The sensitivity study conducted here revises the probabilities of activity for Dames & Moore sources DAM-41 and DAM-53 from the above P_a values to a P_a value of 1.0, meaning that these 2 sources will always be active and capable of producing earthquakes with $m_b \geq 5.0$. In effect the activity of source DAM-41 is being increased for this sensitivity study by a factor of 1/0.12 = 8.33, and the activity of source DAM-53 is being increased by a factor of 1/0.26=3.85. Note that at the locations of the alternative sources listed above, the modified P_a values would imply double-counting of seismic hazard, since two sources would be active simultaneously at the same location, both representing seismic activity.

RESULTS OF SENSITIVITY STUDY

Table 1 shows the effect of changing the P_a values for sources DAM-41 and DAM-53 as described above for the Shearon Harris site. The difference in mean UHRS and GMRS amplitudes is shown for the original P_a values and for the modified P_a values. The maximum change in GMRS amplitude is about a 2% increase.

Table 1. Sensitivity of Hazard at Shearon Harris Site to Changes in P_a.

Spectral Frequency	Ground Motion	Amplitudes based on Original P_a	Amplitudes based on Alternative P_a	% Diff
100 Hz	10^{-4} UHRS	0.09	0.091	1.1%
	10^{-5} UHRS	0.283	0.288	1.8%
	GMRS	0.135	0.137	1.5%
25 Hz	10^{-4} UHRS	0.22	0.222	0.9%
	10^{-5} UHRS	0.921	0.94	2.1%
	GMRS	0.415	0.423	1.9%
10 Hz	10^{-4} UHRS	0.202	0.205	1.5%
	10^{-5} UHRS	0.665	0.676	1.7%
	GMRS	0.315	0.32	1.6%
5Hz	10^{-4} UHRS	0.147	0.148	0.7%
	10^{-5} UHRS	0.483	0.488	1.0%
	GMRS	0.228	0.231	1.3%
2.5 Hz	10^{-4} UHRS	0.106	0.106	0.0%
	10^{-5} UHRS	0.329	0.331	0.6%
	GMRS	0.157	0.158	0.6%
1 Hz	10^{-4} UHRS	0.047	0.048	2.1%
	10^{-5} UHRS	0.165	0.166	0.6%
	GMRS	0.077	0.078	1.3%
0.5 Hz	10^{-4} UHRS	0.024	0.024	0.0%
	10^{-5} UHRS	0.112	0.113	0.9%
	GMRS	0.05	0.051	2.0%

Table 2 shows the effect of changing the P_a value for sources DAM-41 and DAM-53 for the Lee site. The maximum change in GMRS amplitude is about an 11% increase.

Table 2. Sensitivity of Hazard at Lee Site to Changes in P_a.

Spectral Frequency	Ground Motion	Amplitudes based on Original P_a	Amplitudes based on Alternative P_a	% diff
100 Hz	10^{-4} UHRS	0.104	0.112	7.5%
	10^{-5} UHRS	0.471	0.524	11.2%
	GMRS	0.212	0.236	11.2%
25 Hz	10^{-4} UHRS	0.249	0.274	10.1%
	10^{-5} UHRS	1.292	1.436	11.1%
	GMRS	0.581	0.646	11.1%
10 Hz	10^{-4} UHRS	0.197	0.212	7.4%
	10^{-5} UHRS	0.820	0.902	10.0%
	GMRS	0.370	0.406	9.7%
5 Hz	10^{-4} UHRS	0.152	0.161	5.9%
	10^{-5} UHRS	0.527	0.568	7.7%
	GMRS	0.247	0.265	7.3%
2.5 Hz	10^{-4} UHRS	0.0946	0.1	5.7%
	10^{-5} UHRS	0.3070	0.322	4.9%
	GMRS	0.146	0.153	5.1%
1 Hz	10^{-4} UHRS	0.0423	0.0445	5.3%
	10^{-5} UHRS	0.1601	0.165	3.1%
	GMRS	0.0736	0.0762	3.5%
0.5 Hz	10^{-4} UHRS	0.0218	0.0229	5.0%
	10^{-5} UHRS	0.1228	0.125	1.8%
	GMRS	0.0553	0.0563	1.8%

Figure 2 plots the PGA hazard curves for the original P_a's and for the modified P_a's for the Lee site. The CAV filter (Ref. 5) was applied in the seismic hazard calculations, so the seismic hazard curves roll over to a constant annual frequency of exceedence at low amplitudes. Figure 2 shows (with red lines) the change in hazard if the GMRS (from the original P_a values) of 0.212g is used instead of the GMRS (from the modified P_a values) of 0.236g. For this ~11% difference in GMRS, the hazard increases about 16%. The reason that the change in hazard is similar to the change in GMRS is that the hazard curve has a log-log slope close to -1.

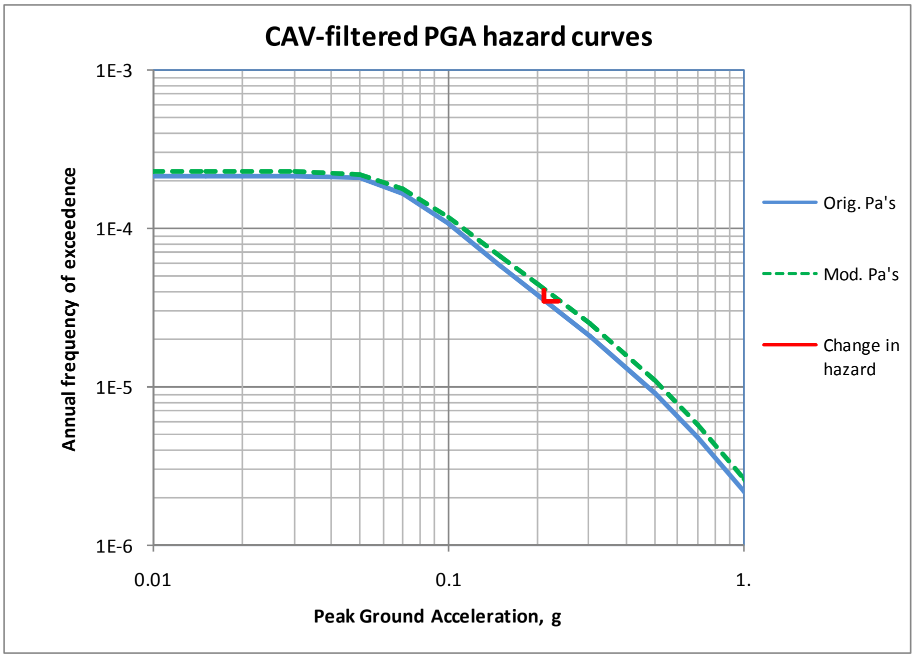

Figure 2: PGA hazard curves for original P_a's and modified P_a's, showing (with red lines) the change in hazard if the GMRS is changed from 0.236g to 0.212g.

CONCLUSIONS

The changes in seismic hazard and GMRS that would occur if alternative probabilities of activity P_a were applied to certain Dames & Moore sources are small. At the Shearon Harris site, the Dames & Moore host source is DAM-53, and the P_a for this source is increased by 385% (P_a is multiplied by a factor of 3.85) for the sensitivity study. The resulting change in overall hazard implies an increase in UHRS values and GMRS of about 2% or less, across all spectral frequencies.

At the Lee site, the Dames & Moore host source is DAM-41, and the P_a for this source is increased by 833% (P_a is multiplied by a factor of 8.33) for the sensitivity study. The resulting change in overall hazard implies an increase in GMRS of about 11% at high frequencies, and 7% or less at frequencies of 5 Hz and lower. The 11% change in high-frequency GMRS implies that, if the original GMRS were used for design (using the Dames & Moore-recommended P_a values), the hazard would be increased by about 16%. Increases at lower spectral frequencies would be smaller.

Changes in mean seismic core damage frequency scale closely with changes in mean hazard at the GMRS (the scaling is exactly proportional if the shape of the mean hazard curve does not change). Thus a change of 16% in mean hazard at the GMRS corresponds to a change of about

16% in mean seismic core damage frequency. This is within the level of change considered to be insignificant.

It should be emphasized again that the modified P_a values for Dames & Moore sources are not supported by any new data that have been observed or by any new theories of earthquake occurrences in the CEUS. The interpretation by Dames & Moore was that certain large seismic sources in the CEUS have some probability that they will never produce an earthquake with m_b>5.0. If earthquakes with m_b>5.0 cannot occur, this is consistent with the observation that certain parts of the earth's crust are stable within the current tectonic environment, that crustal stresses are relatively uniform, and that active faults do not exist with sufficient dimensions to relieve accumulated crustal stress with moderate or large earthquakes. This is one interpretation out of six EPRI-SOG teams for the CEUS, and is an example of the broad range of diverse, informed scientific opinion that is sought in a large seismic hazard project. Until data are collected that render such opinions invalid, or until the EPRI-SOG study is updated by another study of similar breadth and scope, the Dames & Moore interpretation should continue to be considered one valid interpretation among six.

For these reasons, and because the potential change in Dames & Moore P_a values results in estimated changes to mean hazard and to mean seismic core damage frequency that are insignificant, this study validates the ESP and COL applications submitted to date that use the original P_a values for the Dames & Moore team.

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