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ADJUDICATIONS STAFF

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
Thomas S. Moore, Chairman
Charles N. Kelber
Peter S. Lam

In the Matter of	)	August 22, 2003
DUKE COGEMA STONE & WEBSTER	)	Docket No. 070-03098-ML
(Savannah River Mixed Oxide Fuel Fabrication Facility)	)	ASLBP No. 01-790-01-ML

FIRST SUPPLEMENT TO
DOCUMENTS TO BE RELIED UPON
BY DCS'S EXPERT WITNESSES

In accordance with the Commission Order, CLI-01-13 (June 14, 2001), and the Atomic Safety and Licensing Board Order, *slip op* (April 30, 2002), Duke Cogema Stone & Webster ("DCS") hereby supplements the June 27, 2002 list of documents upon which its expert witnesses presently plan to rely for written testimony and at any hearing that may be required on the Construction Authorization Request for the Mixed Oxide Fuel Fabrication Facility ("MOX Facility"). This list does not include documents identified by GANE in its interrogatory responses or during depositions. As before, DCS will make available for inspection and copying the documents from this list that are not already in the Hearing File or otherwise publicly available.

Template = SECY-041

SECY-02

Contention 3 "Inadequate Seismic Design"

The narrowing of Contention 3 has changed the documents upon which DCS's experts plan to rely. The list of documents for Contention 3 provided below replaces, rather than supplements, the list previously provided.

1. Amick, D.R., et al., *Paleoliquefaction Features Along the Atlantic Seaboard,* NUREG/CR-5613, U.S. NRC, Washington, D.C. (1990).

2. Amick, D. & Talwani, P., *Earthquake Recurrence Rates and Probability Estimates for the Occurrence of Significant Seismic Activity in the Charleston Area: The Next 100 Years*, Third U.S. National Conference on Earthquake Engineering, Vol 1, pp. 55-64 (1986).

3. Bernreuter, D.L., *Letter report from Don Bernreuter to Jeff Kimball,* Lawrence Livermore National Laboratory, Fission Energy and Systems Safety Program, NTFS97-123 (May 15, 1997).

4. Cornell, C.A., *Probabilistic Hazard Analysis for Non-Linear Soil Sites – Preliminary Draft (1/14/97)*, Department of Civil and Environmental Engineering, Stanford University, Stanford, CA. (1997).

5. Cumbest, R.J., Stephenson, D.E., Wyatt, D.E., and M. Maryak, *Basement Surface Faulting and Topography for Savannah River Site and Vicinity.* WSRC TR-98-00346, Rev. 0, WSRC, Aiken, SC (1998).

6. Cumbest, R. J., Wyatt, D.E, Stephenson, D.E., and Maryak, M, *Comparison of Cenozoic Faulting at the Savannah River Site to Fault Characteristics of the Atlantic Coast Fault Province: Implications for Fault Capability*, WSRC-TR-2000-00310, Rev. 0 (2000).

7. Domoracki, W., *A Geophysical Investigation of Geologic Structure and Regional Tectonic Setting at the Savannah River Site, South Carolina.* Ph.D. Dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia (1995).

8. DCS, *MOX Fuel Fabrication Facility Site Geotechnical Report*, DCS01-WRS-DCS-NTE-G-00005-E, (June.2003)

9. Herrmann, R.B., *Surface Wave Studies of Some South Carolina Earthquakes,* Bulletin of the Seismological Society of America, Vol.76, No. 1, pp.111-121, (February 1986).

10. Kimball, J., *Recent Ground Motion Attenuation Models*, NNSA, (July 2003).

11. Leon, E, *Effect of Aging of Sediments on Paleoliquefaction Evaluation in the South Carolina Coastal Plain*, Dept. of Civil and Envt'l Engineering, U. of S.C. (2003).

12. Memorandum from Brent Gutierrez to Lawrence Salomone and Fred Loceff, re: Revised Envelope of the Site Specific PC-3 Surface Ground Motion, (September 9, 1999).

13. Obermeier, S.F. et al., Geologic Evidence for Recurrent Moderate to Large Earthquakes Near Charleston, South Carolina, Science, Vol. 227 (1985).

14. Obermeier et al, *Earthquake-Induced Liquefaction Features in the Coastal South Carolina Region,* USGS Open File Report 87-504 (1987).

15. Obermeier et al, *Liquefaction evidence for repeated Holocene earthquakes in the Coastal Region of South Carolina,* Annuals of the N.Y. Academy of Sciences, 558, pp. 183-195 (1989).

16. Obermeier, S.F. et al., *Earthquake-induced Liquefaction Features in the Coastal Setting of South Carolina and in the Fluvial Setting of the New Madird Seismic Zone,* U.S. Geological Survey Professional Paper No. 1504 (1990).

17. Ou, G.B. and R.B. Herrmann, *A Statistical Model for Ground Motion Produced by Earthquakes at Local and Regional Distances*, BSSA, 80, NO. 6, 1397-1417 (1990)

18. Savy, J.B., Fission Energy and Systems Safety Program, May 28, 1996, SANT96-147JBS, Letter from J. B. Savy, Deputy Associate Program Leader Natural Phenomena Hazards to Jeff Kimball, DOE (1996).

19. Stokoe, K.H., et al., *Correlation Study of Nonlinear Dynamic Soil Properties: Savannah River Site, Aiken, South Carolina*, Rev. 0, File No. Savannah River Site-RF-CDP-95, University of Texas at Austin, Department Civil Engineering, (September 13. 1995)

20. Toro, G.R., *Probabilistic of Site Velocity Profiles at the Savannah River Site, Aiken, South Carolina*, Final Report to WSRC (April 4, 1997).

21. Westinghouse Savannah River Company *Investigations of Nonlinear Dynamic Soil Properties at the Savannah River Site,* Report No. WSRC-TR-96 0062, Rev. 0. (March 1996).

22. WSRC, *SRS Seismic Response Analysis and Design Basis Guidelines*, WSRC-TR-97-0085, Rev. 0. (1997).

23. WSRC, *Soil Surface Seismic Hazard and Design Basis Guidelines for Performance Category 1 & 2 SRS Facilities*, by R.C. Lee, WSRC-TR-98-00263, Rev. 0. (1998).

24. WSRC, *Natural Phenomena Hazards (NPH) Design Criteria and Other Characterization Information for the Mixed Oxide (MOX) Fuel Fabrication Facility at Savannah River Site (U)*, WSRC-TR-2000-00454, Rev. 0, Westinghouse Savannah River Company, Savannah River Site, Aiken, SC, (November 2000b).

25. WSRC, *Applicability of SRS Site-Wide Spectra to the MFFF Site*, Calculation Number K-CLC-F-00049, Rev. 0. (2001).

Contention 11 "ER Fails to Address the Waste Stream From Aqueous Polishing"

The following titles are revised:

1. Brossard, M-P, personal communication to M.L. Birch, ER Solid Waste Balance, April 15, 2002. Revised title is: Brossard, M-P. personal communication to M.L. Birch, Modified ER Tables (June 26, 2002).

2. Calculation of accident and normal operations doses from waste processing building. Revised title is: Williford, D.C. interoffice memorandum to R.G. Eble, Data Sources for MFFF ER Appendix G.4 – WSB Accident Analyses and Dose Consequences (July 3, 2002).

3. WSRC, *MFFF ENVIRONMENTAL REPORT UPDATE: Bounding Information For Waste Processing Building.* Preliminary Predecisional Information (March 28, 2002). Revised title is: WSRC, *MFFF Environmental Report Update, Bounding Information of Waste Solidification Building*, Rev. 2 (June 17, 2002).

The following are added to the list of documents to be relied upon for Contention 11:

4. Hastings, P.S. to NRC Document Control Desk, Mixed Oxide Fuel Fabrication Facility, Responses to the Request for Additional Information on the Environmental Report, Revisions 1 & 2, DCS-NRC-000116 (October 29, 2002).

5. Mixed Oxide Fuel Fabrication Facility Environmental Report, Rev. 3 (change pages), DCS-NRC-000143 (June 20, 2003).

Dated: August 22, 2003

Respectfully submitted,

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
Thomas S. Moore, Chairman
Charles N. Kelber
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In the Matter of	)	
DUKE COGEMA STONE & WEBSTER	)	Docket No. 070-03098-ML
(Savannah River Mixed Oxide Fuel Fabrication Facility)	)	ASLBP No. 01-790-01-ML

CERTIFICATE OF SERVICE

I hereby certify that copies of (1) "First Supplement To Documents To Be Relied Upon By DCS's Expert Witnesses" and (2) "Duke Cogema Stone & Webster's Motion for Summary Disposition on Contention 3" and all its attachments, were served this day upon the persons listed below, by electronic and first class mail, with the exception of Attachment G to the Motion for Summary Disposition (relevant pages of Dr. Long's Transcript and errata sheets), which is only being served by First Class Mail.

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August 22, 2003

VIA E-MAIL AND FIRST CLASS MAIL

Administrative Judge Thomas S. Moore, Chairman
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Re: DCS's Motion for Summary Disposition on Contention 3 (Inadequate Seismic Design) and revision to identification of testifying witnesses; *Duke Cogema Stone and Webster* (Savannah River Mixed Oxide Fuel Fabrication Facility), Docket No. 70-3098- ML

Dear Judge Moore:

Please find enclosed Duke Cogema Stone & Webster LLC's (DCS) Motion requesting summary disposition of Georgians Against Nuclear Energy's (GANE) Contention 3, which challenges the seismic design of the MOX Facility. The Motion includes seven attachments:

Attachment A is a recent revision to Contention 3 based on stipulations made by counsel for GANE during the deposition of Dr. Long. This attachment has not been previously submitted to the Board and to the extent necessary, DCS requests that the Board approve this stipulated revision;

Attachment B is a Statement of Material Facts on Which No Genuine Issue Exists;

Attachment C is an Affidavit and résumé of Dr. Carl Stepp, DCS's testifying expert on Contention 3;

Attachment D is a figure depicting the location of the Savannah River Site (SRS) in relation to the assumed epicentral zone of the 1886 Charleston earthquake, and two nearby areas of prehistoric liquefaction (Bluffton and Georgetown);

Attachment E is a figure comparing two seismic hazard spectra for the ground surface at SRS with the spectrum used by DCS for the MOX Facility site;

Attachment F is a figure comparing the MOX Spectrum with 150% of the median 1886 Charleston earthquake ground motions; and

Attachment G contains those pages of Dr. Long's deposition transcript that are cited in the Motion.

In addition to transmitting DCS's Motion for Summary Disposition, by this letter DCS is revising the list of DCS testifying experts for Contention 3. GANE and DCS have worked diligently to narrow Contention 3. DCS now anticipates that if its Motion for Summary Disposition is not granted in its entirety, the testimony of two testifying experts previously identified will no longer be required. Accordingly, DCS hereby withdraws both Mr. Lawrence A. Salamone, Chief Geotechnical Engineer, Westinghouse Savannah River Corporation, and Mr. John M. McConaghy, Jr., Lead Civil/Structural Engineer, DCS, as testifying experts on Contention 3.

Respectfully submitted,

Alex S. Polonsky

cc: Service List

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In the Matter of	)	August 22, 2003
DUKE COGEMA STONE & WEBSTER	)	Docket No. 070-03098-ML
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DUKE COGEMA STONE & WEBSTER'S MOTION FOR SUMMARY DISPOSITION ON CONTENTION 3

I. INTRODUCTION

In Contention 3, Georgians Against Nuclear Energy ("GANE") argues that the seismic analysis presented in the Construction Authorization Request ("CAR") submitted by Duke Cogema Stone & Webster LLC ("DCS") for the proposed Mixed Oxide Fuel Fabrication Facility ("MOX Facility") is inadequate. Specifically, GANE states that "DCS has not performed a seismic analysis that is either adequate in scope or adequately documented."[1]

1 *Georgians Against Nuclear Energy Contentions Opposing a License for Duke Cogema Stone & Webster to Construct a Plutonium Fuel Factory at Savannah River Site* (Aug 13, 2001) ("GANE Contentions") at 13; Revised Contention at 1. A Revised Contention and Basis Statement was included as "Long Exhibit No. 1" to the Deposition Transcript of Dr. Long and is also attached to this Motion as Attachment A.

It is, however, incontrovertible that DCS has complied with the regulations in 10 CFR Part 70 which govern the consideration of earthquake hazards in the design of the MOX Facility. Because Contention 3 presents no genuine issues of material fact, DCS requests that the Contention be summarily disposed of without a hearing.

Accordingly, DCS files this Motion for Summary Disposition on GANE's Contention 3 (Inadequate Seismic Design), pursuant to 10 CFR §§ 2.1237 and 2.749. This Motion is supported by a separate "Statement of Material Facts on Which No Genuine Issue Exists" (Attachment B), and by the sworn Affidavit of Dr. Carl Stepp[2] (Attachment C).

Section II of this Motion presents the law governing summary disposition. Section III discusses the legal standards governing the seismic design of the MOX Facility. Section IV provides an overview of relevant portions of the seismic design of the MOX Facility, and an overview of GANE's concerns that remain to be litigated. Finally, Section V discusses why Contention 3 presents no genuine issues of material fact and why DCS is entitled to disposition of this Contention as a matter of law.

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2 Dr. Stepp is well respected in the scientific community. Even Dr. Long stated that he "would consider his opinion very highly." Deposition Transcript of Dr. Leland Timothy Long at 106:1-2 (June 25, 26, 2003) ("Dr. Long Transcript"). Deposition transcript pages cited in this Motion are included as Attachment G, along with Dr. Long's errata sheets. DCS objects to Dr. Long's errata sheets to the extent they make substantive changes to his testimony, rather than simply correcting the transcript to reflect the testimony actually given. At least some courts agree that "a deposition is not a take home examination." *Greenway v. Int'l Paper Co*, 144 F.R.D. 322, 325 (W.D. La. 1992); *accord Rio v. Welch*, 856 F. Supp. 1499 (D. Kan. 1994). However, other Federal Courts have refused to construe the applicable federal rule as only allowing correction of transcription errors. *E.g.*, *Innovative Mktg. & Tech. v. Norm Thompson Outfitters, Inc.*, 171 F.R.D. 203 (W.D. Tex. 1997). Leaving for another day resolution of this issue with respect to NRC's rule at 10 CFR 2.740a(e), DCS suggests that Dr. Long's errata sheets, and testimony changes therein, be assessed by the Board in reviewing the weight that should be accorded his testimony.

II. STATEMENT OF THE LAW GOVERNING SUMMARY DISPOSITION MOTIONS

Pursuant to 10 CFR § 2.749, summary disposition "as to all or any part of the matters involved in the proceeding"[3] is warranted "if the filings in the proceeding, depositions, answers to interrogatories, and admissions on file, together with the statements of the parties and the affidavits, if any, show that there is no genuine issue as to any material fact and that the moving party is entitled to a decision as a matter of law."[4]

Summary disposition is not simply a "procedural shortcut"; rather, it is designed "to secure the just, speedy and inexpensive determination of every action," and should be granted when appropriate.[5] In fact, Commission policy states that summary disposition should be granted "upon a written finding that such a motion will likely substantially reduce the number of issues to be decided or otherwise expedite the proceeding."[6] In this case, summary disposition of Contention 3 would reduce the number of issues to be addressed at hearing, and would substantially expedite the process.

The Commission has held that Section 2.749 summary disposition motions are analogous to summary judgment motions under Rule 56 of the Federal Rules of Civil Procedure and should be evaluated by the same standards.[7] Pursuant to both NRC and

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3 10 CFR § 2.749(a).

4 10 CFR § 2.749(d).

5 *Celotex Corp. v. Catrett*, 477 U.S. 317, 327 (1986) (citations omitted); *see also Tennessee Valley Authority* (Hartsville Nuclear Plant, Units 1A, 2A, 1B, and 2B), ALAB-554, 10 NRC 15, 19 (1979).

6 *Policy on Conduct of Adjudicatory Proceedings*; Policy Statement, CLI-98-12, 48 NRC 18, 20-21 (1998).

7 *See Advanced Medical Systems, Inc.* (One Factor Row, Geneva, Ohio 44041), CLI-93-22, 38 NRC 98, 102 (1993).

federal caselaw, the party seeking summary disposition bears the burden of showing the absence of a genuine issue as to any material fact.[8] In response, the party opposing the motion must set forth specific facts showing that there is a genuine issue.[9] To be considered genuine, "the factual record, considered in its entirety, must be enough in doubt so that there is a reason to hold a hearing to resolve the issue."[10] Bare assertions or general denials are insufficient to oppose a motion for summary disposition,[11] as are mere "quotations from or citations to [the] published work of researchers [or experts] who have apparently reached conclusions at variances with the movant's affiants."[12] Furthermore, if the party opposing the motion fails to controvert any material fact properly set out in the statement of material facts that accompanies a summary disposition motion, then that fact will be deemed admitted.[13]

If the moving party makes a proper showing, and the opposing party does not show that a genuine issue of material fact exists, then the Licensing Board may

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8 *See Adickes v. Kress & Co.*, 398 U.S. 144, 157 (1970); *Advanced Medical Systems, Inc.*, 38 NRC at 102.

9 *See* 10 CFR § 2.749(b).

10 *Cleveland Electric Illuminating Co.* (Perry Nuclear Power Plant, Units 1 and 2), LBP-83-46, 18 NRC 218, 223 (1983).

11 *See* 10 CFR § 2.749(b); *Advanced Medical Systems, Inc.*, 38 NRC at 102; *Houston Lighting and Power Co.* (Allens Creek Nuclear Generating Station, Unit 1), ALAB-629, 13 NRC 75, 78 (1981).

12 *Carolina Power & Light Co. and North Carolina Eastern Municipal Power Agency* (Shearon Harris Nuclear Plant, Units 1 and 2), LBP-84-7, 19 NRC 432, 435-36 (1984); *see also United States v. Various Slot Machines on Guam*, 658 F.2d 697, 700 (9th Cir. 1981) (holding that "in the context of a motion for summary judgment, an expert must back up his opinion with specific facts" in an affidavit).

13 *See* 10 CFR § 2.749(a); *Advanced Medical Systems, Inc.*, 38 NRC at 102.

summarily dispose of the contention on the basis of the pleadings.[14] As discussed below, GANE Contention 3 is the type of contention for which no evidentiary hearing is necessary, and which can be readily and expeditiously resolved in DCS's favor through summary disposition.

III. THE LEGAL STANDARD GOVERNING THE SEISMIC DESIGN OF THE MOX FACILITY

A. NRC Regulations

GANE states that the only applicable NRC regulations are 10 CFR §§ 70.23(a)(3), 70.23(b), and 70.64(a)(2).[15] 10 CFR § 70.22(f)—referenced in Section 70.23(b)—requires DCS's CAR to contain a "description and safety assessment of the design bases of the principal structures, systems and components of the plant." 10 CFR § 70.23(a) states, in relevant part, that:

> (a) An application for a license will be approved if the Commission determines that:
>
> * * *
>
> (3) The applicant's proposed equipment and facilities are adequate to protect health and minimize danger to life or property.

10 CFR § 70.23(b) states, in relevant part, that the NRC:

> will approve construction of the principal structures, systems, and components of a plutonium processing

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14 *Northern States Power Co.* (Prairie Island Nuclear Generating Plant, Units 1 and 2), CLI-73-12, 6 AEC 241, 242 (1973), aff'd sub. nom. *BPI v. AEC*, 502 F.2d 424 (D.C. Cir. 1974).

15 *See Georgians Against Nuclear Energys and Blue Ridge Environmental Defense League Objections and Responses to Applicant's First Set of Interrogatories and Request for Protective Order* (June 28, 2002) ("First GANE Interrogatory Response") 3.31; *Georgians Against Nuclear Energy's Second Supplemental Response to Applicant's First Set of Interrogatories* ("Second GANE Supplemental Interrogatory Response") (Dec. 20, 2002), 3.31.

> and fuel fabrication plant on the basis of information filed pursuant to 70.22(f) when the Commission has determined that the design bases of the principal structures, systems, and components, . . . provide reasonable assurance of protection against natural phenomena . . . .

(Emphasis added). In turn, Section 70.64(a)(2) states:

> (a) Baseline design criteria. Each prospective applicant or licensee shall address the following baseline design criteria in the design of new facilities. . . .
>
> * * *
>
> (2) Natural phenomena hazards. The design must provide for adequate protection against natural phenomena ***with consideration of the most severe documented historical events*** for the site.

(Emphasis added).

B. NRC Guidance

The MOX Facility Standard Review Plan ("MOX SRP") (NUREG-1718) contemplates that a MOX Facility applicant will use probabilistic seismic analyses.[16] "[N]o regulatory guides in Division 3, Fuels and Materials Facilities, address natural phenomena events."[17] The MOX SRP states that Reg. Guides for nuclear power reactors "provide useful reference information,"[18] so DCS used some of these guidance documents, in particular Reg. Guide 1.60. Of course, all regulatory guides are merely guidance and adhering to them is not mandatory.

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16 The MOX SRP discusses natural phenomena events and states that when assessing earthquakes, the applicant should describe likelihoods associated with a suite of maximum accelerations. *Standard Review Plan for the Review of An Application for a Mixed Oxide Fuel Fabrication Facility* (NUREG-1718), App. B, B-1.

17 *Id.*

18 *Id.* (emphasis added).

IV. BACKGROUND ON, AND OVERVIEW OF GANE'S CONCERNS WITH, THE SEISMIC DESIGN FOR THE MOX FACILITY

This section provides background on the seismic design of the MOX Facility and the history of Contention 3 which challenges the adequacy of that design. Specifically, this section provides background on probabilistic seismic hazard assessments ("PSHAs"), with particular focus on the Electric Power Research Institute ("EPRI") and Lawrence Livermore National Laboratory ("LLNL") PSHAs. DCS relied on these studies, and the Savannah River Site ("SRS")-specific seismic design published in 1997 by the Westinghouse Savannah River Corporation ("WSRC"),[19] as the starting point for the seismic design of the MOX Facility.

This section also presents an overview of GANE's remaining concerns with the MOX Facility's seismic design. This overview is necessary because it is no longer possible to identify GANE's issues by solely reviewing the revised Contention and its Basis Statement. The Contention was clarified considerably through Dr. Long's deposition,[20] and narrowed twice during the past few months: once through an unopposed Motion granted by the Board, and once through stipulations made by GANE

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19 R.C. Lee et al, *SRS Seismic Response Analysis and Design Basis Guidelines* WSRC-TR-97-0085, Rev. 0. (1997). This document is included in Hearing File Document # 54A.

20 Dr. Leland Timothy Long was not retained by GANE when Contention 3 was drafted or when the first round of interrogatories were developed or served. *See e.g.*, Dr. Long Transcript at 231:21-22. Thus, the Contention, its Basis Statement, and the first set of interrogatory questions and responses did not necessarily represent his views. In fact, based on his deposition testimony, Dr. Long appears to have different opinions about the adequacy of the MOX Facility seismic design than GANE's previous seismic advisor. *See e.g.*, Dr. Long Transcript at 231:21—232:2.

during Dr. Long's deposition.[21] It is DCS's intent that this section will simplify the Board's review of the remaining issues.

A. Overview of PSHAs

PSHA is an analytical methodology that estimates the probability that various levels of ground motion will be exceeded at a given location in a given time period, usually one year. The analytical methodology uses weighted alternative interpretations of seismic sources, source parameters (such as magnitude and recurrence frequency), and ground motion models as input for hazard calculation. Because the uncertainty in these inputs are complex, experts may reach different assessments of seismic sources and source parameters and may give different credibility to ground motion models. Consequently, a complete PSHA incorporates alternative inputs prepared by multiple experts. Alternative interpretations by multiple experts or expert teams have been found to reasonably capture the uncertainty of the scientific community, which is a primary objective of a PSHA.[22]

Assessments of inputs for a PSHA may be site-specific, or they may be done for a large geographic region and applied to many sites of interest.[23]

B. EPRI and LLNL PSHAs

For nuclear facilities, two independent PSHA studies have been done for the region of the United States east of the Rocky Mountains. These studies were conducted

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21 *See Duke Cogema Stone & Webster* (Mixed Oxide Fuel Fabrication Facility), Memorandum and Order dated June 20, 2003 (granting unopposed motion to narrow contention 3); *see also* Dr. Long Transcript 403:9-13; 405:11-15; 416:6—417-4.

22 Dr. Stepp Affidavit ¶ 10.

in parallel during the mid to late 1980s by LLNL (on behalf of the NRC)[24] and by EPRI (on behalf of the nuclear utilities).[25] Both studies used multiple experts to assess uncertainty and develop inputs for ground motion hazard computation. The two studies differ primarily in the methodology used to obtain evaluations of seismic source inputs and assessments of uncertainty about the evaluations.[26] Both methodologies are, however, accepted by the NRC as suitable for developing a site-specific PSHA.[27]

The LLNL PSHA used about 10 individual experts to evaluate and characterize seismic sources and seven individual ground motion experts to assess uncertainty in ground motion estimation. The experts' evaluations were obtained for the entire region of the Central and Eastern United States ("CEUS") by eliciting alternative seismic sources and uncertainty distributions on seismic source parameters from each expert. The same approach was used to elicit the ground motion experts' uncertainties on alternative ground motion models. The alternative seismic sources' uncertainty

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23 *Id.* at ¶ 11.

24 D.L. Bernreuter et al, *Seismic Hazard Characterization of 69 Reactor Sites East of the Rocky Mountains*, NUREG/CR-5250 (1989); P. Sobel, *Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of the Rocky Mountains*, NUREG-1488, (April 1994); J.B. Savy et al, *Eastern Seismic Hazard Characterization Update*, UCRL-ID-115111 (June 1993) (collectively "the LLNL PSHA").

25 EPRI, *Probabilistic Seismic Hazard Evaluations at Nuclear Plant Sites in the Central and Eastern United States*, NP-4726, All Volumes (1989-1991) ("the EPRI PSHA").

26 Dr. Stepp Affidavit ¶ 12.

27 *Id.*; *see also* U.S. NRC, *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion*, Reg. Guide 1.165, pp. 2-3 (March 1997) ("the Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI) studies have been reviewed and accepted by the staff"). The U.S. Department of Energy ("DOE") also accepts use of these studies for facilities within its jurisdiction. *See* U.S. Department of Energy, *Natural Phenomena Hazards Assessment Criteria*, DOE-STD-1023-95, Change Notice No. 1, p. 6 (Section 3.1.2.1) (Jan. 1996).

distributions were combined with the ground motion estimation uncertainty distributions to compute the ground motion hazard at 69 nuclear plant sites in the CEUS.[28]

The EPRI study was conducted using six expert teams to evaluate alternative seismic sources and characterize seismic source parameters. The teams included experts in the geology of the CEUS, in seismology, and in tectonophysics. The ground motion input for the EPRI study was based on work completed by EPRI consultants and two additional ground motion models for the CEUS.[29]

C. 1997 SRS-Specific Seismic Analysis Used By DCS

An applicant for an NRC license applies the EPRI and LLNL seismic source and ground motion evaluations to a particular site by entering the site's latitude and longitude into either the LLNL or EPRI computer code, computing the contributions of individual seismic sources to the hazard at the location, then aggregating these to obtain the probability distribution of exceeding various levels of ground motion. Probabilistic seismic hazard output is in the form of the probability distribution of annual frequency of exceedance for a given level of ground motion (such as 0.2 g peak acceleration). For purposes of determining seismic design basis ground motion for a site, hazard is computed for peak ground acceleration ("PGA") and acceleration over the range of structural frequencies that are important for design of the facility to be constructed.[30]

DCS used a 1997 SRS-specific seismic response analysis performed by WSRC that relied on EPRI and LLNL bedrock hazards for the latitude and longitude of the site,

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28 Dr. Stepp Affidavit ¶ 13; *see also* Dr. Long Transcript at 79:13-15; 167:18-21 ("experts had a wide diversity of opinions").

29 Dr. Stepp Affidavit ¶ 14.

and that took into consideration local properties such as soil column thickness, soil and bedrock shear-wave velocity, and soil dynamic properties.[31] The SRS-specific analysis used by DCS relied on an average of the LLNL and EPRI PSHA curves to derive design basis ground motions.[32]

The SRS-specific seismic analyses used by DCS generated seismic design basis ground motions by Performance Category ("PC"), for four categories of facilities at SRS: PC-1 through PC-4. Each Performance Category has a performance goal in terms of the probability of unacceptable damage due to an earthquake based on the importance of structures, systems, and components ("SSCs") in the category to the overall safety performance goal of the facility. The target performance goals range from those included in model building code provisions for office buildings (PC-1) to those SSCs that have radiological protection safety significance for a nuclear facility (PC-3 and PC-4).[33]

In the SRS-specific seismic analysis used by DCS, the seismic performance goals for the applicable PCs are assured by the combination of the seismic design basis ground motion and the capacity against failure achieved by the seismic design criteria. A graded approach is used to establish the seismic design criteria for a PC that reflects its importance to safety. Design criteria for an office building might, for example, have an occupant safety goal, which permits significant damage to the building. A PC-3 SSC in

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[30] *Id.* at ¶ 15.

[31] *Id.* at ¶ 17; *see* R.C. Lee et al, *SRS Seismic Response Analysis and Design Basis Guidelines*, WSRC-TR-97-0085, Rev. 0 (1997). *See also* R.C. Lee, *Soil Surface Seismic Hazard and Design Basis Guidelines for Performance Category 1 & 2 SRS Facilities*, WSRC-TR-98-00263, Rev. 0 (1998).

[32] *See* DOE-STD-1023-95, p. 6 (Section 3.1.2.1); *see also* Dr. Stepp Affidavit ¶ 17.

[33] Dr. Stepp Affidavit ¶ 18.

contrast must maintain its radiological safety function for the seismic design basis ground motion without interruption.[34]

A necessary part of the SRS-specific analysis used by DCS is the determination of the appropriate level of seismic design basis ground motions for which SSCs in the appropriate PCs must be designed in order to assure that the facility meets its intended performance goal. Seismic design basis ground motion inherently has a probability of occurrence associated with it. For example, the SRS PC-3 spectrum has a mean annual probability of exceedance of 5×10^{-4}/yr[35] with a PGA of 0.16 g at the ground surface.[36] PC-3 seismic design basis ground motion is used together with PC-3 deterministic seismic design criteria to provide reasonable assurance that the PC-3 SSCs will perform their intended safety function.[37]

PGA—or peak acceleration—is related to the higher frequency spectral amplitudes which are usually above the range of frequencies important for damage to structures at nuclear facilities. For example, for PC-3, the PGA at the ground surface is at 33 Hz. None of the structures relied on for safety at a nuclear facility resonate at this frequency. In fact, the frequencies of structural interest for many nuclear facilities—including the MOX Facility—are between 2.5 and 9 Hz.[38]

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[34] *Id.* at ¶ 19.

[35] Lee *et al*, WSRC-TR-97-0085, at 22.

[36] *See* Revised CAR at 1.3.6-45 (Table 1.3.6-7).

[37] Dr. Stepp Affidavit ¶ 20.

[38] *Id.* at ¶ 21.

The PC-4 spectrum has a mean annual probability of exceedance of 1 x 10^{-4}/yr[39] with a PGA at the ground surface of 0.23 g.[40] PC-4 seismic design basis ground motion is used together with PC-4 deterministic seismic design criteria to provide reasonable assurance that the PC-4 SSCs will perform their intended safety function.[41]

The seismic design basis ground motions for PC-3 are designed to envelope the ground motions of historical earthquakes within 200 km from the site equal to or larger than magnitude 6.0.[42] This is referred to as the "historical check" and is consistent with NRC's requirement for the MOX Facility in 10 CFR § 70.64(a)(2), which requires consideration of the most severe documented historical earthquake for the site.[43]

The MOX Facility site is located near the center of SRS, which is on the inland border of South Carolina and Georgia.[44] For the MOX Facility, the historical check is represented by a repeat of the 1886 Charleston earthquake placed 120 kms southeast of the site with a moment magnitude of 7.3.[45] DCS relied on calculations of the ground motions at the site for the 1886 Charleston earthquake. As input to these calculations, the Herrmann Crustal Model was chosen, which uses a seismic wave attenuation path from Bowman, S.C. to Atlanta, GA, and an earth's crust simulated with four layers over an infinite layer. The Herrmann Crustal Model was modified to a three layer (over an infinite layer) model by removing the shallowest layer to allow better agreement with

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39 Lee *et al.*, WSRC-TR-97-0085, at 22.

40 *See* Revised CAR at 1.3.6-45 (Table 1.3.6-7).

41 Dr. Stepp Affidavit ¶ 22.

42 DOE-STD-1023-95, p. 11 (Section 3.1.5).

43 Dr. Stepp Affidavit ¶ 23.

44 *See* Attachment D (modified from Revised CAR at 1.3.5-119 (Fig. 1.3.5-34)).

45 Revised CAR, p. 1.3.6-27.

measured local shallow bedrock velocity data. A separate model was used to incorporate the phenomenon of "Moho Bounce"—where seismic waves reflect off the boundary between the Earth's crust and mantle (known as "the Moho"), with a depth to the Moho of about 29 km.[46]

D. MOX Facility Seismic Design Efforts

DCS built upon the work conducted by WSRC for SRS. DCS used two horizontal[47] spectra for the MOX Facility: one for motions at bedrock (located about 900 feet below the ground surface),[48] and one for motions at the ground surface.[49] To achieve the safety performance goals for the MOX Facility set forth in 10 CFR § 70.61 (*i.e.*, to ensure that high consequence events are highly unlikely), DCS used seismic design ground surface motions which lie between the existing SRS PC-3 and PC-4 spectra.[50]

For the ground surface, DCS used the spectral shape provided in NRC Regulatory Guide 1.60, with 5% damping, scaled to an effective 0.2 g PGA at 33 Hz (the "MOX Spectrum").[51] Reg. Guide 1.60 provides a conservative spectral shape encompassing the frequencies of structural interest for nuclear power plants; the Vogtle Electric Generating Plant located across the Georgia border from SRS also has its Reg. Guide 1.60 spectral

46 Dr. Stepp Affidavit ¶ 24.

47 DCS also evaluated vertical ground motion spectra, but GANE does not challenge the vertical spectra. *See* Dr. Long Transcript at 38:5-7 ("Q. Do you have any challenge to the vertical spectrum? A. No, I did not look in detail at the spectrum, or variations in the spectrum.")

48 *See* Dr. Long Transcript at 42:5-16.

49 *See* Revised CAR at 1.3.6-28, 1.3.6.-29.

50 *Id.*; Dr. Stepp Affidavit ¶ 27.

shape anchored at an effective 0.2 g PGA at 33 Hz.[52] The MOX Spectrum envelopes the PC-3 ground surface spectrum and does so with significant margin at frequencies of structural interest for the MOX Facility, which are between 2.5 and 9 Hz.[53] The MOX Spectrum is between the existing SRS PC-3 and PC-4 spectra. The PC-3 and PC-4 spectra used by DOE at SRS, and the Reg. Guide 1.60 spectrum used by DCS for the MOX Facility are depicted in Attachment E.

E. Procedural Background

DCS submitted the original CAR to the NRC on February 28, 2001.[54] GANE filed Contention 3 challenging the seismic design of the MOX Facility discussed in Sections 1.3.5 through 1.3.7 of the original CAR. Contention 3, entitled "Inadequate Seismic Design,"[55] states as follows:

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51 *See* Revised CAR at 1.3.6-28. GANE is no longer challenging the studies conducted by DCS to assess the potential for on-site soil shaking and liquefaction, *see* Revised Contention at 4, therefore, this Motion does not address that issue.

52 Reg. Guide 1.60 provides design response spectra for nuclear power plants at a default setting of 1.0g. These spectra represent the effects of the vibratory motion of the design earthquake on sites underlain by either rock or soil deposits. The design response spectra cover all vibrational frequencies of practical structural interest for nuclear power plants, which are between 2.5 and 9 hertz ("Hz"). *See* Reg. Guide 1.60 spectral shape. An applicant takes the Reg. Guide 1.60 design response spectra and linearly scales both the horizontal and vertical components to the ground motion expected for the design earthquake for that particular facility.

53 *See* Revised CAR at 1.3.6-28. The MOX Spectrum has a return period of 10,000 and 26,000 years at frequencies of 5 and 10 Hz, respectively. *See* Revised CAR at 1.3.6-45 (Table 1.3.6-7).

54 *See* Hearing File Document #29.

55 The title of Contention 3—Inadequate Seismic Design—is somewhat misleading. The contention does not challenge the adequacy of the seismic design of the MOX Facility's principal SSCs. Nor is Dr. Long capable of testifying on this issue. *See* Dr. Long Transcript at 375:11-14 ("I don't evaluate structures for vibrational response."). Rather, the Contention is limited to the assumptions used and relied on by DCS for the seismic hazard spectra. *See generally,* Transcript of April 18, 2002 Teleconference at 22 ("It

> In Sections 1.3.5 through 1.3.7 of the CAR, DCS specifies the design criteria for the MOX Fuel Fabrication Facility to withstand any potential geological hazard. DCS claims that "conservative design criteria" have been established. *Id.* at 1.3.6-23. This assertion is not supported, because DCS has not performed a seismic analysis that is either adequate in scope or adequately documented.[56]

Contention 3 was followed by a lengthy "Basis Statement" with two primary components challenging: (1) the CAR's discussion of the likelihood of a significant seismic event (*i.e.*, an earthquake); and (2) the response of the MOX Facility site to that earthquake. GANE raised numerous issues within each of these two components.

This Atomic Safety and Licensing Board ("Board") admitted Contention 3, in its entirety, in its December 6, 2001 Memorandum and Order.[57] DCS served two sets of interrogatories on GANE.[58] GANE replied to these interrogatories,[59] and supplemented its answers three times.[60] DCS also deposed Dr. Long. DCS submitted a revised CAR to

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seems to me that your contention focused on what is a Design Basis Earthquake") (comments of Judge Kelber).

56 Revised Contention at 1.

57 *Duke Cogema Stone & Webster* (Savannah River Mixed Oxide Fuel Fabrication Facility), Memorandum and Order (Ruling on Standing and Admissibility of Contentions) at 32-33 (Dec. 6, 2001).

58 *See Duke Cogema Stone & Webster's First Set of Interrogatories to Georgians Against Nuclear Energy and Blue Ridge Environmental Defense League* (May 31, 2002); *Duke Cogema Stone & Webster's Second Set of Interrogatories to Georgian's Against Nuclear Energy and Blue Ridge Environmental Defense League* (Dec. 6, 2002).

59 *See* First GANE Interrogatory Responses; *Georgians Against Nuclear Energy's Response to Applicant's Second Set of Interrogatories* (Dec. 20, 2002) ("Second GANE Interrogatory Response").

60 *See Georgians Against Nuclear Energy's First Supplemental Response to Applicant's First Set of Interrogatories* ("First GANE Supplemental Interrogatory Response") (Nov. 11, 2002); Second GANE Supplemental Interrogatory Response *Georgians Against Nuclear Energy's Third Supplemental Response to Applicant's First Set of Interrogatories* ("Third GANE Supplemental Interrogatory Response") (March 5, 2003)

the NRC on October 31, 2002.[61] GANE did not file an amended contention challenging changes in the CAR.

By the mutual agreement of GANE and DCS, the Basis Statement has been narrowed considerably, first through an Unopposed Motion granted by this Board, and then through stipulations and clarifications made by GANE during the Deposition of Dr. Long.[62] A Revised Contention and Basis Statement was included as "Long Exhibit No. 1" to the Deposition Transcript of Dr. Long, and is also attached to this Motion as Attachment A.

F. Overview of GANE's Remaining Issues Regarding Seismic Design

GANE challenges aspects of the EPRI and LLNL PSHAs, DCS's reliance on work conducted for SRS, and the work DCS conducted for the MOX Facility site. For convenience in discussing these issues, a summary is provided below of GANE's position as understood by DCS.

a. Challenges to the "Historical Check"

GANE challenges the crustal velocity model (known as the Herrmann Crustal Model) relied on by DCS for the "historical check." Dr. Long suggests that the Herrmann Crustal Model improperly models the ground motions at the MOX Facility site from the 1886 Charleston earthquake.[63] He estimates an error rate in the model in the

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[61] DCS, *MOX Facility Construction Authorization Request* at 1.3.6-28 (Oct. 31, 2002) ("Revised CAR") (Hearing File Document #121).

[62] *See Duke Cogema Stone & Webster* (Mixed Oxide Fuel Fabrication Facility), Memorandum and Order dated June 20, 2003 (granting unopposed motion to narrow contention 3); *see also* Dr. Long Transcript 403:9-13; 405:11-15; 416:6—417-4.

[63] Dr. Long Transcript at 428:7-9.

range of 10% to 50%. Specifically, GANE believes that a model should have been developed for the specific crustal path from Charleston to the MOX Facility site, rather than using the Herrmann Crustal Model's path of Bowman, S.C. to Atlanta, Georgia.[64] GANE also appears to believe that the model structure and velocities assigned to layers in the model scatter seismic wave reflections as the energy travels over a distance of 120 kms to the MOX Facility site.[65]

b. Challenges to the LLNL and EPRI PSHA studies

GANE has multiple challenges to use of the LLNL and EPRI PSHA studies:

1. GANE believes the EPRI and LLNL studies are inappropriate for site-specific applications. GANE believes the EPRI and LLNL studies were intended only as a "first guess" and were never intended to be the input for a specific site.[66] Accordingly, GANE believes that DCS should have conducted a new, comprehensive PSHA for the MOX Facility.

2. Even if used, GANE believes that the EPRI and LLNL studies are out of date and should be updated to take into account new information. This challenge has six components:

    2.1 GANE contends that the EPRI and LLNL studies did not adequately consider a theory contained in a paper authored by Kafka in 2002 which suggests that there is a 30% chance that a magnitude 7+ earthquake could occur virtually anywhere in South Carolina;

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64 *Id.* at 123:13-20.

65 *Id.* at 31:1-3; 124:5-15; Dr. Stepp Affidavit ¶ 34.

66 Dr. Long Transcript at 175:18.

2.2 GANE contends that the EPRI and LLNL studies did not adequately consider new information which suggests that a magnitude 7.5 earthquake could occur in the Eastern Tennessee Seismic Zone;

2.3 GANE contends that an article authored in 2001 by Talwani and Schaeffer regarding paleoliquefaction data suggests that Bluffton and Georgetown—in addition to Charleston—were epicenters for characteristic Charleston earthquakes, and that these sources were not previously considered in the EPRI and LLNL studies.

2.4 GANE contends that the Talwani and Schaeffer article also suggests that the return interval for major earthquakes (magnitude 7 or greater) in the South Carolina Coastal Plain ("SCCP") is much shorter than previously considered in the EPRI and LLNL studies.

2.5 GANE contends that a study of paleoliquefaction data authored by Hu *et al.* in 2002, suggests that the magnitudes of historical earthquakes in the SCCP may have been much greater than previously considered by the EPRI and LLNL studies;

2.6 GANE contends that the LLNL and EPRI studies did not adequately consider recent attenuation models, such as Atkinson and Boore (1995), which GANE alleges more accurately model a phenomenon where seismic waves are reflected off the boundary between the Earth's crust and mantle ("Moho Bounce").

GANE contends that if the aforementioned new information was taken into account, the ground motions for the MOX Spectrum would likely increase.

c. Challenges to 0.2 g PGA for the MOX Facility

Finally, GANE challenges the peak ground acceleration ("PGA") chosen by DCS to anchor the horizontal ground surface spectrum for the MOX Facility. Although GANE admits that the Reg. Guide 1.60 spectral shape "is appropriate to us[e] as the design earthquake for the MOX Facility," GANE believes that DCS should have scaled that spectrum to a higher PGA than 0.2 g.[67] GANE cites to the June 2002 U.S. Geological Survey Seismic Hazard Maps which show a return frequency for 0.2 g PGA for the MOX Facility of about 2,500 years, while DCS states that the return frequency for the 0.2 g PGA for the MOX Spectrum is approximately 10,000 years.[68]

V. CONTENTION 3 PRESENTS NO GENUINE ISSUES OF MATERIAL FACT, AND DCS IS ENTITLED TO DISPOSITION OF EACH ISSUE AS A MATTER OF LAW

DCS demonstrates below that each of GANE's remaining concerns with the seismic design for the MOX Facility can be adjudicated as a matter of law through summary disposition.

A. Adequacy of the Historical Check

As discussed in Section IV.C, above, DCS relied on studies which considered historical earthquakes within 200 km from the site that had magnitudes equal to or larger than 6.0. This "historical check" allows the design spectrum to, at a minimum, consider a repeat of the most severe documented historical earthquake for the site, in accordance with 10 CFR § 70.64(a)(2).

67 Second GANE Supplemental Answer 3.1 & 3.4. *See also* Dr. Long Transcript at 40:11-13.

68 Second GANE Supplemental Answer 3.2.

For the MOX Facility site, it is undisputed that the most severe documented historical earthquake is the 1886 Charleston earthquake.[69] As an historical check to the PC-3 spectrum, the median ground motions associated with the 1886 Charleston earthquake with a 7.3 moment magnitude and an epicenter located 120 km southeast of the site were used.[70] The median ground motions and attenuation path for the 1886 Charleston earthquake were modeled using a modification of a crustal velocity model known as the Herrmann Crustal Model.

1. GANE's Position

GANE challenges the crustal velocity model relied upon by DCS for the historical check. For support, GANE relies on the opinions of Dr. Long.[71]

Dr. Long admits that a 7.3 moment magnitude earthquake with an epicenter located 120 km southeast of the MOX Facility site is appropriate or conservative for modeling the 1886 Charleston earthquake.[72] Dr. Long also admits that the MOX Spectrum envelopes the ground motions associated with this historical check, as calculated.[73]

However, Dr. Long suggests that the Herrmann Crustal Model miscalculates the ground motions at the MOX Facility site from the 1886 Charleston earthquake. He

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69 First GANE Interrogatory Response 3.32 ("[t]he Charleston earthquake is the most severe documented historical seismic event that is relevant to the seismic design for the MOX Facility."); Dr. Long Transcript at 129:10-15. *See also* Revised CAR at 1.3.6-27.

70 *See* Revised CAR at 1.3.6-20 & Fig. 1.3.5-33.

71 GANE's Basis Statement makes no mention of the "historical check."

72 Dr. Long Transcript at 130:3-5 ("Q. Then what is the moment magnitude of the Charleston earthquake in 1886? A. Probably around 7.0"); 190:1-6 (120 kms is "realistic").

73 *Id.* at 215:16-20.

estimates an error rate in the model in the range of 10% to 50%.[74] For support of this error rate, GANE states that the Herrmann Crustal Model is "seriously outdated" and asserts that "DCS should have used information that is now available about the local crustal structure."[75] GANE describes the Herrmann Crustal Model as using "an average for a path from Charleston to Atlanta", and that "[m]uch of that path is significantly different from the part of the path to SRP [*sic*]."[76] Dr. Long believes that a specific crustal path from Charleston to SRS should have been used rather than using the existing Herrmann Crustal Model, which was developed using average velocities from Bowman, S.C. to Atlanta, Georgia:[77]

> A. [Herrmann's] model was from Bowman to Atlanta or ATL which contains velocities which are significantly different than they are on the coastal plain. His technique was a surface wave technique which takes an average velocity. The average velocity between those two points doesn't necessarily represent the individual velocities for any part of that path.
>
> Q. You said that the position is that the test earthquake from Charleston propagated to the site, if propagated by a proper model, would very likely indicate a higher vibration. What is your basis for saying it would very likely indicate a higher level of vibration?
>
> A. Herrmann's model includes a lower crustal layer of velocity . . . which probably does not exist. That intermediate layer in the model would cause reflections and amplitudes at shorter ranges to be higher and would decrease the energy available for the post critical reflection [or Moho Bounce]. This is a case where a proper model should be used to see what the actual effect is.
>
> Q. Have you done any modeling or any calculations to see what the actual effect is?
>
> A. In this particular case, no.[78]

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[74] *Id.* at 428:7-9.

[75] Second GANE Supplemental Interrogatory Response 3.3.

[76] Second GANE Interrogatory Response 3.45.

[77] Dr. Long Transcript at 123:13-20.

[78] *Id.* at 123:13-22; 124:1-15.

2. There is No Genuine Issue of Material Fact

The Board can dispose of this portion of Contention 3 without the need for testimony. In fact, the Board can dispose of this portion of Contention 3 without delving into the specific technical arguments raised by GANE, because the MOX Spectrum is sufficiently robust to accommodate even a 50% increase of the 1886 Charleston ground motions used as the historical check for the PC-3 spectrum.

Dr. Long suggests that the impact of using the Herman Crustal Model is an error in the ground motion at the site of 50% at most.[79] Even if one increases the ground motions by 50%, the MOX Spectrum still envelopes these dramatically increased ground motions for all frequencies above 0.8 Hz. Thus, the MOX Spectrum envelopes 150% of the 1886 Charleston ground motions produced by the historical check for the PC-3 spectrum for frequencies of structural interest.[80] This simple calculation is shown in graphical form in Attachment F. (The technical reasons why the MOX Spectrum is so robust are discussed by Dr. Stepp in ¶ 37 of his Affidvait.) Thus, GANE 's claim fails to raise any genuine issue of material fact.

In addition, GANE provided an error range of 10% to 50% before acknowledging that the Herrmann crustal model was revised to reflect shallow bedrock velocity data, and to incorporate the phenomenon of "Moho Bounce."[81] Thus, any error range is likely lower than 50%.

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79 *Id.* at 428:7-9.

80 As stated earlier, the frequencies of structural interest at the MOX Facility are between 2.5 and 9 Hz.

81 Dr. Long acknowledged that WSRC revised the Herrmann Crustal Model before using it, including in the model a simulation of the Moho Bounce. Dr. Long Transcript at 429:3-12; 435:3-8 ("Would you agree then that the path that was – or the model that was used

Moreover, Dr. Long has not conducted any studies for the purpose of determining any error that would have been caused by using the Herrmann Crustal Model:

> Q. But the distance response might be off by one or two percent with all of the changes they made -- you wouldn't know because you haven't done any calculations; is that right?
> A. I haven't done the calculations for this particular model.[82]

GANE offers only an unsubstantiated opinion without any supporting data or quantification of the potential impact of the alleged flaw identified, and this impact could be very small. Even so, the MOX Spectrum already bounds the upper limit of the potential impact (50%) posited by GANE's expert. Therefore, there is no material dispute regarding the fact that the MOX Spectrum adequately considers the "most severe documented historical events for the site" consistent with 10 CFR § 70.64(a)(2).

Finally, GANE dos not identify an alternative model to the Herrmann Crustal Model for DCS to consider.

Accordingly, this issue should be disposed of summarily.

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was modified to take into account the Moho Bounce? A. The [Ou &]Herrmann model apparently does take into account, according to this, the Moho bounce."); Ou, G.B. and R.B. Herrmann, *A Statistical Model for Ground Motion Produced by Earthquakes at Local and Regional Distances*, BSSA, 80, NO. 6, 1397-1417 (1990) (cited in Lee et al, WSRC-TR-97-0085, at 25); Dr. Long Transcript at 436:15-20.

82 Dr. Long Transcript at 436:15-20.

B. Challenge to the EPRI and LLNL PSHAs

GANE has multiple challenges to the LLNL and EPRI PSHA studies.

1. Site-Specific Use of EPRI and LLNL PSHA results

a. GANE's Position

GANE believes the EPRI and LLNL studies are inappropriate for site-specific application. GANE believes the EPRI and LLNL studies were intended only as a "first guess" and were never intended to be the input for a specific site. GANE's position is based on the opinion of Dr. Long:[83]

> Q. GANE has stated that EPRI and Livermore were intended for first-guess work only. Do you agree with that statement?
>
> A. I agree with the statement that the Lawrence Livermore and EPRI studies were intended to give a regional assessment of the hazard. That their application to a particular site was to be a first guess in the sense that any individual site should be reevaluated given the details of seismicity and details of attenuation relationships for that particular site. Seismicity and attenuation relationships used in EPRI and Lawrence Livermore were regional and meant to be used in a wide area.
>
> Q. What is your basis for that statement, just your understanding --
>
> A. That is my understanding. I remember asking someone about that and I don't remember who and when. It was someone involved in the studies. Basically, I had concern way back then, how can you use these generalized relationships for specific sites and I remember asking someone and he said they were not intended for a final answer but that any new site would have to be evaluated based on recent information.[84]
>
> * * *
>
> Q. What PSHA should an applicant for a MOX Facility use?
>
> A. I think they should redo it.[85]

[83] Dr. Long Transcript at 175:18.

[84] Dr. Long Transcript at 175:11—176:1-13.

[85] *Id.* at 197:21-22; 198:1.

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> Q. Do you know whether NRC regulations require an applicant for a MOX Facility to redo a PSHA for a MOX Facility site?
>
> A. No. It is just the understanding I had before from conversations that individual sites should be recomputed to take into account local conditions and variations.
>
> Q. What does take "into account local conditions and variations" -- are those site-specific or do they go 200 kilometers?
>
> A. They are probably site-specific and 200 kilometers is site-specific.[86]

Accordingly, GANE appears to believe that DCS should have conducted a new PSHA for the MOX Facility.

b. There is No Genuine Issue of Material Fact

GANE's concerns are contrary to NRC guidance and practice. NRC has a long standing history of using the LLNL and EPRI results in site specific applications.[87] In addition, NRC guidance explicitly allows an applicant to use the EPRI and LLNL PSHA study results for a specific site. NRC Regulatory Guide 1.165 explicitly permits the use of the EPRI and LLNL PSHA studies:

> To determine the [Safe Shutdown Earthquake] in the [Central and Eastern United Stated (CEUS)], an accepted PSHA methodology with a range of credible alternative input interpretations should be used. For sites in the CEUS, the seismic hazard methods, the data developed, and seismic sources identified by the Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI) have been reviewed and accepted by the staff.[88]

86 *Id.* at 198:8-22.

87 Dr. Stepp Affidavit ¶ 39.

88 NRC Reg. Guide 1.165, pp. 2-3.

The fact that the NRC permits the use of LLNL and EPRI studies demonstrates that GANE's allegations that those studies are not intended for site-specific use are misplaced.[89]

Moreover, Dr. Stepp has pointed out that the EPRI PSHA outputs were expected to be used for specific sites.[90] As the developer of the methodology for the EPRI PSHA, Dr. Stepp has first hand knowledge.[91]

Dr. Long is simply unfamiliar with regulatory requirements and he freely admits that his teaching and research have "stayed pretty much on the science end of it, not the regulatory end."[92] For this reason, Dr. Long is not an expert regarding NRC regulations or guidance.[93] In fact, Dr. Long has not once read through the seismic design regulations in 10 CFR Part 70 or the MOX SRP.[94] Nor has Dr. Long ever developed a seismic response spectrum for a nuclear facility.[95] Dr. Long's lack of familiarity with NRC regulations and guidance explains his failure to consider them, but it does not create a material fact in dispute.

Dr. Long's point of reference also demonstrates that his concerns have little regulatory significance. Dr. Long appears to be more interested that DCS use a "correct"

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89 DOE also permits use of the LLNL and EPRI PSHA studies. DOE Standard 1023 allows a facility's seismic design to use an average of the mean hazard curves from the EPRI and LLNL studies. DOE-STD-1023-95, p. 6 (Section 3.1.2.1).

90 Dr. Stepp Affidavit ¶ 41.

91 *Id.*

92 Dr. Long Transcript at 59:6-8.

93 *Id.* at 115:6-8 (not familiar with NRC regulations); 143:8-10 (no experience with NRC regulations); 139:13-19 (not an expert with NRC regulations and guidance); 144:13-21 (not familiar with NRC guidance including the MOX SRP); 145:3-4 (not familiar with Reg. Guide 1.60).

94 *Id.* at 115:10-11 (10 CFR Part 70); 144:18-21 (MOX SRP).

hazard spectrum than that DCS use a hazard spectrum that is appropriately conservative, consistent with regulatory requirements and accepted standards of practice:

> Q. Would you agree that if the Livermore and EPRI studies are wrong in your view, but are wrong on the conservative side, would they be acceptable to use?
> A. I think you should establish that they are not in error. I think you should establish what is a correct value and determine whether or not your error or conservative values are above or below the correct value.
> Q. Your assumption is that it should be correct, not more conservative, not less conservative?
> A. Yes.[26]

Also, when asked if DCS would have satisfied the NRC's requirements by the fact that NRC found it acceptable to use the EPRI or LLNL studies, Dr. Long answered that "[i]n a legal sense it would have . . . but perhaps not in a moral sense."[27]

Accordingly, this is an issue which can easily be adjudicated through summary disposition.

2. Updating the EPRI and LLNL PSHA results

If used, GANE believes that the EPRI and LLNL studies are out of date and should be updated to take into account new information. In support of this claim, GANE's expert, Dr. Long, indicates that the following "new" information should be taken into account:

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25 *Id.* at 153:16-18.

26 *Id.* at 303:14—304:4.

27 *Id.* at 302:18-19.

1. Floating Magnitude 7+ Earthquakes – a theory in a recently published paper that "large" magnitude earthquakes could occur just about anywhere.

2. Consideration of a 7.5 Magnitude Earthquake in the Eastern Tennessee Seismic Zone – a supposition that a "New Madrid-type" magnitude 7.5 earthquake could occur in the Eastern Tennessee Seismic Zone.

3. "Additional" Epicenters for a Charleston-Type Earthquake – epicenters for large earthquakes at Georgetown and Bluffton, South Carolina, should be considered based upon recently published re-analysis of pre-existing paleoliquefaction data.

4. Shorter Recurrence Interval for Charleston-Type Earthquakes – a recently published theory regarding the recurrence interval for large magnitude Charleston-type earthquakes, which GANE suggests is shorter than previously thought.

5. Increased Magnitude of Historical Earthquakes on the SCCP – a recently published theory concluding that paleoliquefaction data suggests that there have been a greater number of major earthquakes (above magnitude 7) in the South Carolina Coastal Plain ("SCCP") than previously thought.

6. Consideration of New Ground Motion Attenuation Models – a supposition that recently developed ground motion attenuation models might produce higher ground motions for the MOX Facility site than those produced in the EPRI and LLNL PSHAs.

Upon review of the facts, it becomes clear that there is no genuine issue of material fact. Either the "new" information identified by GANE is not in fact new, but rather was previously considered in development of the MOX Spectrum, or the new information does not support the conclusion suggested by GANE. Each of these issues is discussed below.

2.1 <u>Floating magnitude 7+ earthquakes</u>

a. GANE's Position

GANE contends that the EPRI and LLNL studies did not adequately consider the potential (30% probability) that a magnitude 7+ earthquake could occur virtually

anywhere in South Carolina.[98] For support, GANE relies on the opinions of Dr. Long and a statistical theory contained in a paper authored by Kafka in 2002.[99]

b. There is No Genuine Issue of Material Fact

The Board can also summarily dispose of this part of the contention. The hypothesis of major earthquakes potentially occurring anywhere was, in fact, considered among the range of alternative interpretations that were input into the EPRI and LLNL PSHAs. Thus, GANE's interpretation of Kafka's theory does not represent "new" information. In addition, Kafka's paper did not consider any earthquake above a magnitude 4.8 in the Southeast United States, so its relevance to seismic design of nuclear facilities is not clear. Finally, the floating earthquake theory is not generally accepted in the scientific community.

The principle suggested by Dr. Long, that magnitude 7+ earthquakes could occur anywhere, was considered in the seismic design of the MOX Facility. It is undisputed that the EPRI and LLNL studies included alternative interpretations that major earthquakes could occur practically anywhere along the eastern seaboard/United States:

> Q. Do you think the opinion of Kafka was taken into account by one of the opinions in the Livermore or EPRI studies?
> A. In a very general sense it might have been included. I think, yes, there was at least one expert who said we have no idea where the major earthquakes will occur next. Does that have an effect? Yes. That expert would have one extreme view. Other experts had other views and they were averaged out.[100]

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98 Second GANE Supplemental Interrogatory Response 3.7 ("significant probability (30%) that new [earthquakes] will be in new areas").

99 A.L. Kafka, *Statistical Analysis of the Hypothesis that Seismicity Delineates Areas Where Future Large Earthquakes Are Likely to Occur in the Central and Eastern United States*, Seismological Research Letters, Vol. 73, p. 992-1003 (Nov./Dec. 2002) ("Kafka").

100 Dr. Long Transcript at 360:7-16; *see also Id.* at 15:19-22 ("the Lawrence Livermore studies pulled in a lot of information on proposed and hypothesized mechanisms with

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Q. So, for example, one expert may have placed a 7.5 earthquake anywhere on the Carolina coastal plain . . .?
A. That is right.[101]

Dr. Long continues by arguing that the impact of taking into account these scenarios would be different today, but as discussed in Section V.B.1, above, NRC guidance allows use of the EPRI and LLNL studies without re-weighing epicenters as suggested by GANE.[102]

Moreover, this theory can be set aside in this proceeding because only small and microearthqukes were used to test it. Kafka's analysis for the Southeastern United States ("SEUS")—the area related to the MOX Facility—compared "small" (2.0 to 3.0 magnitude) and "large" (3.0 to 4.8 magnitude) earthquakes for the period between 1924 and the present.[103] Kafka concluded that during this period, about 60% of the "large" earthquakes in the SEUS had epicenters located within about 30 km of where small earthquakes had occurred.[104]

Kafka then compared the "largest" earthquakes in the SEUS from 1988-2001 (three events magnitude 4.3-4.8) to see whether they had epicenters located within about 30 km of smaller earthquakes. From this, GANE claims that Kafka's statistical work

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experts <u>varying from a large earthquake can occur anyplace for any reason</u> to very specific zones") (emphasis added); *Id.* at 81:18-19 ("One expert had the whole east coast in one big zone.").

101 Dr. Long Transcript at 256:10-15.

102 *See also* Dr. Stepp Affidavit ¶ 43.

103 Kafka at Figure 1. Kafka's use of the term "large" is misleading; not even Dr. Long would consider a magnitude 3.0 earthquake to be large. Dr. Long Transcript at 177:10-12.

104 Kafka at Table 1.

shows that there is a 30%+ chance that a large earthquake (magnitude 7+) could appear anywhere.

Kafka has no demonstrated applicability to a major (magnitude 7+) earthquake on the SCCP.[105] The data set used by Kafka did not include any earthquakes before 1924, so it necessarily excluded the 1886 Charleston earthquake and all the paleoearthquakes associated with the Charleston Seismic Zone. In fact, as a statistical paper, it purposefully ignored all known geologic/liquefaction data associated with the South Carolina Coastal Plain.[106]

Also, Kafka's data set for the SEUS was limited to small and microearthquakes with comparison to only three earthquakes between magnitude 4.3 and 4.8. The scientific community generally accepts the observation that small and microearthquakes can occur essentially anywhere.[107] This observation does not, however, support an extrapolation of the Kafka results to large and major earthquakes.[108]

Moreover, Kafka's theory is not generally accepted in the scientific community. Kafka himself states that it is "still 'exploratory.'"[109] Even Dr. Long believes Kafka's theory is "a pioneer paper."[110] This is consistent with Dr. Long's statement that for the EPRI or LLNL studies, one expert "drew a big circle around the whole eastern United

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105 Dr. Stepp Affidavit ¶ 44.

106 Dr. Long Transcript at 364:8-11 ("Q. As an academic exercise, would you agree that Kafka specifically ignored geology and any known geologic features? A. Yes.").

107 Dr. Stepp Affidavit ¶ 46.

108 *Id.*

109 Kafka, at 1002.

110 Dr. Long Transcript at 358:10.

States and said you can have events anyplace and gave a rate for it. That is one outlier."[111]

Kafka's position is also undermined by the other articles GANE cites, namely Talwani & Schaeffer (2001) and Hu *et al.* (2002) (discussed below in Sections V.B.2.3. and 2.5). Those papers discuss the paleoliquefaction features on the SCCP believed to be caused by earthquakes that occurred over the past 6,000 years. Those studies do not indicate that major earthquakes occur in new places.

Accordingly, Kafka raises no material issues for resolution at a hearing.

2.2 Consideration of a 7.5 Magnitude Earthquake in the Eastern Tennessee Seismic Zone

a. GANE's Position

GANE contends that the EPRI and LLNL studies did not adequately consider Dr. Long's opinion that a magnitude 7.5 earthquake could occur in the Eastern Tennessee Seismic Zone. "In particular, a New Madrid type Event (Magnitude 7.5) should be considered for southeastern Tennessee for evaluation of potential effects on the Savannah River Site."[112] GANE's support for this issue is the opinion of Dr. Long. GANE contends that if this new information were taken into account, the ground motions for the MOX Facility's seismic hazard spectra would likely increase.

b. There is No Genuine Issue of Material Fact

This concern can be summarily disposed of for a number of very simple reasons. First, it is undisputed that the EPRI and LLNL PSHA studies did consider the possibility

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111 *Id.* at 158:1-3.

112 Second GANE Interrogatory Response 3.45(a).

of a 7.5 earthquake in southeastern Tennessee. As discussed in Section IV.B, above, many experts were involved in the EPRI and LLNL studies. They developed alternative evaluations regarding the location of earthquake source zones and the magnitude of earthquakes that could occur in those zones.[113] At least one interpretation was included in both of those studies which placed a 7.5 earthquake in the Eastern Tennessee Seismic Zone.[114] In addition, Dr. Long himself admits that, when he was an expert on the LLNL seismology panel, he would have assigned a 7.0 to 7.8 magnitude for an earthquake in Southeast Tennessee,[115] and that one expert "drew a big circle around the whole eastern United States and said you can have events anyplace and gave a rate for it."[116] Accordingly, GANE is simply not correct that a 7.5 magnitude earthquake for southeastern Tennessee was not previously considered by DCS.

Second, it is not generally accepted that a 7.5 magnitude earthquake could occur in this zone. Southeast Tennessee is an area of frequent small earthquakes, but none of these earthquakes has had a moment magnitude greater than about 5.[117] Even Dr. Long admits that "when I talk about eastern United States major earthquakes, I am probably a bit of an outlier in the sense that [earthquakes] are not due to existing faults but due to weaknesses in crusts which evolve in both the earthquake and the fault."[118] Dr. Stepp concludes that the geophysical structure underlying the Eastern Tennessee Seismic Zone

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[113] *See e.g.* Dr. Long Transcript at 82:11-18; 83:22; 84:1-7.

[114] Dr. Stepp Affidavit ¶ 48.

[115] Dr. Long Transcript at 93:13-22.

[116] *Id. at* 158:1-3.

[117] Dr. Stepp Affidavit ¶ 49.

[118] Dr. Long Transcript at 159:2-5.

is very unlikely to support magnitude 7+ earthquakes.[119] Dr. Stepp's opinion is consistent with the views generally accepted in the scientific community regarding this seismic zone.[120]

Accordingly, this issue raises no material issues for resolution at a hearing.

2.3 "Additional" Epicenters for Charleston-Type Earthquakes

a. GANE's Position

GANE claims that DCS did "not consider recent paleoseismic work on the South Carolina Coastal Plain ("SCCP") showing more seismic activity in the last 6,000 years, and over a wider area, than previously known."[121] Specifically, GANE contends that Bluffton and Georgetown—in addition to Charleston—were epicenters for characteristic Charleston earthquakes over the past 6,000 years, and that these epicenters were not previously considered by DCS. GANE relies on the opinion of Dr. Long and an article published in 2001 by Talwani & Schaeffer[122] which discusses paleoliquefaction along the coast of South Carolina. GANE's Basis Statement states:

> As DCS states at page 1.3-5, excavation and detailed analyses of the "liquefaction flow features" in the area of the 1886 Charleston, South Carolina earthquake provided the "first insight into the pre-history of the Charleston earthquake." On page 1.3.5-41-42 of the CAR, the applicant notes four pre-1886 liquefaction events on the coastal plain linked to Charleston events. A liquefaction episode is

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119 Dr. Stepp Affidavit ¶ 50.

120 *Id.*

121 Revised Contention at 1.

122 P. Talwani & W. Schaeffer, *Recurrence rates of large earthquakes in the South Carolina coastal plain based on paleoliquefaction data*, Journal of Geophysical Research, v. 106, No. B4, 6621-6642 (Apr. 10, 2001) ("Talwani & Schaeffer") (included as Exhibit 5 to GANE Contentions (August 2001). GANE's reference to "Talwani Pradeep and Schaeffer" appears to be incorrect since "Talwani" is the last name of "Pradeep;" *i.e.*, they are the same person.

caused by ground shaking strong enough for soils to start to flow like a liquid. A strong enough earthquake will leave features such as sand craters, sand vents and sand fissures, as described in the application. Once located, these relict features can be dated and provide a rough timeline of pre-historic seismic events. However, the features cannot usually be used to pinpoint the earthquake location. DCS claims that paleoliquefaction episodes in areas other than the Charleston coastal plane [*sic*] are not addressed in the literature, and are also unlikely because of the different geology. CAR at 1.3.5-43.

> Most regional paleoseismic work has only dealt with events in the Charleson [*sic*] Seismic Zone because liquefaction features were originally located there. A recent paper by Talwani Pradeep and Schaeffer, indicates . . . that major events need not be limited to the Charleston seismic zone. [citation omitted].[123]

b. <u>There is No Genuine Issue of Material Fact</u>

GANE solely relied on Talwani & Schaeffer to support its Basis Statement that the CAR "do[es] not consider recent paleoseismic work on the South Carolina Coastal Plain showing more seismic activity . . . over a wider area, than previously known."[124] As discussed below, Talwani & Schaeffer conducted no new work on the SCCP for DCS to consider, and not even Dr. Long believes that Talwani & Schaeffer show seismic activity over a wider area than previously known.[125]

As its title indicates, Talwani & Schaeffer (2001) focused on <u>recurrence rates</u> of large earthquakes on the SCCP, not their location.[126] In the context of discussing recurrence rates, Talwani & Schaeffer also discussed two scenarios to explain the

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123 Revised Contention at 1-2.

124 *Id.* at 1.

125 Dr. Long Transcript at 257:21—258:3 (Q. So you are pointing to this one paper and GANE is stating that this paper shows that there is seismic activity over a wider area than previously known? A. I don't think it says that. . . .).

126 *See* Footnote 122, above.

location of existing paleoliquefaction data.[127] One scenario places the epicenter of all earthquakes near Charleston, S.C. The other places the epicenters near Bluffton, S.C., Georgetown, S.C., and Charleston. Bluffton is located on the Atlantic Coast of South Carolina, but south of Charleston, near the Georgia/South Carolina border.[128] Georgetown is also located along the Atlantic Coast, but north of Charleston.[129]

However, Talwani & Schaeffer conducted no new work regarding the location of Charleston-type earthquakes for DCS to consider. Talwani & Schaeffer state in the very first sentence of the Abstract to their article, that they merely "present a reanalysis of results of 15 years of paleoliquefaction investigations in the South Carolina Coastal Plain."[130] Thus, the two scenarios discussed in Talwani & Schaeffer are not new.

In fact, these two scenarios were raised a decade earlier in a document explicitly referenced by Talwani & Schaeffer.[131] In 1990, NUREG/CR-5613 identified liquefaction features to the north and south of Charleston in the same locations as the Bluffton and Georgetown locations identified in Talwani & Schaeffer.[132] The NUREG even includes explanations for the presence of the liquefaction features located to the north and south of

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127 Talwani & Schaeffer at 6621 (Abstract).

128 *See* Attachment F. GANE's Basis Statement suggested that "major events may have occurred much closer to the SRS than the Charleston Seismic Zone," and it appears that GANE believed that Bluffton is located closer to SRS than the Charleston Seismic Zone. However, Bluffton is not closer. Dr. Long concedes this fact. *See* Dr. Long Transcript at 317:18—318:1 ("Q. Do you know why in the contention they state that Bluffton is closer. A. No. Q. Do you agree? A. I think that was in there before I came on.").

129 *See* Attachment F.

130 Talwani & Schaeffer at 6621 (Abstract).

131 Talwani & Schaeffer at 6641.

132 D. Amick et al, *Paleoliquefaction Features Along the Atlantic Seaboard*, NUREG/CR-5613, p. 77, Fig 10.2 (1990). This NUREG was included as a reference to Lee et al, WSRC-TR-97-0085, at 48.

Charleston, including that earthquake epicenters could have been outside of Charleston.[133]

Moreover, Dr. Long admits that Talwani & Schaeffer's opinions are not new:

> Q. So the opinion here is not necessarily a new opinion about location of earthquakes since the opinion that an earthquake could occur anywhere on the coastal plain has been out there for 20 years?
> A. That is true, yes. That idea has been around for a long time.[134]

Finally, and most importantly, the scenario presented in Talwani & Schaeffer and NUREG/CR-5613 of epicenters located along coastal South Carolina, but outside of Charleston, was considered in the seismic design of the MOX Facility.[135] In addition, the EPRI and LLNL studies included alternative evaluations that major earthquakes could occur practically anywhere along the eastern seaboard/United States:

> Q. So, for example, one expert may have placed a 7.5 earthquake anywhere on the Carolina coastal plain, not just limited to the three places Talwani and Schaeffer did?
> A. That is right.
> Q. So, for Livermore and probably EPRI, there are opinions that encompass the locations identified in the Talwani and Schaeffer paper?
> A. That would be true.[136]

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133 NUREG/CR-5613, p. 98 ("they could be the result of liquefaction associated with seismic events originating outside the Charleston epicentral area"); p. 117 ("this earthquake [1800+-200 years ago] could have originated in the Georgetown/Myrtle Beach area").

134 Dr. Long Transcript at 257:15-20.

135 NUREG/CR-5613 was included as a reference to the SRS seismic response analysis relied upon by DCS. *See* Lee et al, WSRC-TR-97-0085, at 48.

136 Dr. Long Transcript at 256:10-18. Dr. Long continues by arguing that the impact of taking into account these scenarios would be different today, but as discussed in Section V.D.1.c, above, NRC guidance allows use of the EPRI and LLNL studies without re-weighing epicenters as suggested by GANE.

Thus, Talwani & Schaeffer did not present any new information for DCS to consider regarding location of earthquakes in coastal South Carolina.

Even if the Talwani & Schaeffer discussion of locations was new, GANE has not provided any support that consideration of these locations would increase the ground motions of the design earthquake for the MOX Facility. Dr. Long admits that "it may or may not change any of the results,"[137] and he has conducted no independent analyses to suggest the seismic hazard would increase.[138] The burden to sustain this issue in the proceeding now is much higher than when GANE sought to admit the contentions, and GANE has not met that burden. Accordingly, GANE has not supported its argument that there is "more seismic activity . . . over a wider area, than previously known."[139]

This issue also should be disposed of summarily.

2.4 Shorter Recurrence Interval of Charleston-Type Earthquakes

a. GANE's Position

Using the same Talwani & Schaeffer article, GANE contends that the recurrence interval for characteristic Charleston earthquakes along coastal South Carolina is much shorter than previously considered in the EPRI and LLNL studies.[140] GANE claims that

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137 Dr. Long Transcript at 272:19—273:1; *see also Id.* at 316:7-13 ("If one were to revise then the [PSHA] and utilize this new information, then the results may change") (emphasis added).

138 *Id.* at 45:7-11 ("I have not done computations for this. I have simply looked at the data and expressed opinions based on my experience and background, I guess back-of-the-envelope calculations I have done, but not actual analyses.").

139 Revised Contention at 1.

140 *See* Revised Contention at 2 ("the frequency of major events is higher in the South Carolina Coastal Plain than previously thought").

"One scenario [in Talwani & Schaeffer] calls for seven magnitude seven (or stronger) Charleston events in the last 6,000 years, with a recurrence interval of 600 years."[141]

b. There is No Genuine Issue of Material Fact

On its face, GANE's argument makes little sense. Seven earthquakes in the last 6,000 years can not have an average recurrence interval of 600 years. Rather, simple math shows that 6,000 years divided by seven events yields an average of 857 years. What GANE appears to be referring to is the greater weight placed by Talwani & Schaeffer on the recurrence interval of the few most recent Charleston-type earthquakes, which is about 600 years.[142]

Even this hypothesis of a 600 year recurrence interval is not new. Again, NUREG/CR-5613, published more than a decade before Talwani & Schaeffer, states that "[t]he paleoliquefaction data suggest that the apparent return interval between liquefaction episodes has decreased from as much as 2000 years during the mid-Holocene times to about 600 years in more recent times."[143] And as stated above, NUREG/CR-5613 was included in the seismic design of the MOX Facility.[144] Moreover, new information regarding the magnitude of earthquakes causing liquefaction on the SCCP does not support a 600 year return interval for magnitude 7 earthquakes as GANE suggests, but rather for magnitude earthquakes ranging between 5.3 and 6.8, as discussed below in Section 2.5.

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141 *Id.*

142 Talwani & Schaeffer at 6641 (focusing on "four Charleston earthquakes before 2000 years B.P.").

143 NUREG/CR-5613, p. xii (emphasis added).

144 NUREG/CR-5613 was included as a reference to the SRS seismic response analysis relied upon by DCS. *See* Lee et al, WSRC-TR-97-0085, at 48.

For these reasons, the Board can dispose of this issue summarily.

2.5 Increased Magnitude of Historical Earthquakes on the SCCP

a. GANE's Position

GANE contends that magnitudes of historical earthquakes in the SCCP may have been much greater than previously considered by the EPRI and LLNL studies. For support, GANE relies on the opinion of Dr. Long, who relies on two articles discussing a recent study of paleoliquefaction data from the SCCP authored by Hu, Gassman, and Talwani ("Hu *et al.* 1 and 2") in 2002.[145]

b. There is No Genuine Issue of Material Fact

The Board can summarily dispose of this issue because Hu *et al.*'s conclusions are not valid. It has now been demonstrated that Hu *et al.* relied on a flawed assumption regarding soil strength.

Hu *et al.* 1 describes soil properties (strength, sand and silt content, *etc.*) analyzed from new soil samples collected at known paleoliquefaction sites. Hu *et al.* 2 attempts to estimate magnitudes and accelerations of paleoearthquakes based on soil properties at the locations of the paleoliquefaction features collected for Hu *et al.* 1. The magnitudes generated in Hu *et al.* 2 (which are as high as 7.8) for earthquakes that occurred over the past 6,000 years on the SCCP are larger than the magnitudes identified for those same events in Talwani & Schaeffer.

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145 *See* Second GANE Supplemental Interrogatory Response, General Interrogatory 3 (identifying Ke Hu, Sarah L. Gassman, and Pradeep Talwani, *In-situ Properties of Soils at Paleoliquefaction Sites in the South Carolina Coastal Plain*, Seismological Research Letters, v. 73, No. 6. 964-978 (2002); Ke Hu, Sarah L. Gassman, and Pradeep Talwani, *Magnitudes of Prehistoric Earthquakes in the South Carolina Coastal Plain from Geotechnical Data*, Seismological Research Letters, v. 73, No. 6, 979-991 (2002)).

Hu *et al.* 1 is flawed because the authors did not correct the soil strength data to account for aging.[146] This is significant because old soil deposits are more resistant to liquefaction than younger deposits. As Dr. Long explains:

> A. Geologists learn early in their career that the strength or hardness of the rock is a function of age, that rocks change with age, that they condense, they compress, and they get sometimes stiffer and harder.[147]
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> * * *
>
> My opinion is that an older soil would be a more stable soil and that with time it would take a higher acceleration to cause liquefaction, so if [Hu *et al.*] assumed it was younger, then it would perhaps take a lesser acceleration to cause liquefaction.[148]

Consequently, the calculation of earthquake magnitude in Hu *et al.* 2 would have to be lowered if it was determined that less acceleration was required to cause liquefaction.

Hu *et al.* did not consider how aging affects soil strength. Specifically, they used current soil strengths rather than correcting these to obtain the strength of the soil at the time of the prehistoric earthquake.[149] Consequently, Hu *et al.* overestimated the strength of the soils, resulting in an assumption that a higher magnitude earthquake would be needed to liquefy those soils.[150] This flaw was very recently discussed in a Masters Thesis prepared at the University of South Carolina.[151] By correcting for aging, the author of that Thesis concluded that "the prehistoric earthquakes that occurred during the

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146 Dr. Stepp Affidavit ¶ 61.

147 Dr. Long Transcript at 296:17-21.

148 *Id.* at 297:12-17.

149 Hu *et al.* 1 at 977 ("source sands in SCCP were associated with 200,000-year old sands, where as the empirical relations developed elsewhere were primarily associated with younger Holocene sands.")

150 Dr. Stepp Affidavit ¶ 61.

past 6,000 years and caused paleoliquefaction features in the SCCP have magnitudes ranging from 5.3 to 6.8."[152]

This flaw is not likely to come as a surprise to the authors of the Hu *et al.* papers for two reasons: they acknowledge in Hu *et al.* 1 that they did not correct for aging;[153] and two of the authors—Sarah Gassman and Pradeep Talwani—oversaw the Masters Thesis as evidenced by their signatures on its cover page.[154]

Nor can Dr. Long dispute these findings. Dr. Long can not provide an expert opinion on the issue of how soil properties can affect magnitude because Dr. Long admits he is not an expert in this field.[155] In short, Dr. Long provides no independent analysis and the only analysis upon which he relies has been discredited.

Accordingly, there is no material issue for hearing.

2.6 Consideration of new ground motion attenuation models

a. GANE's Position

GANE contends that the LLNL and EPRI studies did not adequately consider recent attenuation models, which GANE contends more accurately model post-critical

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151 Leon, E, *Effect of Aging of Sediments on Paleoliquefaction Evaluation In the South Carolina Coastal Plain*, Dept. of Civil and Envt'l Engineering, U. of S.C. (2003)("Leon").

152 *Id.* at iv.

153 Hu *et al.* 1, at 977.

154 *See* Leon (cover approval page); *see also* Dr. Stepp Affidavit ¶ 63.

155 *See* Dr. Long Transcript at 278:21 (because "[t]hat is really not my field"); *Id.* at 280:19-22 ("I don't feel that is an area where I am an expert, nor do I need to know that material for assessment of seismicity").

reflection.[156] The issue of "post critical reflection" is a phenomenon where seismic waves are reflected off the boundary between the Earth's crust and mantle—called the Mohorovicic (or "Moho") discontinuity.[157] This discontinuity is located about 29 kms beneath the ground surface in the vicinity of Charleston and the MOX Facility site.[158] This phenomenon is referred to as the "Moho Bounce," and results in non-uniform decay of seismic energy in a distance range of between 80 and 120 kms.[159]

GANE states that it "generally agrees that the approach taken by DCS in computing the PSHA is appropriate."[160] However, GANE states that:

> DCS relied on attenuation data inherent in the LLNL and EPRI studies referenced in the Supplemental CAR, without taking into account more recent studies that provide more detailed and site-relevant information. As a result, it is likely that DCS has underestimated the amplitude of the design basis earthquake at the Savannah River Site.[161]

GANE also states that DCS relied on the EPRI and LLNL studies which "did not appropriately model the attenuation of earthquake [ground motion] amplitude over a

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156 The Basis Statement does not mention recent attenuation studies. Rather, the Basis Statement is limited to the statement that: "In addition, the approach to the PSHA has been insufficiently conservative." Revised Contentions at 4.

157 Dr. Stepp Affidavit ¶ 25.

158 *Id.*

159 *Id.*

160 Third GANE Supplemental Interrogatory Response 3.30; Dr. Long Transcript at 135:8-22 ("DCS has taken a standard procedure"); *Id.* at 136:1-13 ("that is generally the approach that most seismologists take").

161 Second GANE Supplemental Interrogatory Response, General Interrogatory 3. GANE acknowledges, however, that the "shape of the spectra would remain largely unchanged, although there are some variations in the frequency content that occur with a change in magnitude." Second GANE Supplemental Interrogatory Response 3.14.

distance of approximately 110 [km] . . . because they assumed uniform decay of amplitude over that distance."[162]

During his deposition, Dr. Long only identified one ground motion attenuation model he thought DCS should have considered, namely Atkinson & Boore (1995).[163] He further claimed that if the Atkinson & Boore model was used, it would result in an increase in amplitude at the MOX Facility from a factor of two to four.[164]

b. There is No Genuine Issue of Material Fact

This part of the Contention should also be summarily disposed of because the EPRI and LLNL studies include assessments of uncertainty in ground motion attenuation that adequately consider the new attenuation model identified by GANE.

Numerous new ground motion attenuation models have been published since the EPRI and LLNL PSHA studies were published. These studies include Atkinson and Boore (1995), but they also include many others published after 1995: such as Frankel (1996), Toro, et al. (1997), Sommerville (2001), and Campbell (2002).[165]

Dr. Long has only identified Atkinson and Boore (1995); in fact, he believes it is questionable whether the other models identified above are appropriate for ranges of 80 to 100 kms.[166] Dr. Long appears to favor Atkinson and Boore (1995) because the curve presented in that model exhibits pronounced non-uniform decay to account for the "Moho Bounce." "Moho Bounce" is dependent on the depth of the earthquake and the thickness

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162 Third GANE Supplemental Interrogatory Response 3.6.

163 Atkinson, G.M. and Boore, D.M., *Ground-Motion Relations for Eastern North America*, BSSA, Vol. 85, No. 1 pp. 17-30 (Feb. 1995) (Long Deposition Exhibit No. 5).

164 Dr. Long Transcript at 46:20-22; 47:1-4.

165 Dr. Stepp Affidavit ¶ 66.

of the Earth's crust along the travel path of the seismic energy, and it is primarily important for earthquakes that have epicenters located between about 80 and 120 kms from the MOX Facility site.[167] Accordingly, it would be important to take into account "Moho bounce" when modeling a repeat of the 1886 Charleston earthquake, which was placed 120 kms from the site. That is why a model that incorporated "Moho bounce" was used in the calculation of the "historical check."

However, it is unclear why consideration of Atkinson and Boore (1995) would materially affect the seismic design of the MOX Facility.[168] Consideration of Moho Bounce in a PSHA is different than for an "historical check." A PSHA takes into account, with various weights, multiple earthquakes at multiple distances and azimuths with respect to a particular location.[169] Many of these locations are <u>not</u> within the distance range where Moho bounce would occur. Moho Bounce—and thus, Atkinson & Boore (1995)—would not be applicable for these potential earthquake locations.

In any event, as discussed in detail by Dr. Stepp, the ground motion attenuation uncertainty assessments used in the LLNL and EPRI PSHAs envelope the Atkinson and Boore (1995) model such that consideration of that model would not materially affect the MOX Facility seismic design.[170]

The LLNL and EPRI studies have been approved for use by the NRC, and GANE has provided no genuine issue as to why the experts' assessment of uncertainty used in

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166 Dr. Long Transcript at 424:15—425:3.

167 Dr. Stepp Affidavit ¶ 67.

168 *Id.* at ¶ 69

169 *Id.*

170 *Id.* at ¶ 71.

the EPRI and LLNL studies are not sufficiently broad to capture the uncertainty in different attenuation models, including the Atkinson & Boore (1995) model.

C. USGS Hazard Maps

The U.S. Geological Survey ("USGS") publishes seismic hazard maps for the entire United States. These hazard maps are revised periodically, with the latest revisions dated June 2002.

1. GANE's Position

GANE attempts to make a meaningful comparison between the USGS hazard maps and the MOX Spectrum. GANE challenges the 0.2 g effective PGA used by DCS to anchor the Reg. Guide 1.60 horizontal ground surface spectrum at 33 Hz for seismic design of the MOX Facility. Although GANE admits that the Reg. Guide 1.60 spectral shape "is appropriate to [u]se as the design earthquake for the MOX Facility" GANE believes that DCS should have scaled that spectrum to a higher PGA than 0.2 g.[171]

For support, GANE points to the June 2002 U.S. Geological Survey Seismic Hazard Maps which allegedly show a return period for 0.2 g PGA at the MOX Facility site of about 2,500 years, while DCS states that the return period for the 0.2 g effective PGA for the MOX Spectrum is approximately 10,000 years.[172] Dr. Long retrieved this

171 Second GANE Supplemental Answer 3.1 & 3.4. *See also* Dr. Long Transcript at 40:11-13 ("Q. Do you have any concern with the shape of the surface spectra for the MOX Facility? A. In general, no.").

172 GANE's Basis Statement makes no mention of the USGS Hazard Maps for 2002 since that revision was not available at the time the Contention was drafted.

information from the USGS website.[173] GANE does not specify what the higher PGA should be, nor does Dr. Long have an opinion as to how high it should be.[174]

2. There is No Genuine Issue of Material Fact

As an initial matter, even Dr. Long states that he disagrees with using USGS maps for a specific site.[175] Accordingly, GANE's use of the USGS Seismic Hazard Maps here has no value, by its expert's own admission, and does not raise a genuine issue as to any material fact. Moreover, GANE's comparison of the MOX Spectrum and the USGS maps is a comparison of apples to oranges. The seismic hazard maps developed by the USGS cannot meaningfully be compared with the hazard developed for the MOX Facility.

The USGS seismic hazard map ground motions are developed using site condition assumptions characterized by USGS as "firm-rock."[176] Such conditions are intended to represent rock properties generally prevalent in the Western United States.[177] However, firm-rock conditions do not exist beneath or in the vicinity of the MOX Facility. Rather, "hard-rock" conditions exist beneath and in the vicinity of the MOX Facility.[178]

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173 Dr. Long Transcript at 414:22-415:1.

174 *Id.* at 133:1-5; 183:1-4.

175 *Id.* at 35:19-20 ("I disagree with using their maps for a specific site").

176 *Documentation for the 2002 Update of the National Seismic Hazard Maps, Open-File Report* 02-420, at 2 (2002) ("USGS (2002)") (cited by GANE in Second Supplemental Interrogatory Response at 4).

177 Dr. Stepp Affidavit ¶ 75.

178 Lee et al, WSRC-TR-97-0085, at 25-26; *see also* Revised CAR § 1.3.6.4.3; Dr. Stepp Affidavit ¶ 75.

This distinction has significance. The USGS modeled firm-rock site conditions with a shear-wave velocity of 760 m/sec,[179] but the shear-wave velocity of hard-rock at SRS has been measured at between 2,438 and 3,352 m/sec.[180] Applying USGS firm-rock assumptions to a hard-rock site overestimates the ground motions at the site.[181] This effectively causes a decrease in the return period for a given peak acceleration such as 0.2 g. This is consistent with GANE's observation that the June 2002 USGS seismic hazard maps suggest a 2,500 year return period for 0.2 g PGA rather than a 10,000 year return period for the 0.2 g effective PGA for the MOX Spectrum.[182]

There are further material differences which make the USGS comparison to the MOX Spectrum spectra unsupportable. The depth to rock at the proposed MOX Facility is about 300 meters.[183] Unlike the USGS national hazard maps, the 1997 SRS-specific seismic analysis relied upon by DCS contains site-specific hazard estimates that account for the thickness of this soil, other soil properties, and bedrock material properties.[184] On-site soil conditions alter earthquake ground motions and, therefore, it is critical that the modeled soil (and bedrock) closely approximate the proposed facility site's geology. USGS did not consider these site-specific conditions.[185]

In addition, it is undisputed that the USGS hazard maps are not appropriate for facilities where an applicant is concerned about earthquakes with annual probabilities of

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179 USGS 2002, at 2.

180 Lee et al, WSRC-TR-97-0085, at 26 (8,000-11,000 ft/sec).

181 Dr. Stepp Affidavit ¶ 76.

182 *Id.*

183 *See* Revised CAR, at 1.3.6-21.

184 Revised CAR, at 1.3.6-21; *see generally* Lee et al, WSRC-TR-97-0085, at 26.

185 Dr. Stepp Affidavit ¶ 77.

exceedance of 1 x 10^{-4} and lower (*i.e.*, 10,000 years and longer).[186] The USGS hazard maps depict probabilistic ground motions with 10%, 5%, and 2% probabilities of exceedance in 50 years, which corresponds to 500, 1,000 and 2,500 years return periods.[187] Unlike EPRI and LLNL, the USGS maps were not developed for nuclear facilities and are not intended for such use. In fact, the maps were developed specifically for use in conjunction with seismic design codes for ordinary new buildings—the International Building Code and the National Earthquake Hazard Reduction Program ("NEHRP") Recommended Seismic Provisions—which have performance requirements that are significantly less demanding than performance requirements of nuclear facilities.[188]

Finally, the methodology used to make the maps was less structured and differs in several other ways from the methodologies used by EPRI and LLNL specifically for assessing ground motion hazard for the seismic design and risk assessment of nuclear facilities. For example, the USGS procedures heavily rely on historic seismicity and place less reliance on rigorous evaluation and characterization of seismic sources and assessments of uncertainty in these evaluations.[189]

In summary, a comparison of the USGS national seismic hazard maps to the MOX Spectrum ignores differences that are materially significant. Such an apples and oranges comparison is not technically supportable and the Board can dispose of the comparison as a matter of law.

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186 Dr. Long Transcript at 411:20—412:4; Dr. Stepp Affidavit ¶ 78.

187 Dr. Stepp Affidavit ¶ 79.

188 *Id.* at ¶ 79.

189 *Id.* at ¶ 80.

VI. CONCLUSION

The seismic design of the MOX Facility complies with the regulations in 10 CFR Part 70 which govern the consideration of earthquake hazards in the design of the MOX Facility. Contention 3 is therefore meritless. Because Contention 3 fails to present any genuine issues of material fact, the Board should grant summary disposition.

Dated: August 22, 2003

Respectfully submitted,

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Contention 3. Inadequate Seismic Design

In Sections 1.3.5 through 1.3.7 of the CAR, DCS specifies the design criteria for the MOX Fuel Fabrication Facility to withstand any potential geological hazard. DCS claims that "conservative design criteria" have been established. *Id.* at 1.3.6-23. This assertion is not supported, because DCS has not performed a seismic analysis that is either adequate in scope or adequately documented.

Basis: The seismic hazard at a site depends on two factors: one, the likelihood of a significant seismic event, and two, the expected site response to such an event. Precisely predicting the likelihood of a future seismic event is not currently possible; the best one can do is extrapolate from past seismicity, compare regional tectonics to those of similar regions, and seek evidence for recent tectonic activity.

The site response depends upon how the local geology, soils, sediments and bedrock, would respond to an expected seismic event, the design basis earthquake. Understanding site response is a rapidly evolving field, and much is being learned as strong motion accelerographs are deployed in areas that experience earthquakes. It is essential, therefore, that any seismic study of the MFFF be complete, accurate and up-to-date.

Likelihood of significant seismic event

In Section 1.3.5, the CAR concludes that "there are no geologic threats affecting the MFFF site, except for the Charleston Seismic Zone and the minor random Piedmont earthquakes." *Id.* at 1.3.5-1. In addition, DCS states that "no conclusive evidence of large prehistoric earthquakes originating outside of coastal South Carolina have been found." CAR at p. 1.3.5-41. These assertions do not consider recent paleoseismic work on the South Carolina Coastal Plain showing more activity in the last 6000 years, and over a wider area, than previously known.

As DCS states at page 1.3-5, excavation and detailed analyses of the "liquefaction flow features" in the area of the 1886 Charleston, South Carolina earthquake provided the "first insight into the pre-history of the Charleston earthquake." On page 1.3.5-41-42 of the CAR, the applicant notes four pre-1886 liquefaction events on the coastal plain linked to Charleston events. A liquefaction episode is caused by ground shaking strong enough for soils to start to flow like a liquid. A strong enough earthquake will leave features

such as sand craters, sand vents and sand fissures, as described in the application. Once located, these relict features can be dated and provide a rough timeline of pre-historic seismic events. However, the features cannot usually be used to pinpoint the earthquake location. DCS claims that paleoliquefaction episodes in areas other than the Charleston coastal plane are not addressed in the literature, and are also unlikely because of the different geology. CAR at 1.3.5-43.

Most regional paleoseismic work has only dealt with events in the Charleson Seismic Zone because liquefaction features were originally located there. A recent paper by Pradeep Talwani and William T. Schaeffer, indicates both that the frequency of major events is higher in the South Carolina Coastal Plain than previously thought, and that major events need not be limited to the Charleston seismic zone. Talwani, et al., Recurrence Rate of Large Earthquakes in the South Carolina Coastal Plain Base on Paleoliquefaction Data, Journal of Geophysical Research, Vol. 106, April 2001, copy attached as Exhibit 5.

The Talwani/Schaeffer study includes liquefaction features along the South Carolina coast and points to two scenarios for paleoseismic activity. One scenario calls for seven magnitude seven (or stronger) Charleston events in the last 6000 years, with a recurrence interval of 600 years. The other scenario would put one magnitude six event near Bluffton, South Carolina, only 100 miles from the SRS, and the others near Charleston and Georgetown. In other words, contrary to what the CAR says, major events may have occurred much closer to the SRS than the Charleston Seismic Zone.

~~DCS claims to evaluate "the relationship between geologic structure and seismic sources within the general site region." However, it is impossible to evaluate the accuracy of this section because of the report's lack of references. Most tables and figures in Section 1.3.6.2 are not referenced to any published work. For those figures that do indicate the source of the information, no citation to a reference document is provided in the list of references (Section 1.3.8). *See*, for instance, Figure 1.3.6-2 (p. 1.3.6-45), Figure 1.3.6-5 (p. 1.3.6-51), and Figure 1.3.6-10 (p. 1.3.6-61). Other referenced reports are not widely available. For instance, the CAR cites a number of Westinghouse Savannah River Company technical reports that are not available through major university research libraries (e.g, The University of Colorado Boulder or the Colorado~~

School of Mines). Although the Westinghouse Savannah River Site web site is supposed to have reports on their website, few of the ones listed in the CAR are available. Thus, it is not possible to verify the assertions made in the CAR regarding the MFFF site geology.

Table 1.3.6-1 purports to list "Significant Earthquakes Within 200 Miles of SRS (Intensity > 4 or Magnitude > 3). No references are provided for the sources used to construct Table 1.3.6-1. Thus, they cannot be verified. Moreover, a comparison with the U.S. Geological Survey's Preliminary Determination of Epicenters, Monthly Listing, (URL: http://neic.usgs.gov/neis/epic/epic_global.html) catalog shows that it is inaccurate and incomplete at least for the period from 1974 onwards. For the August 2, 1974, event, the CAR reports a maximum magnitude of 4.3, while the USGS PDE lists a magnitude of 4.9, an energy release four times greater. Table 1 lists other catalogued events within 200 miles of the SRS of magnitude equal to or greater than 3.0 that were omitted in the CAR.

Table 1

Date (yyyy/mm/dd)	Location (Lat N)	(Lon E)	Depth (km)	Magnitude	Distance from SRS (km)
1974/10/28	33.79	81.92		3.00 ML	66
1974/11/05	33.73	82.22		3.70 ML	75
1979/08/26	34.93	82.97	2	3.70 UK	223
1986/02/13	34.76	82.94	5	3.50 Mn	205
1987/12/12	34.24	82.63	5	3.00 Mn	143
1988/01/23	32.94	80.16	7	3.30 Mn	145
1995/04/17	32.95	80.07	10	3.90 Mn	153
1998/04/13	34.61	80.47	5	3.90 Mn	190
1998/06/05	35.48	80.82	5	3.20 Mn	262
2000/01/18	32.99	83.21	5	3.50 Mn	144

Between the recent evidence for prehistoric earthquakes and the failure to note all recent regional seismic events, the CAR does not adequately account for the risk of a major event.

Site response

The shaking experienced at a particular location during an earthquake is called the "site response." It depends upon a number of factors, including distance to the event, regional geology and topography, and local geology and topography. The CAR cites several site response studies within the SRS, but does not indicate that a quantitative site response study for the MFFF has been done. In section 1.3.5.2, the applicant states, "Subsurface soils at the MFFF site will also be evaluated to determine whether they have any potential for liquefaction," *Id.*, p. 1.3.5-28. and, "the exploration borings, CPT holes, geophysical test results, and laboratory test results will be used to establish static and dynamic geotechnical design criteria," *Id*, p. 1.3.5-29. Thus, the potential for intense shaking or soil liquefaction at the MFFF site has not been established.

Moreover, as noted by the NRC staff in its February 28, 2001, request for additional information (RAI) at pages 4-9, the Probabilistic Seismic Hazard Assessment (PSHA) is incomplete. (A copy of the RAI is available on the NRC's MOX website). GANE concurs with the need for clarification on all points mentioned in the RAI.

In the Standard Review Plan for Review of Final Safety Analysis Reports for Nuclear Power Plants the NRC states that license applicants should develop a site-specific design spectrum. NUREG-0800, Section 2.5.6 (1997). This means that the probability for seismic hazard, that is, the risk of a major event combined with the expected site response, should be expressed as a spectrum of the intensity of shaking at frequencies of structural interest. In the CAR, the applicant asserts that the "MFFF design earthquake is the existing SRS PC-3 spectrum." *Id.*, p. 1.3.6-23. This spectrum is not site-specific, but was computed for the whole of the Savannah River Site in 1997. A site-specific spectrum would include the soil properties determined in the geotechnical studies, such as those presented in Figures 1.3.5-23 through 1.3.5-25. The applicant has not provided detailed methodologies or references for spectral shape changes applied to the starting spectrum.

In addition, the approach to the PSHA has been insufficiently conservative. In table 1.3.6-7 (p 1.3.6-39), the applicant estimates the return period for Sa(g)=0.375g at 5hz is 2700 years. These estimates are derived from Westinghouse Savannah River Company reports (WSRC-TR-97-0085 and WSRC-TR-98-00263), that are not publicly available. In contrast, the National Seismic Hazard Mapping Project (URL:

~~http://geohazards.cr.usgs.gov/eq/) estimates a return period of 1200 years for the same event at the SRS.~~

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
Thomas S. Moore, Chairman
Charles N. Kelber
Peter S. Lam

In the Matter of	)	August 22, 2003
DUKE COGEMA STONE & WEBSTER	)	Docket No. 070-03098-ML
(Savannah River Mixed Oxide Fuel Fabrication Facility)	)	ASLBP No. 01-790-01-ML

STATEMENT OF MATERIAL FACTS ON WHICH NO GENUINE ISSUE EXISTS IN SUPPORT OF DCS' MOTION FOR SUMMARY DISPOSITION ON CONTENTION 3

DCS submits, in support of its Motion for Summary Disposition on Contention 3, this Statement of Material Facts as to which DCS contends there is no genuine issue to be heard.

Historical Check

1. 10 CFR § 70.64(a)(2) requires that DCS include in the seismic design of the MOX Facility, consideration of the most severe documented historical earthquake for the MOX Facility site.

2. The 1886 Charleston earthquake is the most severe historical documented earthquake for the MOX Facility.[1]

3. A 7.3 moment magnitude earthquake with an epicenter located 120 km southeast of the MOX Facility site is appropriate or conservative for modeling the historic 1886 Charleston earthquake ground motions.[2]

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1 First GANE Interrogatory Response 3.32; Dr. Long Transcript at 129:10-15. *See also* Revised CAR at 1.3.6-27.

4. DCS relied on seismic studies performed for the Savannah River Site ("SRS") which used the median ground motions associated with the 1886 Charleston earthquake with a 7.3 moment magnitude and an epicenter located 120 km southeast of the MOX Facility site as an historical check against the PC-3 spectrum.[3]

5. The horizontal ground surface spectrum for the MOX Facility ("MOX Spectrum") is a Reg. Guide 1.60 spectrum anchored at 0.2 g peak ground acceleration ("PGA").

6. The MOX Spectrum is more conservative than the PC-3 spectrum because of the Reg. Guide 1.60 spectral shape and because the PC-3 spectrum is anchored at 0.16 g PGA.

7. For the 1886 Charleston earthquake, DCS relied on a computation of ground motions at the site that used modifications to a crustal velocity model known as the Hermann Crustal Model.

8. Dr. Long suggests that the use of the Hermann Crustal Model may produce erroneous ground motions at the MOX Facility from the 1886 Charleston earthquake with an error rate of as much as 50%.[4]

9. Even if one increases by 50% the 1886 Charleston earthquake ground motions used in the historical check of the PC-3 spectrum relied upon by DCS, the MOX Spectrum still envelopes these dramatically increased ground motions for all frequencies of practical structural interest for the MOX Facility (between 2.5 and 9 Hertz).

10. GANE has not identified an alternative model to the Hermann Crustal Model.

Site-Specific Use of EPRI and LLNL PSHA results

11. The Electric Power Research Institute ("EPRI") and Lawrence Livermore National Laboratory ("LLNL") probabilistic seismic hazard assessment ("PSHA") studies are appropriate for site-specific use.

12. NRC Regulatory Guide 1.165 explicitly permits the use of the EPRI and LLNL PSHA studies.

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2 Dr. Long Transcript at 130:3-5 ("Q. Then what is the moment magnitude of the Charleston earthquake in 1886? A. Probably around 7.0"); 190:1-6 (120 kms is "realistic").

3 *See* Revised CAR at 1.3.6-20 & Fig. 1.3.5-33.

4 Dr. Long Transcript at 428:7-9.

Floating Magnitude 7+ Earthquakes

13. GANE contends that the EPRI and LLNL studies did not adequately consider a theory contained in a paper authored by Kafka in 2002 which GANE characterizes as suggesting that there is a 30% chance that a magnitude 7+ earthquake could occur virtually anywhere in South Carolina.

14. The EPRI and LLNL studies included opinions that major earthquakes could occur practically anywhere along the eastern United States.[5]

15. As a statistical paper, Kafka purposefully ignored all known geologic/liquefaction data associated with the South Carolina Coastal Plain.[6]

16. The data set used by Kafka did not include any earthquakes before 1924, so it necessarily excluded the 1886 Charleston earthquake and all the paleoearthquakes associated with the Charleston Seismic Zone.

17. Kafka's data set for the Southeastern United States appears to include no earthquakes greater than magnitude 4.8, and only three between magnitude 4.3 and 4.8.

18. Kafka's theory is not generally accepted in the scientific community.

19. Kafka himself states that his work is "still 'exploratory.'"[7]

20. Dr. Long believes Kafka's theory is "a pioneer paper."[8]

21. Kafka's position is undermined by other articles GANE cites, namely Talwani & Schaeffer and Hu *et al.* Those papers discuss the paleoliquefaction features on the South Carolina Coastal Plain believed to be caused by earthquakes that occurred over the past 6,000 years. Those studies do not indicate that major earthquakes occur in new places.

Consideration of a 7.5 Magnitude Earthquake in Eastern Tennessee Seismic Zone

22. The EPRI and LLNL PSHA studies did consider the possibility of a 7.5 earthquake in southeastern Tennessee.[9]

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5 Dr. Long Transcript at 360:7-16; *see also* Dr. Long Transcript at 15:19-22 ("the Lawrence Livermore studies pulled in a lot of information on proposed and hypothesized mechanisms with experts varying from a large earthquake can occur anyplace for any reason to very specific zones") (emphasis added); 81:18-19 ("One expert had the whole east coast in one big zone."); Dr. Long Transcript at 256:10-15 ("Q. So, for example, one expert may have placed a 7.5 earthquake anywhere on the Carolina coastal plain . . .? A. That is right").

6 Dr. Long Transcript at 364:8-11 ("Q. As an academic exercise, would you agree that Kafka specifically ignored geology and any known geologic features? A. Yes.").

7 Kafka, at 1002.

8 Dr. Long Transcript at 358:10.

23. Southeast Tennessee is an area of frequent earthquakes, but these earthquakes have had a magnitude no greater than about 5.

24. The generally accepted view in the scientific community is that the geophysical structure underlying the Eastern Tennessee Seismic Zone is very unlikely to support magnitude 7+ earthquakes.

"Additional" Epicenters for a Charleston-Type Earthquake

25. Talwani & Schaeffer conducted no new work on the SCCP for DCS to consider, as evidenced by the very first sentence of the Abstract to their article, that they merely "present a reanalysis of results of 15 years of paleoliquefaction investigations in the South Carolina Coastal Plain."

26. Talwani & Schaeffer discuss two scenarios for their reanalysis of existing paleoliquefaction data. One scenario places the epicenter of all earthquakes near Charleston. The other places the epicenters near Bluffton, S.C., Georgetown, S.C., and Charleston.

27. Bluffton is located on the Atlantic Coast of South Carolina, but south of Charleston, near the Georgia/South Carolina border. Georgetown is also located along the Atlantic Coast, but north of Charleston.

28. The two scenarios raised by Talwani & Schaeffer were raised a decade earlier in a document explicitly referenced by both the seismic analysis for SRS relied upon by DCS,[10] and by Talwani & Schaeffer.[11] In 1990, NUREG/CR-5613 identified liquefaction features to the north and south of Charleston in the same locations as the Bluffton and Georgetown locations identified in Talwani & Schaeffer. The NUREG even includes explanations for the presence of the liquefaction features located to the north and south of Charleston, including that epicenters of earthquakes could have been outside of Charleston.[12]

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9 Dr. Stepp Affidavit ¶ 48; Dr. Long Transcript at 360:7-16; *see also* Dr. Long Transcript at 15:19-22 ("the Lawrence Livermore studies pulled in a lot of information on proposed and hypothesized mechanisms with experts varying from a large earthquake can occur anyplace for any reason to very specific zones") (emphasis added); 81:18-19 ("One expert had the whole east coast in one big zone").

10 *See* Lee et al, WSRC-TR-97-0085, at 48.

11 Talwani & Schaeffer at 6641.

12 NUREG/CR-5613, p. 98 ("they could be the result of liquefaction associated with seismic events originating outside the Charleston epicentral area"); p. 117 ("this earthquake [1800+-200 years ago] could have originated in the Georgetown/Myrtle Beach area").

29. Talwani & Schaeffer do not show seismic activity over a wider area than previously known.[13]

30. GANE has not provided any analysis or data to show that consideration of the earthquake sequences identified in Talwani & Schaeffer would increase the ground motions of the design earthquake for the MOX Facility.[14]

Shorter Recurrence Interval for Charleston-Type Earthquakes

31. GANE contends that the return interval for characteristic Charleston earthquakes along coastal South Carolina is much shorter than previously considered in the EPRI and LLNL studies.[15] GANE claims that "One scenario [in Talwani & Schaeffer] calls for seven magnitude seven (or stronger) Charleston events in the last 6,000 years, with a recurrence interval of 600 years."[16]

32. Seven earthquakes in the last 6,000 years can not have an average return interval of 600 years; 6,000 years divided by seven events yields an average of 857 years.

33. Talwani & Schaeffer place greater weight on the recurrence interval of the few most recent Charleston-type earthquakes, which is about 600 years.

34. The return interval proposed by Talwani & Schaeffer is not new information for DCS to consider. NUREG/CR-5613, referenced in, and published more than a decade before Talwani & Schaeffer, included the same return interval.[17]

35. NUREG/CR-5613 was included as a reference to the seismic analysis for SRS relied upon by DCS.

36. New information regarding magnitude of earthquakes causing liquefaction on the South Carolina Coastal Plain does not support a 600 year return interval for magnitude 7 earthquakes, but rather for magnitude earthquakes ranging between 5.3 and 6.8.

37. GANE has not provided any analysis or data to show that consideration of a shorter return interval for earthquakes along the coast of South Carolina ranging in magnitude

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13 Dr. Long Transcript at 257:15-20.

14 *Id.* at 272:19—273:1 ("it may or may not change any of the results"); *see also Id.* at 316:7-13 ("If one were to revise then the [PSHA] and utilize this new information, then the results may change") (emphasis added).

15 *See* Revised Contention at 2 ("the frequency of major events is higher in the South Carolina Coastal Plain that previously thought").

16 *Id.*

17 NUREG/CR-5613, p. xii ("[t]he paleoliquefaction data suggest that the apparent return interval between liquefaction episodes has decreased from as much as 2000 years during the mid-Holocene times to about 600 years in more recent times.") (emphasis added).

between 5.3 and 6.8 would increase the ground motions of the design earthquake for the MOX Facility.

Increased Magnitude of Historical Earthquakes on the SCCP

38. Relying on two articles discussing recent study of paleoliquefaction data from the South Carolina Costal Plain authored by Hu, Gassman, and Talwani ("Hu *et al.* 1 and 2") in 2002, GANE contends that magnitudes of historical earthquakes in the South Carolina Coastal Plain may have been much greater than previously considered by the EPRI and LLNL studies.

39. Hu *et al.* 1 is flawed because the authors did not correct the soil strength data to account for aging.

40. By correcting for aging, the prehistoric earthquakes that occurred during the past 6,000 years and caused paleoliquefaction features in the South Carolina Coastal Plain have magnitudes ranging from 5.3 to 6.8.

Consideration of New Ground Motion Attenuation Models

41. GANE contends that the LLNL and EPRI studies did not adequately consider recent attenuation models which more accurately model Moho Bounce.

42. The only attenuation model GANE identifies is Atkinson and Boore (1995).

43. GANE believes that the curve presented in the Atkinson and Boore (1995) ground motion model exhibits pronounced non-uniform decay to approximate the Moho Bounce.

44. Moho Bounce is only important for earthquakes which have epicenters located between about 80 and 120 kms from the MOX Facility.

45. A PSHA—like the EPRI and LLNL studies—takes into account, with various weights, multiple earthquakes at multiple distances from a particular location. Many of these locations are not within the distance range where Moho bounce would occur. Moho bounce is not relevant for these potential earthquake locations.

46. In any event, the LLNL and EPRI PSHAs envelope the Atkinson and Boore (1995) model such that consideration of that model would not materially affect the MOX Facility seismic design.

47. GANE has not provided any analysis or data to show that consideration of Atkinson and Boore (1995) or any other model would increase the ground motions of the design earthquake for the MOX Facility.

Comparison to USGS Hazard Maps

48. GANE alleges that the June 2002 U.S. Geological Survey Seismic Hazard Maps show a return period for 0.2g at the MOX Facility site of about 2,500 years, while DCS states that the return period for 0.2g PGA at the MOX Facility is approximately 10,000 years.

49. Unlike EPRI and LLNL, the USGS maps were not developed for nuclear facilities and are not intended for such use. The USGS hazard maps are not appropriate for facilities where an applicant is concerned about earthquakes with annual probabilities of exceedance of 1×10^{-4} or lower (*i.e.*,10,000 years or longer).[18] The USGS hazard maps depict probabilistic ground motions with 10%, 5%, and 2% probabilities of exceedance in 50 years, which corresponds to return periods of 500, 1,000 and 2,500 years.

50. The USGS maps were developed specifically for use in conjunction with seismic design codes for ordinary new buildings—the International Building Code and the National Earthquake Hazard Reduction Program ("NEHRP") Recommended Seismic Provisions—which have performance requirements that are significantly different from the performance requirements of nuclear facilities.

51. The USGS hazard map ground motions are developed using site conditions assumptions characterized by USGS as "firm-rock".[19] Such conditions are intended to represent rock properties generally prevalent in the Western United States. The USGS modeled firm-rock site conditions with a shear-wave velocity of 760 m/sec.[20]

52. Firm-rock conditions do not exist beneath or in the vicinity of the MOX Facility site. Rather, "hard-rock" conditions exist beneath and in the vicinity of the MOX Facility site.[21] The shear-wave velocity of hard-rock near the MOX Facility site has been measured at between 2,438 and 3,352 m/sec.[22]

53. Applying USGS firm-rock assumptions to a hard-rock site overestimates the ground motions at the MOX Facility site. This effectively causes a decrease in the return period for a given peak acceleration such as 0.2 g. This is consistent with GANE's observation that the June 2002 USGS seismic hazard maps suggest a 2,500 year return period for 0.2g PGA rather than a 10,000 year return period as identified in the CAR.

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18 Dr. Long Transcript at 411:20—412:4; Dr. Stepp Affidavit ¶ 78.

19 *Documentation for the 2002 Update of the National Seismic Hazard Maps, Open-File Report* 02-420, at 2 (2002).

20 *Id.* at 2.

21 Lee et al, WSRC-TR-97-0085, at 25-26; *see also* Revised CAR § 1.3.6.4.3; Dr. Stepp Affidavit ¶ 77.

22 Lee et al, WSRC-TR-97-0085, at 26 (8,000-11,000 ft/sec).

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION
ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
Thomas S. Moore, Chairman
Charles N. Kelber
Peter S. Lam

In the Matter of	)	August 6, 2003
DUKE COGEMA STONE & WEBSTER	)	Docket No. 070-03098-ML
(Savannah River Mixed Oxide Fuel Fabrication Facility)	)	ASLBP No. 01-790-01-ML

AFFIDAVIT OF DR. CARL STEPP

City of Blanco)
)
State of Texas)

Dr. Carl Stepp, being duly sworn, states as follows:

INTRODUCTION

1. This Affidavit is submitted in support of Duke Cogema Stone and Webster's Motion for Summary Disposition on Contention 3.

2. GANE Contention 3 alleges that the seismic design of the MOX Facility as described in the February 28, 2001 version of the Construction Authorization Request ("CAR"), and documents referenced in the CAR, is inadequate.

3. The purpose of this Affidavit is to address GANE's allegations regarding the seismic design of the MOX Facility.

Experience

4. I am an experienced geophysicist, with more than 40 years experience in earthquake hazards analysis, seismic regulation, and engineering seismology. I earned a Doctorate Degree in Geophysics from the Pennsylvania State University in 1971, a Masters Degree from the University of Utah in 1961, and a Bachelor of Science in Geology from the Oklahoma State University in 1959. Over the years, I have refereed numerous Journal articles in the field of seismology, participated in numerous workshops and other seismic proceedings, and participated in many probabilistic seismic hazard assessments ("PSHAs"). Further details regarding these activities are provided in my resume which is appended hereto.

5. I have been an independent consultant providing services in engineering seismology, earthquake hazards, and seismic regulation since 1993. I am currently a Principle in Earthquake Hazards Solutions, a registered Sole Proprietorship. Recent projects include acting as Chairman for five national and international seismic review panels, and consulting on the development of the seismic design basis for Yucca Mountain.

6. From 1983 to 1993, I was the Manager of the Seismic Center at Electric Power Research Institute, Inc. ("EPRI"). In that position, I developed products for use by the U.S. Nuclear Regulatory Commission ("NRC") to support resolution of nuclear plant seismic regulatory issues. While at EPRI, I developed the methodology for PSHA and resolution of seismic issues for nuclear power plants in the central and eastern United States. This is the work which is referred in this proceeding as the EPRI PSHA. I also provided, through the Nuclear Energy

Institute, the technical basis for revision to seismic provisions in 10 CFR Parts 50 and 100. I also supervised the development of more than 60 technical reports on a range of ground motion evaluation and seismic analysis and design methods, and two large-scale model soil-structure interaction experiments that had multi-national participation.

7. From 1973 until 1979, I worked in the Nuclear Reactor Regulation Division of the NRC as Chief of the Geoscience Branch. During my time at the NRC, I managed the geology, seismology, and geotechnical engineering sections of safety analysis reports submitted in support of nuclear plant license applications. I authored, with others, NRC Standard Review Plan (NUREG-0800), Chapter 2.5.

<u>Seismic Design of the MOX Facility</u>

8. I have reviewed the relevant portions of the Revised CAR and relevant documents referenced in the Revised CAR.[1]

9. The seismic design of the MOX Facility relies upon PSHAs conducted in the late 1980s and early 1990s by the Lawrence Livermore National Laboratory ("LLNL") and EPRI.

10. PSHA is an analytical methodology that estimates the probability that various levels of ground motion will be exceeded at a given location in a given time period, usually one year. The analytical methodology uses weighted alternative interpretations of seismic sources, source parameters (such as magnitude and recurrence frequency), and ground motion models as input for hazard calculation.

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1 DCS, MOX Facility Construction Authorization Request (Oct. 31, 2002) ("Revised CAR").

Because the sources of uncertainty in these inputs are complex, experts may reach different assessments of alternative seismic sources and source parameters and may give different credibility to alternative ground motion models. Consequently, a complete PSHA incorporates alternative inputs prepared by multiple experts. Alternative interpretations by multiple experts or expert teams have been found to reasonably capture the uncertainty of the scientific community, which is a primary objective of a PSHA.

11. Assessments of inputs for a PSHA may be site-specific or they may be done for a large geographic region and applied to many sites of interest.

12. For nuclear facilities, two independent PSHA studies have been done for the region of the United States east of the Rocky Mountains. These studies were conducted in parallel by LLNL (on behalf of the NRC) and by EPRI (on behalf of the nuclear utilities). Both studies used multiple experts to assess uncertainty and develop inputs for ground motion hazard computation. The two studies differ primarily in the methodology used to obtain evaluations of seismic source inputs. Both methodologies are, however, accepted by the NRC as suitable for obtaining a site-specific PSHA.

13. The LLNL PSHA used about 10 individual experts to evaluate and characterize seismic sources and seven individual experts to assess uncertainty in ground motion. The experts' evaluations were obtained for the entire region of Central and Eastern United States ("CEUS") by the process of eliciting alternative seismic sources and uncertainty distributions on seismic source parameters from each expert, facilitated by an expert in elicitation of expert judgments. The same

approach was used to elicit the ground motion experts' uncertainties on alternative ground motion models. The alternative seismic sources uncertainty distributions were combined with the ground motion estimation uncertainty distributions to compute ground motion hazard at 69 nuclear plant sites in the CEUS.

14. The EPRI study was conducted using six expert teams to evaluate alternative seismic sources and characterize seismic source parameters. The teams included experts in the geology of the CEUS, in seismology, and in tectonophysics. The ground motion input for the EPRI study was based on work completed by EPRI consultants and two additional ground motion models for the CEUS.

15. An applicant applies the EPRI and LLNL seismic source and ground motion evaluations to a particular site by entering its latitude and longitude into either the LLNL or EPRI computer code, computing the contributions of individual seismic sources to the hazard at the location, then aggregating these to obtain the probability distribution of exceeding various levels of ground motion. Probabilistic seismic hazard output is in the form of the probability distribution of annual frequency of exceedance for a given level of ground motion (such as 0.2 g peak acceleration). For purposes of determining seismic design basis ground motion for a site, hazard is computed for peak ground acceleration ("PGA") and spectral values of acceleration over the range of structural frequencies that are important for design of the facility to be constructed.

16. I am intimately familiar with the EPRI and LLNL PSHA studies. For the EPRI studies, I developed the project plan and directed the development of the

methodology for its PSHA and provided technical leadership to obtain a generic topical review of the methodology by the NRC. For the LLNL studies, I was one of the experts who provided seismic source evaluations.

17. DCS relied upon the Savannah River Site ("SRS")-specific seismic response analysis conducted in 1997 by WSRC, which used an average of the EPRI and LLNL bedrock outcrop hazards for the latitude and longitude of the site, and that took into consideration site-specific properties such as soil column thickness, soil and bedrock shear-wave velocity, and soil dynamic properties.

18. This specific analysis relied upon by DCS generated seismic design basis ground motions by Performance Category ("PC"), for four categories of facilities at SRS: PC-1 through PC-4. Each Performance Category has a performance goal in terms of the probability of unacceptable damage due to an earthquake based on the importance of systems, structures, and components ("SSCs") in the category to the overall safety performance goal of the facility. The target performance goals range from those included in model building code provisions for office buildings (PC-1) to those SSCs that have radiological protection safety significance for a nuclear facility (PC-3 and PC-4).

19. The seismic performance goals for the various PCs is assured by the combination of the seismic design basis ground motion and the capacity against failure achieved by the seismic design criteria. A graded approach is used to establish the seismic design criteria for a PC that reflects its importance to safety. Design criteria for an office building might, for example, have an occupant safety goal, which permits significant damage to the building. A PC-3 SSC in contrast must

maintain its radiological safety function for the seismic design basis ground motion without interruption.

20. Any seismic design basis ground motion inherently has a probability of occurrence associated with it. For example, the SRS PC-3 spectrum relied upon by DCS has a mean annual probability of exceedance of 5×10^{-4}/yr with a peak ground acceleration ("PGA") of 0.16 g at the ground surface. PC-3 is considered a 5×10^{-4} mean annual uniform hazard ("UHS") spectrum because the amplitude for each spectral frequency has a 5×10^{-4} mean annual probability of non exceedance. PC-3 seismic design basis ground motion is used together with PC-3 deterministic seismic design criteria to provide reasonable assurance that the PC-3 SSCs will perform their intended safety function.

21. PGA—or peak acceleration—is related to the spectral amplitudes at higher frequencies which are usually above the range of frequencies important for damage to structures. For example, for PC-3, the PGA is at 33 Hz. None of the structures relied on for safety at a nuclear facility resonate at this frequency. In fact, the frequencies of structural interest for many nuclear facilities— including the MOX Facility—are between 2.5 and 9 Hz.

22. The SRS PC-4 spectrum has a mean annual probability of exceedance of 1×10^{-4}/yr with a PGA at the ground surface of 0.23 g. PC-4 seismic design basis ground motion is used together with PC-4 deterministic seismic design criteria to provide reasonable assurance that the PC-4 SSCs will perform their intended safety function.

23. The seismic design basis ground motions for PC-3 envelope the ground motions of historical earthquakes within 200 km from the site equal to or larger than magnitude 6.0. This "historical check" is consistent with NRC's requirements for the MOX Facility in 10 CFR § 70.64(a)(2), which requires consideration of the most severe documented historical earthquake for a site. The MOX Facility is located on SRS, which is on the inland border of South Carolina and Georgia. As such, the historical check for the MOX Facility is represented by a repeat of the 1886 Charleston earthquake placed 120 kms southeast of the site with an assumed moment magnitude of 7.3.

24. The ground motions at the MOX Facility site were modeled for the 1886 Charleston earthquake. As input to this model, the Herrmann Crustal Model which chosen. This crustal velocity model was developed using a seismic wave attenuation path from Bowman, S.C. to Atlanta, GA, and an earth's crust was simulated with four layers over an infinite layer. The Herrmann Crustal Model was modified to a three layer (over an infinite layer) model by removing the shallowest layer to allow better agreement with measured local shallow bedrock velocity data. To incorporate the phenomenon of "Moho Bounce," a model developed by Ou & Herrmann (1990), and a depth to the Moho of about 29 km, were used.

25. "Moho Bounce" is a phenomenon where seismic waves are reflected off of the boundary between the Earth's crust and mantle—called the Mohorovicic (or "Moho") discontinuity. This discontinuity is located about 29 kms beneath the ground surface in the vicinity of Charleston and the MOX Facility site. "Moho

Bounce" results in non-uniform decay of seismic energy in a distance range of between about 80 and 120 kms.

26. In developing the MOX Facility's seismic design, DCS built upon the work conducted by others for SRS. DCS used two horizontal spectra for the MOX Facility: one for motions at bedrock (located about 900 feet below the ground surface), and one for motions at the ground surface.

27. To achieve safety performance goals for the MOX Facility as required by 10 CFR § 70.61 (*i.e.*, to ensure that high consequence events are highly unlikely), DCS used seismic design ground motions which lie between the existing SRS PC-3 and PC-4 spectra.

28. For the ground surface, DCS used the spectral shape provided in NRC Regulatory Guide 1.60, with 5% damping, scaled to an effective 0.2 g PGA at 33 Hz (the "MOX Spectrum"). Reg. Guide 1.60 provides a conservative spectral shape encompassing the frequencies of structural interest for nuclear power plants; the Vogtle Electric Generating Plant located across the Georgia border from the site also has its Reg. Guide 1.60 spectral shape anchored at an effective 0.2 g PGA at 33 Hz. The MOX Spectrum envelopes the PC-3 surface spectrum and does so with significant margin at frequencies of structural interest for the MOX Facility, which are between 2.5 and 9 Hz. The MOX Spectrum is between the existing SRS PC-3 and PC-4 spectra. The PC-3 and PC-4 spectra used at SRS, and the Reg. Guide 1.60 spectrum used for the MOX Facility are depicted in Attachment E to DCS's Motion.

OPINIONS OF DR. LONG

I. The MOX Spectrum Includes Consideration of the Most Severe Documented Historical Earthquake for the Site

29. The most severe documented historical earthquake for the MOX Facility site is the 1886 Charleston earthquake. This earthquake was modeled with a moment magnitude of 7.3 and an epicenter located 120 kms southeast of the site. This distance and magnitude are conservative.

30. The exact location of the Charleston earthquake epicenter is not known. Instruments used today to measure the ground motions associated with an earthquake—generally referred to as seismographs—were not available at the time. Thus, no seismograph recordings of ground motions for the 1886 earthquake exist. However, scientists have estimated the 1886 earthquake's magnitude based on newspaper and other reports which describe the intensity of the ground shaking in terms of the resulting damage in different places in the eastern United States. These intensity reports are grouped and ranked, with areas of intensity ranging from as low as I to as high as X. This ranking is referred to as the Modified Mercali Intensity ("MMI") scale. 120 kms was used as the distance for the 1886 Charleston because that is the closest point to the site which coincides with the MMI X damage, or mesoseismal zone. In other words, the epicenter was placed at the closest point to the site within the area of highest reported ground shaking effects.

31. The exact magnitude of the 1886 Charleston earthquake is also not known. However, based on the reports of damage from that earthquake, it is reasonable to assume that its moment magnitude was 7.0 or slightly lower. Recent studies have

placed the magnitude at around 6.8. It was conservative for 7.3 to be used as the moment magnitude for modeling the 1886 Charleston earthquake ground motion.

32. Once the magnitude and location of the 1886 Charleston earthquake were established, the seismic energy from that earthquake needed to be propagated to the site. For computing the actual ground motions, a Band Limited White Noise/Random Vibration Theory ("RVT") ground motion model was used. This model is widely accepted. A separate model (Ou and Hermann (1990)) to account for direct and reflected seismic arrivals, including "Moho Bounce" was also used. I believe that the use of RVT and the "Moho Bounce" model was appropriate. GANE does not appear to be challenging use of these models.

33. GANE does challenge the use of the Hermann Crustal Model which models crustal velocity. The model was developed from surface wave dispersion data for a path from Bowman, S.C. to Atlanta, GA.

34. The modified Hermann Crustal Model has three layers with varying thicknesses and velocities. GANE appears to believe that the model structure and assigned velocities scatter seismic wave reflections, such that the model understates the energy of reflected seismic waves arriving at the MOX Facility site.

35. Dr. Long has suggested that the use of the Hermann Crustal Model therefore produced lower ground motions than should have been expected, and that correcting for the errors in this model could increase the ground motions for the historical check. He estimates that the magnitude of the increase could be in the range of 10% to 50%.

36. The MOX Spectrum is sufficiently robust that even if Dr. Long is correct in suggesting that the ground motions determined for the 1886 Charleston historical check should be increased by 50%, the MOX Spectrum still envelopes the increased ground motions. If one increases the ground motions by 50%, the MOX Spectrum still envelopes these dramatically increased ground motions for all frequencies above 0.8 Hz. Thus, the MOX Spectrum envelopes 150% of the 1886 Charleston ground motions produced by the historical check for the frequencies of structural interest. This simple calculation is shown in graphical form in Attachment F to DCS's Motion.

37. This conservatism is inherent in the MOX Spectrum for a number of reasons. First, the median ground motions associated with the 1886 Charleston earthquake were evaluated in conjunction with the SRS PC-3 probabilistic spectrum and both were enveloped to derive PC-3 seismic design basis ground motions. But DCS did not use the PC-3 seismic design basis ground motions. Rather, DCS used the Reg. Guide 1.60 spectrum, which is designed for nuclear power plants and, when compared to PC-3, is significantly more conservative at the MOX Facility's frequencies of structural interest (between 2.5 and 9 Hz).

II. EPRI & LLNL PSHA Results Were Intended To Be Used For Specific Sites

38. GANE believes the EPRI and LLNL studies were intended only as "first guess" and were never intended to be used for a specific site.

39. The NRC has a long standing history of using the LLNL and/or EPRI results in site specific applications.

40. NRC guidance explicitly allows an applicant to use the EPRI and LLNL PSHA study results for a specific site. NRC Regulatory Guide 1.165 explicitly permits the use of the EPRI and LLNL PSHA studies since they have been reviewed and accepted by the NRC Staff.

41. Also, as the developer of the methodology for the EPRI PSHA, I have first hand knowledge that the EPRI PSHA outputs were expected to be used for specific sites.

III. EPRI & LLNL PSHA Studies Appropriately Considered Floating Magnitude 7+ Earthquakes

42. GANE contends that the EPRI & LLNL studies did not adequately consider Kafka's (2002) theory that there is a 30% probability that a magnitude 7+ earthquake could occur virtually anywhere in South Carolina.

43. An equivalent to the floating 7+ earthquake theory was considered in the seismic design of the MOX Facility, by virtue of the fact that the EPRI and LLNL studies included interpretations that major earthquakes could occur practically anywhere along the eastern seaboard of the United States.

44. Kafka's work has no demonstrated applicability to a major earthquake on the South Carolina Coastal Plain ("SCCP"). Kafka's analysis for the Southeastern United States ("SEUS")—the area related to the MOX Facility—compared "small" (2.0-3.0 magnitude) and "large" (≥ 3.0 magnitude) earthquakes for the period between 1924 and the present. Kafka concluded that during this period, about 60% of the large earthquakes had epicenters located within about 30 km of where small earthquakes had occurred. Kafka then compared the "largest"

earthquakes in the SEUS from 1988-2001 (three events magnitude 4.3-4.8) to see whether they had epicenters located within about 30 km of smaller earthquakes.

45. The data set used by Kafka did not include any earthquakes before 1924, so it necessarily excluded the 1886 Charleston earthquake and all the paleoearthquakes associated with the Charleston Seismic Zone. As a statistical paper, it purposefully ignored all known geologic/liquefaction data associated with the SCCP. Kafka's data set for the SEUS also appears to include no earthquakes greater than magnitude 4.8, and only three between magnitude 4.3 and 4.8. Thus, not one of the earthquakes used by Kafka is of a magnitude to be of concern for the seismic design of the MOX Facility.

46. It is also my opinion that Kafka's results cannot be reasonably extrapolated to predict the expected locations of truly large and major earthquakes, which are the primary concern for seismic design of nuclear facilities. His analysis used only microearthquakes and small earthquakes, which occur essentially everywhere and are of no consequence for the seismic design of nuclear facilities. Magnitude 5.0 and larger earthquakes are considered consequential for the design of nuclear facilities. Earthquakes of this magnitude were, for example, incorporated into the EPRI PSHA results by specifically incorporating background seismic zones, which covered the entire geographic region of the CEUS.

IV. EPRI & LLNL PSHA Studies Appropriately Considered a 7.5 Magnitude Earthquake in Eastern Tennessee

47. GANE contends that the EPRI and LLNL studies did not adequately consider that a magnitude 7.5 earthquake could occur in the Eastern Tennessee Seismic Zone.

48. The EPRI and LLNL PSHA studies did consider the possibility of a 7.5 earthquake in this zone. Many experts were involved in the EPRI and LLNL studies. They developed interpretations of existing information regarding the location of earthquake source zones and the magnitudes of earthquakes that could occur in those zones. At least one interpretation was included in both of those studies which placed a 7.5 earthquake in the Eastern Tennessee Seismic Zone.

49. Other EPRI and LLNL experts thought a 7.5 magnitude earthquake could not occur in southeastern Tennessee. Southeast Tennessee is an area of frequent earthquakes, but these earthquakes have never had a moment magnitude greater than about 5.

50. Finally, in my judgement, the geophysical structure underlying the Eastern Tennessee Seismic Zone is very unlikely to support magnitude 7+ earthquakes as suggested by Dr. Long. My judgement is consistent with the views generally accepted in the scientific community regarding this seismic zone.

V. GANE Has Not Identified Any New Information for DCS To Consider Regarding the Location of Charleston-Type Earthquakes

51. GANE claims that DCS did "not consider recent paleoseismic work on the South Carolina Coastal Plain showing more seismic activity in the last 6,000 years, and over a wider area, than previously known." Specifically, GANE contends that Bluffton and Georgetown—in addition to Charleston—were epicenters for characteristic Charleston earthquakes over the past 6,000 years, and that these epicenters were not previously considered. GANE cites an article published in 2001 by Talwani & Schaeffer which discusses paleoliquefaction along the coast of South Carolina.

52. Talwani & Schaeffer conducted no new work on the SCCP. As they state in the very first sentence of the Abstract to their article, they merely "present a reanalysis of results of 15 years of paleoliquefaction investigations in the South Carolina Coastal Plain."

53. Even the hypotheses raised in Talwani & Schaeffer are not new. Talwani & Schaeffer generated two scenarios for their reanalysis of existing paleoliquefaction data. One scenario places the epicenter of all earthquakes near Charleston. The other places the epicenters near Bluffton, S.C., Georgetown, S.C., and Charleston.

54. These hypotheses were raised in 1990 in NUREG/CR-5613, which identified liquefaction features to the north and south of Charleston in the same locations as the Bluffton and Georgetown locations identified in Talwani & Schaeffer. The NUREG includes explanations for the presence of the liquefaction features located to the north and south of Charleston, including that epicenters of earthquakes could have been outside of Charleston.

55. The scenario presented in Talwani & Schaeffer and NUREG/CR-5613, of epicenters located along coastal South Carolina but outside of Charleston, was considered in the seismic design of the MOX Facility. NUREG/CR-5613 was included as a reference to the seismic response analysis conducted for SRS, upon which DCS relies. In addition, the EPRI and LLNL studies included interpretations that major earthquakes could occur practically anywhere along the eastern seaboard/United States.

VI. GANE Has Not Identified Any New Information for DCS To Consider Regarding the Recurrence Interval Of Charleston-Type Earthquakes

56. GANE contends that the return interval for characteristic Charleston earthquakes along coastal South Carolina is much shorter than previously considered. GANE claims that "One scenario [in Talwani & Schaeffer] calls for seven magnitude seven (or stronger) Charleston events in the last 6,000 years, with a recurrence interval of 600 years."

57. Seven earthquakes in the last 6,000 years can not have an average return interval of 600 years; 6,000 years divided by seven events yields an average return interval of 857 years. Talwani & Schaffer places greater weight on the recurrence interval of the few most recent Charleston-type earthquakes, which is about 600 years.

58. This hypothesis of a 600 year return interval is also not new. NUREG/CR-5613 states that "[t]he paleoliquefaction data suggest that the apparent return interval between liquefaction episodes has decreased from as much as 2000 years during the mid-Holocene times to about 600 years in more recent times."

VII. GANE Has Not Identified Any New Information for DCS To Consider Regarding the Magnitude Of Historical Earthquakes On The SCCP

59. GANE contends that magnitudes of historical earthquakes in the SCCP may have been much greater than previously considered. GANE cites two articles discussing recent study of paleoliquefaction data from the SCCP authored by Hu, Gassman, and Talwani ("Hu *et al.* 1 and 2") in 2002.

60. Hu *et al.* 1 describes soil properties (strength, sand and silt content, *etc.*) analyzed from new soil samples collected at known paleoliquefaction sites. Hu *et al.* 2 estimates magnitudes and accelerations of paleoearthquakes based on "soil properties at the locations of the paleoliquefaction features" collected for Hu *et al.* 1. The magnitudes generated in Hu *et al.* 2 for earthquakes that occurred over the past 6,000 years on the SCCP are larger than the magnitudes identified for those same events in Talwani & Schaeffer.

61. Hu *et al.*'s conclusions are not valid because they did not consider how aging affects soil strength. Specifically, Hu *et al.* 1 used current soil strengths rather than correcting these to obtain the strength of the soil at the time of the prehistoric earthquake. Consequently, the authors overestimated the strength of the soils. When the current soil strengths used in Hu *et al.* 1 are corrected for the effects of aging, soil strengths and the magnitudes computed for prehistoric earthquakes are reduced.

62. This oversight was very recently documented in a Masters Thesis prepared at the University of South Carolina: Leon, E, *Effect of Aging of Sediments on Paleoliquefaction Evaluation In the South Carolina Coastal Plain*, Dept. of Civil and Envt'l Engineering, U. of S.C. (2003). The author of that Masters Thesis concluded that "the prehistoric earthquakes that occurred during the past 6,000 years and caused paleoliquefaction features in the SCCP have magnitudes ranging from 5.3 to 6.8."

63. This oversight is not likely to come as a surprise to the authors of Hu *et al.* 1 and 2 for two reasons: they acknowledge in their paper that they did not correct

for aging; and two of the authors—Sarah Gassman and Pradeep Talwani—oversaw the Masters Thesis as evidenced by their signatures on its cover page.

VIII. EPRI & LLNL PSHA Studies Appropriately Considered Ground Motion Attenuation

64. GANE contends that the LLNL and EPRI studies did not adequately consider recent attenuation models, such as Atkinson and Boore (1995), which GANE contends more accurately model the Moho Bounce.

65. I am familiar with the Atkinson and Boore (1995) ground motion attenuation model, as well as other more recent models.

66. As a threshold matter, numerous new ground motion attenuation models have been published since the EPRI and LLNL PSHA studies were published. These studies include Atkinson and Boore (1995), but they also include many others published after 1995, such as Frankel (1996), Toro, et al. (1997), Sommerville (2001), and Campbell (2002).

67. Dr. Long appears to focus on Atkinson and Boore (1995) because he believes the curve presented in that model exhibits pronounced non-uniform decay to account for the "Moho Bounce." "Moho Bounce" is dependent on the depth of the earthquake and the thickness of the Earth's crust along the travel path of the seismic energy and is primarily important for earthquakes that have epicenters located between about 80 and 120 kms from a site. Accordingly, it would be important to take into account "Moho bounce" when modeling a repeat of the 1886 Charleston earthquake, which was placed 120 kms from the MOX Facility site.

68. The "Moho Bounce" tends to appear in the closest range of 80-90 kms when the Moho is located at around 30 kms depth and in the range of 100-120 kms where the Moho is around 40-50 kms depth.

69. A PSHA takes into account, with various weights, multiple earthquakes at multiple distances and azimuths with respect to a particular location. Many of these locations are not within the distance range where Moho bounce would occur. Moho bounce is not relevant for these potential earthquake locations. Accordingly, it is unclear why consideration of Atkinson and Boore (1995) would materially affect the seismic design of the MOX Facility.

70. I am familiar with the composite ground motion attenuation model used in the LLNL PSHA. I am also familiar with the three ground motion attenuation models used for the EPRI PSHA, namely Nuttli, McGuire, and Boore-Atkinson (not to be confused with Atkinson and Boore (1995)).

71. The LLNL and EPRI ground motion attenuation models encompass a large range of uncertainty, and the Atkinson and Boore (1995) model favored by Dr. Long falls within the ranges of uncertainty in the EPRI and LLNL models. Specifically, for a moment magnitude 7.0 earthquake at a distance of 100 kms, Atkinson and Boore (1995) produces accelerations of 66.5 and 148.1 cm/sec^2 at 2.5 and 10 Hz spectral frequencies, respectively. These accelerations fall between the 15th and 50th fractile of uncertainty of the composite LLNL model. For the EPRI model, Atkinson and Boore (1995) produces accelerations that are: slightly higher than those obtained using Boore and Atkinson (1987), and lower than

those obtained using the Nuttli (1988) and McGuire, et al. (1988) curves for 2.5 Hz; and are essentially the same as the McGuire, et al. (1988) curves for 10 Hz.

IX. USGS Hazard Maps Are Not Applicable To the MOX Facility.

72. GANE attempts to make a meaningful comparison between USGS Seismic Hazard Maps and the return periods of the MOX Spectrum. Specifically, GANE challenges the 0.2 g effective PGA used by DCS to anchor the MOX Spectrum.

73. GANE relies on the June 2002 U.S. Geological Survey Seismic Hazard Maps which show a return period for 0.2 g PGA at the MOX Facility site of about 2,500 years, while DCS states that the return period for the 0.2 g effective PGA for the MOX Spectrum is approximately 10,000 years.

74. GANE's comparison of the MOX Spectrum and the USGS Seismic Hazard Maps has little technical merit.

75. The USGS Seismic Hazard Map ground motions are developed using site condition assumptions characterized by USGS as "firm-rock." Such conditions are intended to represent rock properties generally prevalent in the Western United States. However, "hard-rock" conditions exist beneath and in the vicinity of the MOX Facility site.

76. This distinction has significance. The USGS modeled firm-rock site conditions with a shear-wave velocity of 760 m/sec. But the shear-wave velocity of hard-rock near the MOX Facility site has been measured at between 2,438 and 3,352 m/sec. Applying USGS firm-rock assumptions to a hard-rock site overestimates the ground motions at the site. This effectively causes a decrease in the return period for a given peak acceleration such as 0.2 g. This is consistent with, and

explains GANE's observation that the June 2002 USGS Seismic Hazard Maps suggest a 2,500 year return period for the 0.2 g effective PGA for the MOX Spectrum.

77. There are further material differences which make the USGS comparison to the MOX Spectrum unsupportable. The depth to rock at the proposed MOX Facility is about 300 meters. Unlike the USGS Seismic Hazard Maps, the seismic response analysis for SRS relied upon by DCS contains site-specific hazard estimates that account for the thickness of this soil, other soil properties, and bedrock material properties. On-site soil conditions alter earthquake ground motions and, therefore, it is critical that the modeled soil (and bedrock) closely approximate the proposed facility site's geology. USGS did not consider these site-specific conditions.

78. It is also my opinion that the USGS Seismic Hazard Maps are not appropriate for facilities where an applicant is concerned about earthquakes with annual probabilities of exceedance of 10^{-4} and lower. Unlike the EPRI and LLNL PSHAs, the USGS maps were not developed for nuclear facilities and are not intended for such use.

79. The USGS Seismic Hazard Maps depict probabilistic ground motions with 10%, 5%, and 2% probabilities of exceedance in 50 years, which correspond to return periods of 2,500, 1,000 and 500 years, respectively. The maps were developed specifically for use in conjunction with seismic design codes for ordinary new buildings – the International Building Code and the National Earthquake Hazard Reduction Program ("NEHRP") Recommended Seismic Provisions – which have

performance requirements that are significantly less demanding than the performance requirements of nuclear facilities.

80. Finally, the methodology used to make the maps was less structured and differs in several other ways from the methodologies used by EPRI and LLNL specifically for assessing ground motion hazard for the seismic design and risk assessment of nuclear facilities. For example, the USGS procedures heavily rely on historic seismicity and place less reliance on rigorous evaluation and characterization of seismic sources and assessments of uncertainty in these evaluations.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Dr. Carl Stepp
871 Chimney Valley Road
Blanco, TX 87606-4643

Subscribed and sworn before me this 6th day of August, 2003.

JEANA MASSEY
NOTARY PUBLIC
STATE OF TEXAS
My Commission Expires 03-07-2006

Notary Public

My Commission Expires: 03/07/06

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Fax: 830 833 5724
cstepp@moment.net

Earthquake Hazards
Seismic Regulation
Engineering Seismology

EDUCATION

Pennsylvania State University, University Park: Ph.D., Geophysics, 1971
University of Utah, Salt Lake City: M. S., Geophysics, 1961
Oklahoma State University, Stillwater: B. S., Geology, 1959

REPRESENTATIVE EXPERIENCE

1993 – Present: Owner and Principle, EHS - providing consulting services in engineering seismology, earthquake hazards, and seismic regulation.

Relevant Current Projects

- Chairman, Peer Review Panel: Clinton Early Site Permit Application for a next generation nuclear generating plant; CH2M Hill.
- Chairman, Peer Review Panel: CEUS Ground Motion Project; Jack R. Benjamin & Associates.
- Chairman, Peer Review Panel: "Probabilistic Seismic Hazard Assessment of Swiss Nuclear Plants", for Swiss Federal Nuclear Safety Inspectorate. (Level 4 PSHA for Swiss Nuclear Plants).
- International Atomic Energy Agency:
  - Instructor, short courses on implementing IAEA Seismic Safety Guidelines,
  - Member of drafting panel for revision of IAEA Seismic Safety Guidelines,
  - Expert reviewer: Safety Guidelines for Korea Advanced Nuclear Reactor
- Executive Director, Consortium of Organizations for Strong Motion Observation Systems.
- Consultant, Yucca Mountain High-Level Waste Repository Project for seismic design basis development and licensing.

Recently Completed Projects (past 5 years)

- Chairman, United States Committee for Advancement of Strong Motion Programs.
- Consultant, Westinghouse Savannah River Project.
- Chairman, Peer Review Panel, "Technical Assistance for Proposed NRC Rulemaking
  – Geological and Seismological Characteristics for Siting and Design of Dry Cask Independent Spent Fuel Storage Installations – Changes to 10 CFR Part 72", ICF Consulting.
- Chairman, Peer Review Panel, USNRC Project to revise standard ground motion response spectra for design of nuclear power plants and develop a design ground motion library for nuclear power plants in the United States.

- Consultant: "Probabilistic Seismic Hazard Evaluation of Korea Nuclear Plants", Korean Electric Power Research Institute.
- Project Director: Probabilistic Seismic Hazard Analyses for Ground Motion and Fault Displacement at Yucca Mountain, Nevada, US Department of Energy.
- Pre-closure Seismic Design Methodology for a Geologic Repository at Yucca Mountain, Topical Report YMP/TR-003-NP, US Department of Energy.
- Member Review Panel, Canadian Atomic Energy Control Board Probabilistic Seismic Hazard Evaluation for the Darlington and Peckering Nuclear plants.

Other Experience (20 years)

1983 - 1993: Manager of the Seismic Center, Electric Power Research Institute, Inc. (EPRI).

- Key products developed by the Seismic Center and used by the NRC supporting resolution of nuclear plant seismic regulatory issues:
  - Validated SSI analysis models supporting resolution of USI A-40;
  - Methodology for Probabilistic Seismic Hazard Assessment and resolution of seismic issues for NPPs in the central and eastern United States (This product was adopted in large part as the SSHAC recommended PSHA methodology);
  - Seismic Margin Methodology for resolution of NPP seismic design margin;
- Other relevant key products
  - Technical basis (through NEI) for revision of the NRC's 10 CFR Part 50 and 10 CFR Part 100 rulemaking and technical basis for Regulatory Guide 1.165.
  - Engineering procedures for estimating earthquake ground motion, accounting for local geology and soil effects.
- Supervised the development of more than 60 technical reports on a range of ground motion evaluation and seismic seismic analysis and design methods and two large-scale model soil-structure interaction experiments that had multi-national participation.

PROFESSIONAL ACTIVITIES

- Chairman, Board of Advisers, Mid-America Earthquake Center, 1997 - 2002
- Chairman, Coalition of Professional Associations for Support of NEHRP, 1996 -
- Co-Chairman, International Advisory Committee, 5th International Conference on Seismic Zonation, 1995.
- Member, Oversight Committee, FEMA Project: Earthquake Risk Reduction in the United States, An assessment of Selected User Needs and Recommendations for the National Earthquake Hazards Reduction Program, 1994.
- Member, Oversight Committee, National Institute of Building Sciences/FEMA, Assessment of the State of the Art Earthquake Loss Estimation Methodologies, 1993 - 95
- Member, NCEER/FHA Highway Seismic Research Council Technical Group, 1992 - 98
- Member, NCEER Scientific Advisory Committee, 1991 – 1996.
- Co-Chairman, ASCE Specialty Conference on Seismic Design of High Level Nuclear Waste Repositories, San Francisco, CA, August 19, 20, 1992.
- Co-Founder, Coalition of Professional Associations for Support of National Earthquake Hazard Reduction Program, 1991.
- Member, ASCE Working Group on Seismic Design of High Level Nuclear Waste Repository Facilities, 1990 - 95
- President, Earthquake Engineering Research Institute, 1990 - 1992.

- Co-Chairman, International Advisory Committee, 4th International Conference on Seismic Zonation, 1991.
- Member, National Research Counsel Subcommittee on Earthquake Engineering Research, 1988-1990.
- Member, American Nuclear Society, Waste Management Committee - Subcommittee on Standards Review, 1981-1984.
- Board of Directors, Earthquake Engineering Research Institute, 1982-1984 and 1989-1993.
- Editorial Board, Earthquake Spectra, 1985-1992.

PROFESSIONAL ASSOCIATIONS AFFILIATION

American Geophysical Union
Earthquake Engineering Research Institute
Society of Exploration Geophysicists
Seismological Society of America
Honor Societies:
  Phi Kappa Phi (1959)
  Sigma Xi (1961)

PUBLICATIONS (Past 15 years)

Monograph

Seismic and Dynamic Analysis and Design Considerations for High Level Nuclear Waste Repositories. (J. Carl Stepp, editor) ASCE Special Report, American Society of Civil Engineers, 1996.

Safety Guides and Guidelines

Guidelines for Installation of Advanced National Seismic System Strong-Motion Reference Stations. R. L. Nigbor, J. C. Stepp, and A. F. Shakal, COSMOS Publication No. CP-2001/02, July 2001.

Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting (Rev. 2). Safety Series No. 50-SG-S2, International Atomic Energy Agency, 2001 (Member of Drafting Team for revision 2)

Refereed Journals

Probabilistic Seismic Hazard Analyses for Fault Displacement and Ground Motions at Yucca Mountain, Nevada (J. Carl Stepp, Ivan Wong, John Whitney, and others, Earthquake Spectra, Vol. 17, No. 1, February 2001.

Lotung Downhole Array: Evaluation of Soil Nonlinear Properties. (M. Aeghal, A-W. Elgamal, H. T. Tang and J. C. Stepp), Geotechnical Engineering Journal, Vol. 121, No. 4, 1993.

Lotung Downhole Array: Evaluation of Site Dynamic Properties. (A-W. Elgamal, M. Aeghal, H. T. Tang, and J. C. Stepp), Geotechnical Engineering Journal, Vol. 121, No. 4, 1993.

Spatial Coherency of Shear Waves from the Lotung, Taiwan Large-Scale Seismic Test. (Norman Abrahamson, John F. Schneider and J. Carl Stepp), *Structural Safety*, Vol. 10, 1991.

Empirical Spatial Coherency Functions for Application to Soil-Structure Interaction Analyses. (N. A. Abrahamson, J. F. Schneider and J. C. Stepp), *Earthquake Spectra*, Vol. 7, 1991.

Assessment of the Potential for Tectonic Fault Rupture for High Level Nuclear Waste Repositories. (F. H. Swan, J. Carl Stepp and Robin K. McGuire), *Quarterly Journal of Engineering Geology*, 1991.

Seismic Hazard and Its Uncertainty in the Eastern US. (R. K. McGuire, J. C. Stepp and G. R. Toro), *In New Risks, Issues and Management*, edited by L. A. Cox, Jr. and P. R. Ricci, Plenum Press, New York and London, 1990.

A Wedging System for Downhole Accelerometers. (T. L. Youd, Y. K. Tang, J. C. Stepp, T. L. Holzer, and G. O. Jackson), *Earthquake Spectra*, Vol. 5, 1989.

A Dense Seismic Engineering Array at Parkfield, CA. (J. C. Stepp, P. K. Spudich, J. F. Schneider, Y. B. Tsai and A. F. Shakal), *Seismological Research Letters*, Vol 59, 1988.

Proceedings

Workshop on Archiving and Web Dissemination of Geotechnicl Data. Eds. J. Swift, J. C. Stepp, C. Roblee, L. Turner, C. Real, W. U. Savage, COSMOS Publication No. CP-2001/03, October 2001.

Workshop on Strong-Motion Instrumentation of Buildings. Eds. J. C. Stepp, R. L. Nigbor, W. U. Savage, and C. A. Cornell, COSMOS Publication NO. CP-2002/04, November 2001.

A Probabilistic Analysis of Fault Displacement and Vibratory Ground Motion and the Development of Seismic Design Criteria for Yucca Mountain, Nevada. (Carl Stepp, and Others), *Proceedings, FOCUS'95*, American Nuclear Society, La Grange, IL.

Criteria for Design of the Yucca Mountain Structures, Systems and Components for Fault Displacement. (Carl Stepp and Others), *Proceedings, FOCUS'95*, American Nuclear Society, Lagrange, IL.

Probabilistic Approaches for Nuclear Plant Siting and Determination of Seismic Design Loads. (J. C. Stepp and M. W. McCann, Jr.), *Proceedings, International Conference on Design and Safety of Advanced Nuclear Power Plants*, Tokyo, Japan, October 25-29, 1992.

Lessons Learned from the Loma Prieta Earthquake of October, 1989. (Joseph Penzien and J. Carl Stepp), *Proceedings, 10WCEE,* Madrid, Spain, July, 1992.

The Spatial Variation of Earthquake Ground Motion and Effects of Local Site Conditions. (John F. Schneider, Norman A. Abrahamson, and J. Carl Stepp), *Proceedings, 10WCEE*, Madrid, Spain, July, 1992.

Engineering Characterization of Strong Ground Motion at Rock Sites in North America. (R. B. Darragh, W. J. Silva, C. Stark, J. Schneider and J. C. Stepp), *Proceedings Fourth International Conference on Seismic Zonation*, EERI, August 25-29, 1991.

Ground Motion Model for the 1989 M 6.9 Loma Prieta Earthquake Including Crustal Path and Site Effects. (J. F. Schneider, W. J. Silva and J. C. Stepp), *Proceedings, New Horizons in Strong Motion: Seismic Studies and Engineering Practice*, Santiago, Chile, June 4-7, 1991.

Strong Motion Array Data - Applications for Blind Predictions and Nuclear Power Plant Seismic Response Studies. (H. T. Tang, J. C. Stepp and Y. K. Tang), *Geotechnical News*, March, 1991.

Site Response Evaluations Based Upon Generic Soil Profiles using Random Vibration Methodology. (C. Stepp, W. Silva, H. B. Seed, I. M. Idriss, R. McGuire and J. Schneider), *Proceedings Fourth International Conference on Seismic Zonation*, EERI, August 25-29, 1991.

Estimation of Ground Motion at Close Distances using the Band-Limited-White-Noise Model. (J. F. Schneider, W. J. Silva, S. J. Chiou and J. C. Stepp), *Proceedings, Fourth International Conference on Seismic Zonation*, EERI, August 25-29, 1991.

Selection of Review Method and Ground-Motion Input for Assessing Nuclear Power Plant Resistance to Potential Severe Seismic Accidents. (Robert T. Sewell, Thomas F. O'Hara, C. Allin Cornell, and J. Carl Stepp), *3rd Symposium on Current Issues Related to Nuclear Plant Structures, Equipment and Piping*, North Carolina State University, December, 1990.

Industry Perspective on Individual Plant Examination of External Events (IPEEE). (O. Gurbuz, D. J. Modeen, J. C. Stepp, and R. P. Kassawara), *3rd Symposium on Current Issues Related to Nuclear Plant Structures, Equipment and piping*, North Carolina State University, December, 1990.

The use of Multiple Experts in Risk-Based Approaches to Decision-Making. (Robert A. Shaw, J. Carl Stepp, Robin McGuire and Robert F. Williams), *IAEA Technical Committee Meeting on "The Use of Decision-Aiding Techniques in Nuclear Safety and Radiation Protection,"* IAEA, Vienna, Austria, November 19-23, 1990.

A Methodology to Estimate Design Response Spectra in the Near-source Region of Large Earthquakes using the Band-Limited-White-Noise Ground Motion Model. (Walter Silva, Robert Darragh, Cathy Stark, Ivan Wong, J. Carl Stepp, John F. Schneider and Shayh-Jeng Chiou), *Proceedings, Fourth U. S. National Conference on Earthquake Engineering*, EERI, May 20-24, 1990.

Maximum Spectral Amplification and High-Frequency Truncation Filters in the Band Limited White Noise Ground Motion Model at Rock Sites. (Robert Darragh, Walter Silva, J. Carl Stepp and John F. Schneider), *Proceedings, Fourth U. S. National Conference on Earthquake Engineering,* EERI, May 20-24, 1990.

Spatial Variation of Strong Ground Motion for use in Soil-Structure Interaction Analysis. (N. A. Abrahamson, J. F. Schneider and J. C. Stepp), *Proceedings, Fourth U. S. National Conference on Earthquake Engineering,* Palm Springs, CA, EERI, May 20-24, 1990.

Spatial Variation of Ground Motion from EPRI's Dense Accelerograph Array at Parkfield, California. (J. F. Schneider, N. A. Abrahamson, P. G. Somerville and J. C. Stepp), *Proceedings, Fourth U. S. National Conference on Earthquake Engineering,* Palm Springs, CA, May 20-24, 1990.

Need for Performance-Based Approach to Characterize and License the Yucca Mountain HLW Repository. (J. Carl Stepp and Robert F. Williams), *Proceedings, Nuclear Waste Isolation in the Unsaturated Zone,* American Nuclear Society, September 17-21, 1989.

Approaches that use Seismic Hazard Results to Address Topics of Nuclear Power Plant Seismic Safety, with Application to the Charleston Earthquake Issue. (Robert T. Sewell, J. Carl Stepp, Robin K. McGuire, Gabriel R. Toro and C. Allin Cornell), *Proceedings, 2nd Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping, with Emphasis on Resolution of Seismic Issues in Low Seismicity Regions,* EPRI NP-6437-D, 1988.

Probabilistic Seismic Hazard Assessment: EPRI Methodology. (Gabriel R. Toro, Robin K. McGuire and J. Carl Stepp), *Proceedings 2nd Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping, with Emphasis on Resolution of Seismic Issues in Low Seismicity Regions*, EPRI NP-6437-D, 1988.

A Decision Framework Using Seismic Hazard Results to Address Issues of Nuclear Power Plant Seismic Safety. (Robert T. Sewell, Robin K. McGuire, Gabriel R. Toro, and J. Carl Stepp), *Proceedings 2nd Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping, with Emphasis on Resolution of Seismic Issues in Low Seismicity Regions,* EPRI NP-6437-D, 1988.

Spatial Coherency of Shear Waves from the Lotung, Taiwan Large-Scale Seismic Test. (N. A. Abrahamson, J. F. Schneider and J. C. Stepp), *Proceedings, International Workshop on Spatial Variation of Earthquake Ground Motion,* Princeton University, November 9-11, 1988.

Liquefaction Instrumentation Arrays in California. (T. L. Holzer, T. L. Youd, D. Anderson, and J. C. Stepp), *Joint IASPEI/IAEE Working Group Meeting on the Effects of Surface Geology on Seismic Motion,* Vancouver, Canada, August 12, 1987.

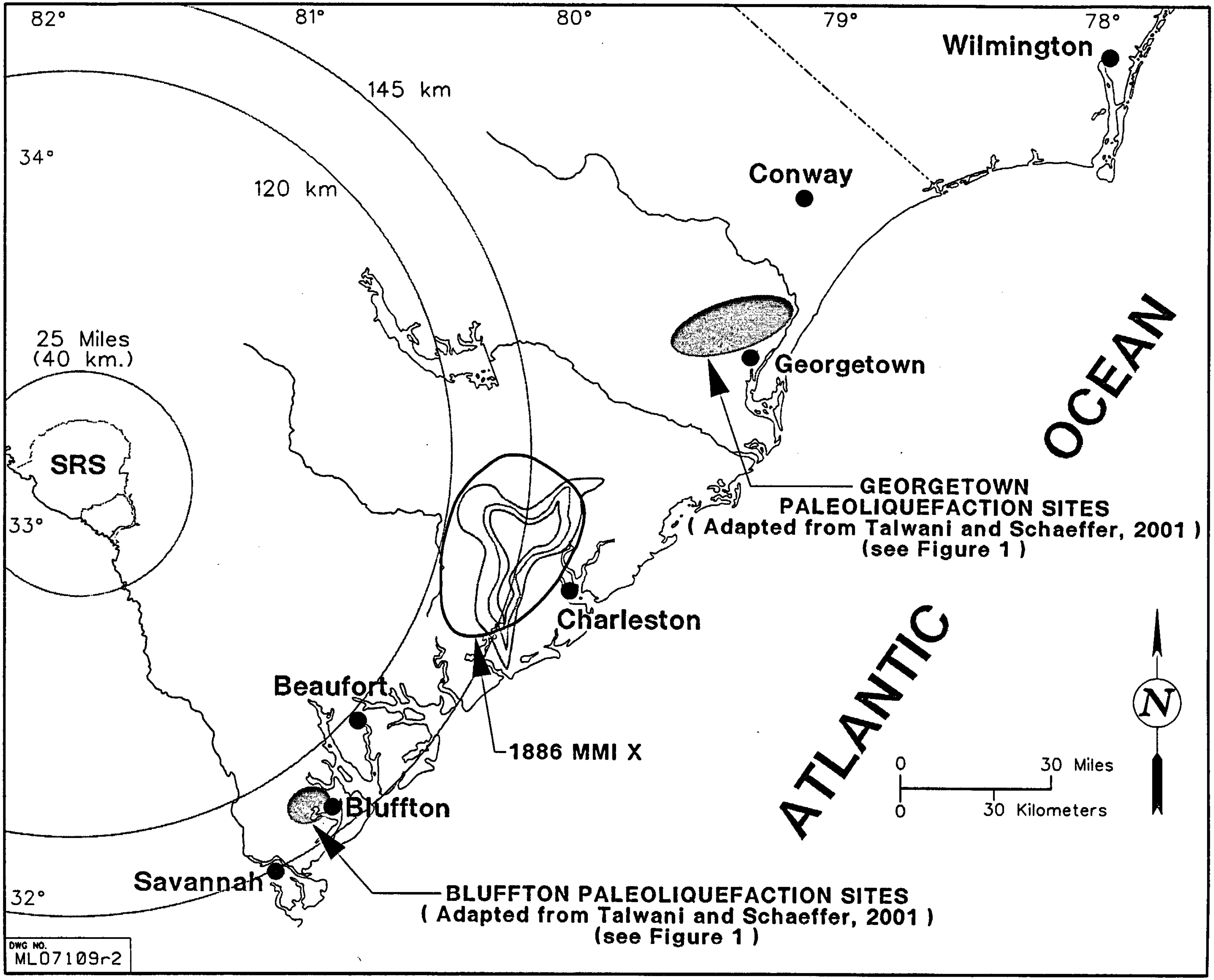
EPRI's On-Site Soil-Structure Interaction Research and its Application to Design/Analysis Verification. (J. C. Stepp and H. T. Tang), *Proceedings, International ENEA/ISMES/ENS*

Specialist Meeting on On-Site Experimental Verification of the Seismic Behavior of Nuclear Reactor Structures and Components, Bologna-Brasemane, Italy, May 4-7, 1987.

Validation of Seismic Soil-Structure Interaction Analysis Techniques using Lotung Experiment Data -- EPRI Program. (Y. K. Tang, H. T. Tang and J. C. Stepp), *Proceedings, Workshop on Lotung Large-Scale Seismic Experiment*, EPRI NP-6154, vol. 1, Palo Alto, CA, December, 1989.

Seismic Hazard Methodology for Nuclear Facilities: Modeling Input Interpretations. (J. Carl Stepp and R. K. McGuire), *Proceedings, 14th Water Reactor Safety Research Information Meeting*, USNRC, Washington, D. C., October 26-30, 1986.

A Seismic Hazard Methodology for the Central and Eastern United States. (J. Carl Stepp and Jerry L. King), *Proceedings, 14th Water Reactor Safety Research Information Meeting*, USNRC, Washington, D. C., October 26-30, 1986.



82°
81°
80°
79°
78°
Wilmington
145 km
34°
Conway
120 km
25 Miles
(40 km.)
Georgetown
OCEAN
SRS
GEORGETOWN
PALEOLIQUEFACTION SITES
(Adapted from Talwani and Schaeffer, 2001)
(see Figure 1)
33°
Charleston
ATLANTIC
Beaufort
1886 MMI X
N
0
30 Miles
0
30 Kilometers
Bluffton
Savannah
32°
BLUFFTON PALEOLIQUEFACTION SITES
(Adapted from Talwani and Schaeffer, 2001)
(see Figure 1)
DWG NO.
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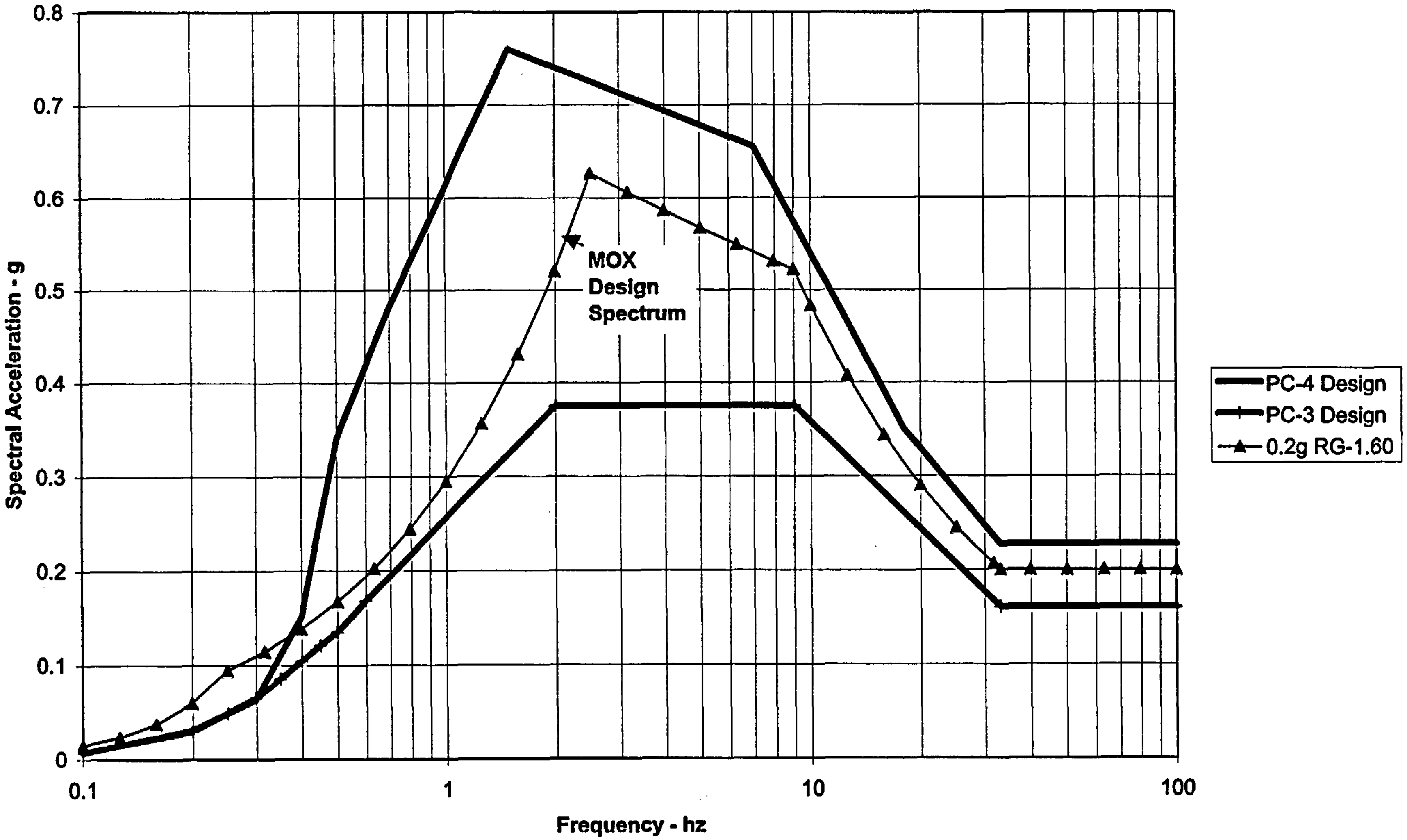

Spectral Acceleration - g
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PC-3 Design
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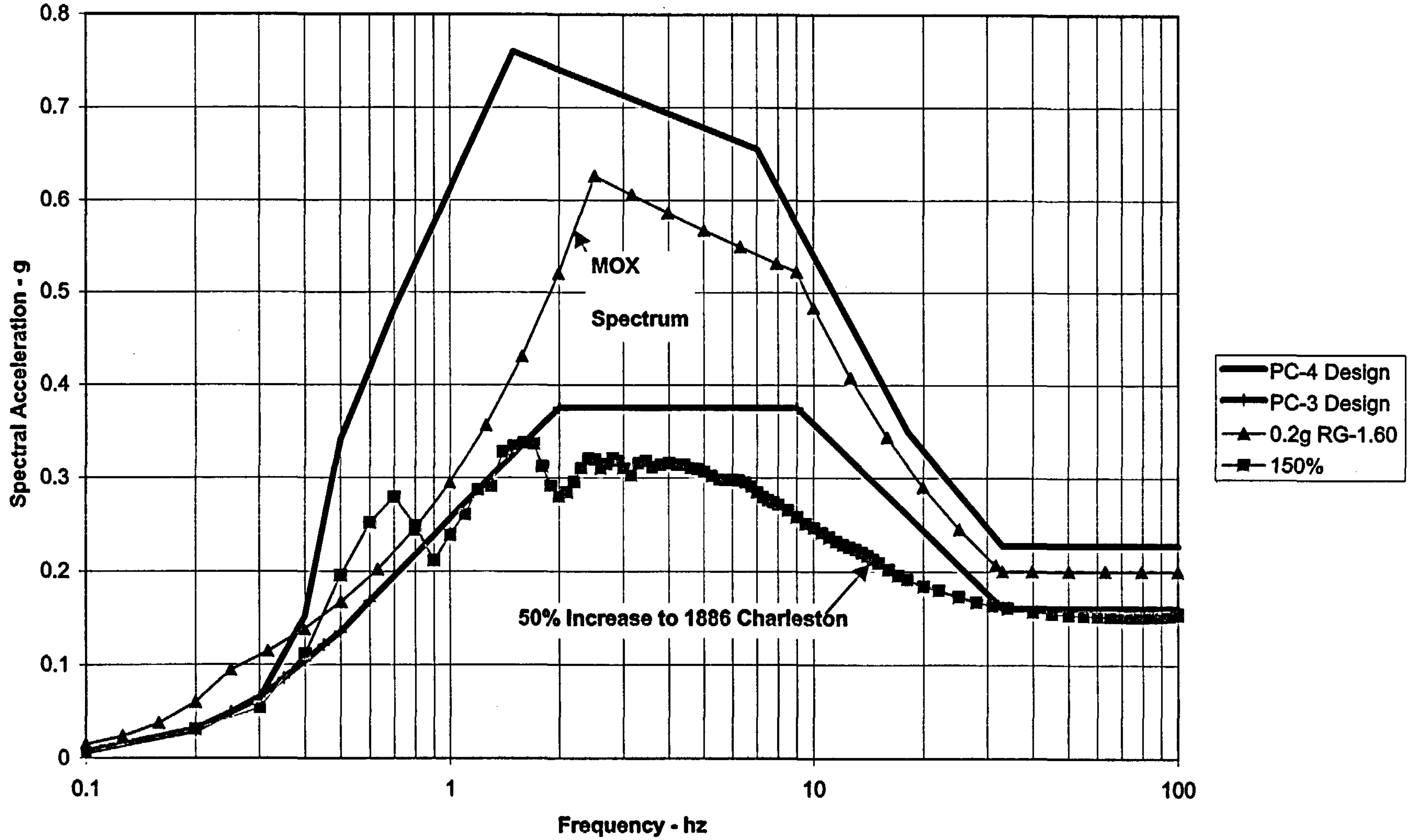

0.8
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Spectral Acceleration - g
0.1
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10
100
Frequency - hz
MOX
Spectrum
50% Increase to 1886 Charleston
PC-4 Design
PC-3 Design
0.2g RG-1.60
150%

TRANSCRIPT OF PROCEEDINGS

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

- x

In the Matter of: :

DUKE COGEMA STONE & WEBSTER :

(Savannah River Mixed Oxide :
Fabrication Facility) :

- x

Deposition of DR. LELAND TIMOTHY LONG

Pages 1 through 249

Washington, D. C.
June 25, 2003

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ERRATA SHEET

To the Deposition of Dr. Leland Timothy Long on June 25, 2003

The deponent, having a right to make any changes necessary, hereby makes the following changes in the deposition and states the reason for each change accordingly.

PAGE	LINE	CHANGE	REASON FOR CHANGE
7	13	change "valuable" to "viable"	incorrect transcription
7	18-19	change "one theory" to "two theories, one for major earthquakes and one for shallow smaller earthquakes"	misspoke
8	2	insert "occurring on" after "faults as"	incorrect transcription
8	5	change "everything" to "every earthquake"	incorrect transcription
8	6	change "Everything" to "Every earthquake"	incorrect transcription
8	7	insert "(earthquakes") after "They"	incorrect transcription
8	8	change "seismic hazards" to "seismicity"	incorrect transcription
8	17	delete first "crust"	incorrect transcription
8	19	change "is failed" to "fails"	incorrect transcription
8	20	change "failed" to fails,"	incorrect transcription
8	20	insert comma after "perhaps"	incorrect transcription
11	9	insert "earthquakes" after "intraplate"	incorrect transcription
11	11	insert "the" after "respect to"	incorrect transcription
11	11	insert "The New Madrid seismicity" after "seismicity."	clarification
11	11	delete "and that"	incorrect transcription
12	11	insert period after "activity"	incorrect transcription
12	11	delete "that,"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
13	8	delete "contract or"	incorrect transcription
13	15	insert "of the seismicity" after "characteristics"	incorrect transcription
13	16	insert "that would support this hypothesis" after "correlation"	clarification
15	22	insert quotation mark before "a large"	incorrect transcription
16	1	delete "very specific zones,"	incorrect transcription
16	1	insert quotation mark after "reason"	incorrect transcription
16	2	insert quotation mark before "very"	incorrect transcription
16	3	insert quotation mark after "responsible."	incorrect transcription
16	3-4	change "ambiguity in accepting" this multiple hypothesis" to "reluctance to accept these multiple hypotheses."	misspoke
16	4	change "USGS perhaps" to "The USGS hazard maps perhaps"	incorrect transcription
6	5	delete "from the fact"	incorrect transcription
16	7	change "Elgin Mercer" to "Algermissin"	incorrect transcription
16	8	insert period after "zones"	incorrect transcription
16	8	Change "in" to "In"	incorrect transcription
16	9	insert semicolon after "known"	incorrect transcription
16	9	insert comma after "so"	incorrect transcription
16	11	insert comma after "So,"	incorrect transcription
16	15	change "there, where" to "where other"	incorrect transcription
16	20	change "seismic" to "seismicity, that is"	incorrect transcription
16	21	insert comma after first "earthquakes"	incorrect transcription
17	1	delete "represent they"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
17	3	change "documented by" to "documented. By"	incorrect transcription
17	8	insert "relative to the 1995 maps" after "The 2000 maps"	incorrect transcription
19	19	change "Perdita Uani" to "Pradeep Talwani"	incorrect transcription
19	21	change "There" to "These"	incorrect transcription
20	1	insert "and" after "United States,"	incorrect transcription
20	3	change "Perdita Uani" to "Pradeep Talwani"	incorrect transcription
20	13	delete "be"	incorrect transcription
20	13	insert "agree with a"	incorrect transcription
21	2	change "depth with significant" to "depths from five to 15 kilometers with"	incorrect transcription
21	3	change "major strength on the U.S. across," to "strongest portion of the crust."	incorrect transcription
21	4	delete "which is anywhere from five to 15 kilometers"	misspoke
21	9	change ""Knees" to "These"	incorrect transcription
21	9	change "type" to "types"	incorrect transcription
23	4	change "New Madrid," to "New Madrid, (which is"	incorrect transcription
23	5	change "Southeastern but" to "Southeastern) and the"	incorrect transcription
24	2	change "dam resevoir" to "dammed rivers and waters in the reservoirs"	incorrect transcription
24	6	change "indication is that" to "inclination is to believe that"	incorrect transcription
24	8	change "and" to "(and"	incorrect transcription
24	10	change "surface" to "surface)"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
24	10	delete "many of these earthquakes"	incorrect transcription
24	11	change second "that" to "these"	incorrect transcription
24	14	correct spelling of "perturbations"	incorrect transcription
24	15	delete comma after "reservoir-induced and insert "seismicity."	incorrect transcription
24	16	insert "These theories are," before "in part"	incorrect transcription
24	16	change "fluids" to "fluid pressure"	incorrect transcription
24	16	insert "change in water level in a" after "from the"	misspoke
24	17	change "reservoir, that" to ""'reservoir"	incorrect transcription
24	17	change "falls so" to "faults and"	incorrect transcription
24	18	change "fractures separating them, causing them" to "fractures causing them to separate and"	incorrect transcription
25	1	insert "for which" after "and"	incorrect transcription
25	2	insert "depth" after "in the"	incorrect transcription
25	3	insert "depth range" after "kilometer"	incorrect transcription
25	10	delete "and say that is an earthquake"	incorrect transcription
25	11	insert (the mechanism) after "into it	clarification
26	2	change comma to period after "agree"	incorrect transcription
26	3	Insert "It" before "doesn't"	incorrect transcription
26	8	change "of" to "in"	incorrect transcription
26	9	delete "rocks of fairly"	incorrect transcription
26	14	insert "was caused by" after "was"	incorrect transcription
26	22	change "fluid conductiveness" to "fluid permeability"	misspoke
27	8	change "design of set up the" to "design or set-up of the"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
27	12	delete dash and insert "an" before "under"	incorrect transcription
27	12	insert "of" after "estimate"	incorrect transcription
27	15	change "and to" to "in the"	incorrect transcription
27	21	change "that" to "the design inadequate."	incorrect transcription
28	13	change "mobile" to "Moho"	incorrect transcription
28	13	insert "at the" after "bounce"	incorrect transcription
28	14	insert "distance" after "reflection"	incorrect transcription
28	15	change "vibration, and that was" to vibration. That was"	incorrect transcription
30	16	insert "the crustal structure along the entire" after "average of"	clarification
30	17	insert "to Atlanta." after "Bowman"	incorrect transcription
30	17	delete "—excuse me, there was a"	incorrect transcription
30	18	delete "Bowman earthquake used"	incorrect transcription
30	18	change "from" to "From"	incorrect transcription
30	18	change "central" to "epicentral"	incorrect transcription
30	21	change "model but" to model. But"	incorrect transcription
30	22	delete "either"	incorrect transcription
31	2	change "really of a" to "of the crust as"	incorrect transcription
31	4	delete "propagating,"	incorrect transcription
31	5	change "it" to "the model"	clarification
31	8	change "released" to "reduced"	incorrect transcription
31	8	change "mobile" to "Moho"	incorrect transcription
31	9	change "longer" to "larger"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
31	9	change "and" to "at"	incorrect transcription
31	18	delete "whether—"	incorrect transcription
32	2	insert period after "else"	incorrect transcription
32	2	insert "I don't know if" before "the"	incorrect transcription
32	3	delete comma and "I don't know"	incorrect transcription
32	4	change "it" to "them"	incorrect transcription
32	5	change "falls" to "fall"	incorrect transcription
33	11	delete second "a"	incorrect transcription
33	12	delete "seismically"	incorrect transcription
33	12	change "historically" to "by historical"	incorrect transcription
33	13	delete "controlled"	incorrect transcription
33	15-16	delete "The utilization is something like – it is possible"	incorrect transcription
33	21	change "what" to "where"	incorrect transcription
35	7	insert "occurred" after "earthquake"	incorrect transcription
35	7	change "past" to "more"	incorrect transcription
35	8	insert "likely" after "have"	incorrect transcription
35	9	change "Atkinson/Boore but" to "Atkinson/Boore. The attenuation relation"	incorrect transcription
35	10	insert "the" after "for"	incorrect transcription
35	11	change "mobile" to "Moho"	incorrect transcription
35	13	insert "(from different azimuths") after "direction,"	clarification
35	20	change "site, when their technique although" to "site. Although"	incorrect transcription
35	22	insert "the USGS maps used" before "an"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
35	22	delete "was"	incorrect transcription
36	1	change "technique, it" to "technique. It"	incorrect transcription
41	10	insert "also" after "have"	incorrect transcription
41	13	insert "(bedrock)" after "rock"	clarification
41	13	insert "zone of high seismic velocity, usually the unweathered" after "as the"	incorrect transcription
41	19	insert "bedrock" after "that"	incorrect transcription
41	22	change "pseudo hard" to "pseudo-hard"	incorrect transcription
42	1	delete "the --"	incorrect transcription
42	2	insert "computations" after "USGS"	incorrect transcription
44	9	insert "vibration" after "surface"	
44	10	insert "in the model" after "everything"	clarification
46	20	change "has" to "was"	incorrect transcription
47	15	change "paper," to "paper. However, the answer is yes."	incorrect transcription
48	21	change "this normal" to "the abnormal"	incorrect transcription
49	20	insert "B.S." after "is"	incorrect transcription
49	22	change "physics" to "geophysics"	incorrect transcription
50	9	change "Burke" to "Berg"	incorrect transcription
51	4	change "micros seisisms" to "microseisisms"	incorrect transcription
51	8	insert dash between "micro" and "earthquakes	incorrect transcription
52	1	insert dash between "wave" and "form"	incorrect transcription
52	3	change "new" to "New"	incorrect transcription
52	6	delete "attenuation --"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
52	9	change "lawyers" to "layers"	incorrect transcription
52	10	change "better and" to "better. I"	incorrect transcription
53	1	delete comma after "is"	incorrect transcription
53	8	change "Nevada, and in" to "Nevada. In"	incorrect transcription
53	10	change "it was a basin layer" to "there was a basin"	incorrect transcription
53	10	insert "depth to" after "shallow"	incorrect transcription
53	14	change "The program you all" to "In the program you"	incorrect transcription
53	16	change "is" to "are"	incorrect transcription
53	22	change "area" to "depth range"	clarification
54	1	insert "Is shallow," before "50"	incorrect transcription
54	17	delete "earth's"	incorrect transcription
56	14	change "a large bar" to "Watts Bar"	incorrect transcription
56	17	delete "had not -- I"	incorrect transcription
56	20	change "tomorrow and the" to "tomorrow. The"	incorrect transcription
56	20	insert "that" after "was"	incorrect transcription
56	21	change "a 45 degree" to "45 degrees"	incorrect transcription
57	1	change "in one" to "depending on the direction of propagation"	incorrect transcription
57	2	delete "direction than the other"	incorrect transcription
57	4	after "different", insert "in different directions."	incorrect transcription
57	5-6	delete "But I did the engineering."	incorrect transcription
57	15	change "seismic" to "seismicity"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
59	15	change "point" to "project"	incorrect transcription
59	16	change "conversion" to "inversion"	incorrect transcription
59	16	delete "shallow"	incorrect transcription
59	19	after "use to," insert "get an image of what is inside the area."	clarification
60	11	change "censor" to "sensor"	incorrect transcription
64	2	insert "issues" after "two"	incorrect transcription
67	16	change "Waldon" to "Walton/Oconee"	incorrect transcription
68	16	change "Waldon" to "Walton/Oconee"	incorrect transcription
72	4	delete "in the middle of"	incorrect transcription
73	20	delete "in elevators"	incorrect transcription
75	7	insert "Emergency" after "Georgia"	incorrect transcription
75	7	delete "Service"	incorrect transcription
79	7	delete "You are the expert."	incorrect transcription
80	20	change "end" to "opinion"	incorrect transcription
81	19	delete "one of the expert panels"	incorrect transcription
81	21	insert period after "zones"	incorrect transcription
81	21-22	delete "and I think this was the basis of one of them."	incorrect transcription
85	14	change "to you" to "you to"	incorrect transcription
86	6	change "resolving" to "now reducing"	incorrect transcription
86	6	insert "a" before "moment"	incorrect transcription
86	7	delete "of"	incorrect transcription
86	19	change "or" to "of"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
87	2	delete "root"	incorrect transcription
87	3	change "three" to "100"	correction
87	13	insert "(the square of)" before "that"	incorrect transcription
87	14	change "five" to "high"	incorrect transcription
87	15	delete comma	incorrect transcription
87	16	change "attitude" to "magnitude"	incorrect transcription
87	17-19	delete "so you . . . high frequencies."	incorrect transcription
88	18	change "come" to "came"	incorrect transcription
89	1	change "K" to "decay"	incorrect transcription
93	10	change "would" to "would, and"	incorrect transcription
93	11	delete "been"	incorrect transcription
93	11	after "have", insert "put in a seismic zone in southeastern Tennessee"	incorrect transcription
93	12	delete "would have been on the Tennessee side."	incorrect transcription
93	20	delete "of"	incorrect transcription
95	2	change "Elvin" to "Albin"	incorrect transcription
96	7	change "the" to "a"	incorrect transcription
96	8	change "Elvin" to "Albin"	incorrect transcription
96	11	insert "blow" after "low"	incorrect transcription
96	21	insert "seismicity" before "so"	incorrect transcription
96	22	insert "is" before "on"	incorrect transcription
97	8	change "the dam at Quarters" to "Carters"	incorrect transcription
97	14	change "Maytech" to "Maytec"	incorrect transcription
101	20	change "Law" to "large"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
102	1	change "available" to "viable"	incorrect transcription
103	11	change "sites" to "studies"	incorrect transcription
103	13	delete "two"	incorrect transcription
106	6	change "coastal" to "coast and geodetic"	incorrect transcription
107	15	change "opinion" to "person"	incorrect transcription
109	5	change "Makajani" to "Talwani"	incorrect transcription
109	7	change "Makajani" to "Talwani"	incorrect transcription
110	9	change "anything" to "anyone else"	incorrect transcription
122	13	change "mobile" to "Moho"	incorrect transcription
125	2	change "Macke" to "Mckey"	incorrect transcription
125	2-3	delete "I am not sure how we did that."	incorrect transcription
125	18	insert "the" before "intermediate"	incorrect transcription
125	21	insert "reflection" before "part"	incorrect transcription
126	21	change "version" to "inversion"	incorrect transcription
129	11	change "post" to "past"	incorrect transcription
142	11	change "develop" to "measure"	incorrect transcription
145	20	change "conversion" to "inversion"	incorrect transcription
146	22	change "rocket" to "lack of a"	incorrect transcription
146	22	insert "due to" after "was"	incorrect transcription
147	3	change "reporting" to "recording"	incorrect transcription
147	5	insert "quickly" after "field"	incorrect transcription
149	10	change "Service" to "Survey"	incorrect transcription
151	2	change "happen" to "happy"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
151	3	change "or" to "of"	incorrect transcription
151	6	insert "Q." before "You stated"	incorrect transcription
151	8	insert "A." before "The particle"	incorrect transcription
153	7	insert "if" before "it	incorrect transcription
153	11	insert "reflection from the Moho and its contribution to the" after "critical"	clarification
153	12	insert "post" before "critical"	incorrect transcription
154	11	change "publicity" to "multiplicity"	incorrect transcription
155	8	delete "strongly held"	misspoke
157	8	change "it is designed" to "that person is handled."	clarification
158	2	change "you have anyplace" to "you can have events anyplace"	incorrect transcription
158	6	change "the fact" to "his observation"	incorrect transcription
158	8	change "this" to "his"	incorrect transcription
159	4	change "crusts" to "the crust"	incorrect transcription
159	5	change "evolve" to "results"	incorrect transcription
160	17	change "Elgin" to "Algermissin"	incorrect transcription
161	7	insert "in" before "intraplate"	incorrect transcription
161	7	insert "earthquakes" after "intraplate"	incorrect transcription
161	8	insert "stress" before "but"	incorrect transcription
161	9	insert "earthquake" before "may"	incorrect transcription
161	16	insert "signs of a" before "definition"	incorrect transcription
161	17	insert "process" after "chaotic"	incorrect transcription
161	21	delete "now, or"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
162	5	change "small things" to "minor differences in the conditions in a rupture zone"	incorrect transcription
162	11	change "inability" to "instability"	incorrect transcription
162	19	change "Nutterly" to "Nuttly"	incorrect transcription
162	20	insert "theory" after "that"	incorrect transcription
163	9	insert "distribution" after "normal"	incorrect transcription
163	9	change "refractal" to "a fractal"	incorrect transcription
169	17	insert dash between "after" and "shocks"	incorrect transcription
166	2	insert "change in the" before "properties"	incorrect transcription
166	12	change "conversion" to "inversion"	incorrect transcription
166	13	change "conversion" to "inversion"	incorrect transcription
169	4	change "advice" to ""'a" values"	incorrect transcription
169	9	change "differentiate" to "differ substantially"	incorrect transcription
171	5	change "application" to "reflection"	incorrect transcription
174	8	insert "not" before "addressed"	incorrect transcription
175	5	change "The" to "In the"	incorrect transcription
175	6	insert "studies" after "EPRI"	incorrect transcription
176	19	insert dash between "micro" and "earthquake"	incorrect transcription
176	22	change "less in" to "less. In"	incorrect transcription
176	22	change U.S. they" to "U.S. They"	incorrect transcription
177	3	insert "(the earthquakes)" after "they"	clarification
177	5	insert dash between "micro" and "earthquakes"	incorrect transcription
178	13	insert "magnitude" after "the"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
179	1	change "three" to "0.3"	correction
179	3	change "Nutterly" to "Nuttly"	incorrect transcription
179	4	change "point one five" to "15"	correction
182	16	change "Marconi" to "Oconee"	incorrect transcription
182	21	insert "estimates" after "best"	incorrect transcription
183	6-7	change "epi center" to "epicenter"	incorrect transcription
187	13	delete " -- must have occurred"	incorrect transcription
183	22	insert "available" after "was"	incorrect transcription
185	11	change "epi center" to "epicenter"	incorrect transcription
185	15	change "epi center" to epicenter"	incorrect transcription
186	9	insert "on existing weaknesses" after "or"	incorrect transcription
186	11	insert "of the Charleston area" after "southwest"	incorrect transcription
186	12	delete ", in the Charleston area"	incorrect transcription
186	18	insert dash between "paleo" and "seismic"	incorrect transcription
188	4-5	delete "-- prepared by people at that but"	incorrect transcription
188	5	before "I", insert "researchers at Lamont."	incorrect transcription
188	6	insert "research" before "at"	incorrect transcription
189	21	insert "relevant" after "be"	incorrect transcription
191	6	insert "be" after "would"	incorrect transcription
192	4	change "epi centers" to "epicenters"	incorrect transcription
193	15	change "salt" to "basalt"	incorrect transcription
193	19	change "basin" to "basins"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
193	22	insert "composed of" after "is"	incorrect transcription
193	22	change "a" to "an"	incorrect transcription
194	1	delete"temporary"	incorrect transcription
194	1	insert "was created" after "that"	incorrect transcription
196	2	change "drilling" to Brune"	incorrect transcription
196	4	insert "double corner model for a" after "indicated a"	incorrect transcription
196	5	insert "earthquakes." after "U.S."	incorrect transcription
196	17	change "level" to "Moho"	incorrect transcription
196	21	change "mobile" to "Moho"	incorrect transcription
199	20	change "vocal" to "local"	incorrect transcription
199	21	delete "about"	incorrect transcription
199	22	change "you look at" to "look like"	incorrect transcription
202	4	change "there and even their" to "there. Their"	incorrect transcription
202	5	change "should model" to "should be modeled"	incorrect transcription
202	6	changed "is seen" to "was used"	incorrect transcription
203	3	change "force" to "reflection"	incorrect transcription
206	7	change "period" to "area"	incorrect transcription
209	7	change "Mirrors" to "Meers"	incorrect transcription
211	10	change "epi center" to "epicenter"	incorrect transcription
211	12	change "epi center" to "epicenter"	incorrect transcription
212	3	delete "unless you get into the plastics --"	incorrect transcription
216	22	change "metric" to "mafic"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
218	11	insert "its" after "and"	incorrect transcription
219	21	change "A PS--"to "In a PSHA or"	incorrect transcription
221	1	insert "at" after "occur,"	incorrect transcription
221	6	insert "a" after "that"	incorrect transcription
221	7	change "exceeding" to "exceeded"	incorrect transcription
228	7	delete "they look at --"	incorrect transcription
230	10	change "it" to "of the conclusions"	clarification
230	11	change "he has" to "Talwani and others have"	clarification
230	22	insert dash between "paleo" and "seismic"	incorrect transcription
231	6	insert dash between "paleo" and "seismic"	incorrect transcription
237	5	change "epi center" to "epicenter"	incorrect transcription
245	13	change "two" to "200"	incorrect transcription
246	6, 8	insert dash between "paleo" and "liquefaction"	incorrect transcription
246	17	change "in" to "into"	incorrect transcription

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Dr. Leland Timothy Long

the camp that there is a California model that earthquakes -- sorry, faults cause earthquakes and that the USGS is primarily in that camp.

A. I would say many investigations in New Madrid that come out of the USGS are in that camp. I am not saying that all of the individuals in USGS are.

Q. Would you say that the USGS -- let me back up. Are you familiar with the USGS seismic hazard maps?

A. Yes.

Q. Are you familiar with the 2002 revision of those maps?

A. Not in detail but I have looked at them.

Q. Are you familiar with the 1996 maps?

A. I have looked at those too.

Q. Would you say that the 2002 USGS hazard maps follow the California model for New Madrid?

A. The USGS maps are -- the Lawrence Livermore studies pulled in a lot of information on proposed and hypothesized mechanisms with experts varying from a large earthquake can occur anyplace

anyplace along the line. It is a fact that the crustal thickness varies. So the model really of a two-layer model is not appropriate.

When propagating, using the theory to propagate waves through a two-layer model, it disturbs and perturbs the attenuation of the distance functions and I believe in such a way that it would have released the amplitude of the mobile bounce and put in longer amplitudes and shorter distances. That is a relationship which should be checked by using a proper crustal model, not speculating.

Q. Do you have any opinions as to any other inadequacy in the seismic design of the MOX Facility other than what you have just told us?

A. Lots of small details here. I think I would want to go through the contention point by point and look at it to see whether -- what those issues were in detail. There are small details like how many earthquakes are there at Charleston of large magnitude, where could a Charleston type earthquake occur, is it limited to Charleston or in

A. The USGS study used attenuation relationships that were one-third Atkinson Boore and two-thirds other -- the original -- the 2000 USGS study was one-third Atkinson/Boore and two-thirds relationships used in the '95 study, and in my opinion the study for the region, where the Charleston earthquake should have used a past specific attenuation relationship which would have been similar to the Atkinson/Boore but should have been corrected and adjusted for very likely possibility that the mobile bounce is going to give you a larger signal. For seismicity in the other direction, which is probably not as significant, a different attenuation relationship should be used.

Q. So you disagree with the way USGS was preparing for the 2000 maps because they used one-third Atkinson/Boore and two-thirds other studies left over from the 2000 maps?

A. I disagree with using their maps for a specific site, when their technique although appropriate for getting an estimate for the whole eastern United States, was an appropriate

program and in the definition of the velocity structure to where I didn't feel I could contribute to it. I know that some studies were done with observed data. I don't know that those results were included in this.

Q. In this, are you referring to the surface spectra?

A. In the surface spectra, yes.

Q. Do you have any concerns at all with the shape or wear -- let me ask it in parts.

Do you have any concern with the shape of the surface spectra for the MOX Facility?

A. In general, no.

Q. Do you have any concern with where that shape was anchored at deep ground acceleration?

A. With amplitude, yes. We anchored the shape at a given amplitude.

Q. What was that amplitude?

A. My understanding was it was anchored at .2 hard rock and it was at a given frequency. I would have to look it up.

Q. When you say .2 hard rock, what do you

opinion to GANE as to whether they were appropriate or not.

(The witness consulted with counsel.)

THE WITNESS: Is that the interrogatory answer, I believe, I was referring to? The first interrogatory was not something I put together. So most of the work -- I have not done computations for this. I have simply looked at the data and expressed opinions based on my experience and background, I guess back-of-the-envelope calculations I have done, but not actual analyses.

BY MR. POLONSKY:

Q. You started off by saying actual studies have been limited. That implies that you have done some studies. What are those studies?

A. Later on I said I have done back-of-the-envelope studies. I have done a lot of studies but not with respect to this specifically and I have been able to draw on those to say whether or not the contentions were viable.

Q. What kind of back-of-the-envelope studies have you done?

A. Just estimating numbers and calculations -- by that I mean just small estimates, nothing that involved computer simulation.

Q. When you say estimating numbers and calculations, we have spoken a lot -- spoken about many different types of relationships --

A. I can give you an example --

Q. I would actually like all of the examples, if you could recall them?

A. There is no way I could recall all the examples. This has gone on for a year or two, at various times. This is not something -- when you do back-of-the-envelope calculation you don't necessarily keep track of it. One example is when I looked at the 1995 Atkinson/Boore article and looked at their observed attenuation relationships and at the end of the article they plot a comparison data with their composite or theoretical curves which has utilized by the USGS. Then if you look at the 100 kilometer distance range you see a note -- that they note in the article that there

are some anomalous features there, that the amplitudes that are observed vary from a factor of two to a factor of four above their theoretical curves.

Q. Have you documented any of your back-of-the-envelope calculations?

A. No. That is why they are back-of-the-envelope.

Q. Are they recorded in paper form anywhere?

A. Probably not.

Q. Do you intend to at any point to put them to paper?

A. None of them were extensive enough to warrant publication and that would be putting them to paper, yes. There are a number of things that have come out of this that I think probably should be published.

Q. Are there any back-of-the-envelope calculations that you have done, in the literal sense, without meaning publications, have been reduced to a piece of paper?

A. All of the documentation -- all of the

A. I don't believe so. Seismological Society of America. All seismologists pretty much belong to that.

Q. Have you done any consulting with respect to NRC requirements governing seismic design?

A. I don't believe so. Again, I have stayed pretty much on the science end of it, not the regulatory end.

Q. What is your current title?

A. Professor of geophysics.

Q. What are your duties and responsibilities in that position?

A. Teach and research.

Q. What research are you involved in?

A. Right now my major point is tomographic conversion of surface waves for shallow -- detection of shallow structures.

Q. What is tomographic conversion?

A. It is what we use to -- if you have data outside of an area, you use tomography to get an image of what is inside the area.

Q. What equipment is used to get that image?

earthquakes. I think a lot of those efforts like mine were dropped because the USGS finally did what they should have.

Q. Next item is Lawrence Livermore lab --

A. LLNL.

Q. What was the timeframe for that?

A. You are the expert. Those were the '70s, late '70s, around there. This was the contract by NRC to Lawrence Livermore to come up with a probalistic estimate and I served as an expert on seismology.

Q. On one of those panels?

A. The panel was a seismology panel and then they had a ground motion panel. I was a singular expert on the seismology. I was given a code number. One to 12, and one of those is mine.

Q. There were 12 other seismology experts on the same panel?

A. I think on that order, 11 or 12, and, of course, the definition of expert comes in here. You might not agree with that.

Q. Expert people, those people on the panel

same thing.

Q. So your input was one of 11 or 10 or 12 inputs into seismology issues within the expert panel?

A. That is right.

Q. What were the seismology issues that you were asked to provide opinions on within the expert panel?

A. I don't know that it was an opinion so much as a data analysis project. We were provided lists of earthquakes and by interaction with Lawrence Livermore people we could have specific things computed. We defined seismic zones. They provided an analysis of those zones for earthquakes. We reviewed those zones, went back and forth with them. We could introduce our own hypothesis and feelings as to what the seismicity should be like. One expert had the whole east in one big zone -- one of the expert panels. Others had micro zoned the area to death. Some of them, like myself, even had overlapping zones, and I think this was the basis of one of them.

One of the outcomes was to say, in essence, what is the status or the current understanding by people working in the field of the seismicity of the Southeast and how should it be put into a hazard assessment program.

Q. Was the Livermore study solely focused on the Southeast?

A. No, it was national.

Q. Where was it focused?

A. National, continental U.S.

Q. So as a participant in the expert panel you were asked to provide input on seismic zones for the whole United States?

A. You know, I did not focus on outside the Southeast. I did do some in the Northeast and central U.S., but when you get past the Rockies, I did not make any attempt so I don't know if that was even part of the analysis.

Q. Do you mean to tell me you did not provide any input for any seismic zones west of the Rockies?

A. No, I did not.

Q. You did not provide any input?

A. No.

Q. Do you recall what your input was for the Charleston seismic zone?

A. My guess, it was a zone, a seismic zone surrounding the area of activity.

Q. And that zone of activity would be defined as what -- at the time?

A. At the time -- what was it? I would have to go back to documents to tell you exactly what it was. At that time the locations of a lot of the after shocks were not that well known. There was some question as to where the actual epi-center was. I probably included the Bowman zone as part of that because that was an area I was interested in.

Q. Where is Bowman in relation to Charleston?

A. Northwest, perhaps 30 to 60 kilometers.

Q. Is it on the shore or further inland?

A. Further inland. Northwest is inland.

Q. In addition to giving input to seismic

zones, what other input did you provide as an expert panelist for the Livermore study?

A. We had rates -- seismic zones implies you have a certain rate of activity associated with that. There were -- it wasn't long after that we were also involved with an EPRI study and some of the times the studies get merged in.

Q. If I can hold you to just to the Livermore -- to the best of your recollection, other than rates of seismicity and --

A. Little maps with squares and circles on them.

Q. Showing the location of the seismic source zone --

A. Right.

Q. Were you asked to opine on the likely largest magnitude to be expected within that source zone?

A. One had a maximum assigned to each seismic zones. In one area I had overlapping zones but they worked it out.

Q. Why did you do that?

Q. Do you know, after the fact, looking at the maps for the Livermore study, whether any other participant in the expert panel placed a seismic source zone in Southeast Tennessee?

A. I don't know the numbers exactly. Some, yes -- probably most of them did put a seismic zone in. Some of the zones were very broad and inclusive. There were a couple that were done by outside experts that didn't understand. So there were some strange results but I would Gil Bolinger's would have been -- if he were one of the experts would have been on the Tennessee side.

Q. What magnitude would you have in the moment magnitude scale given to Southeast Tennessee at the time the Livermore study was done and you were an expert on the seismology panel?

A. I would have given it as large a magnitude as New Madrid and Charleston.

Q. And that would have been 7.0 to 7.8 moment of magnitude?

A. Yes. It was my opinion at the time and still is that Southeast Tennessee is as viable a

problems. I would consider his opinion very highly.

Q. Where do you know him from?

A. That goes way back. He was with the NRC and then before that some of the work was -- the coastal survey and then in the EPRI project.

Q. Have you worked with him since then?

A. No.

Q. And that was late '80s?

A. Yes.

Q. Do you know Larry Salomone?

A. No.

Q. Do you have any reason to believe he can't give testimony in the proceeding?

A. Since I don't know him I would have no reason.

Q. Do you know Don McConaghy?

A. No.

Q. Do you have any reason to believe --

A. If I don't know him I wouldn't have a reason.

Q. Are you familiar with Richard Lee?

contention.

(The witness consulted with counsel.)

A. I could add when we recently cut back -- when GANE was going to cut back on the contention, the answers, we approved on those.

Q. Are you familiar with NRC regulations in 10 CFR, part 70, about designing facilities to a standard?

A. I have not studies those in detail.

Q. Have you read through them once?

A. I have not read through them.

Q. But you have had an opportunity to review the original and revised CAR?

A. Yes.

Q. And you provided input on GANE's responses to interrogatories?

A. Yes.

Q. Have you reviewed the NRC's staff's draft safety evaluation report dated April 2003?

A. I looked at that early in the evaluation. If I am interpreting this as the one I looked at. NRC wrote a response.

that you have taken, that the Hermann velocity model is not appropriate?

A. Well, the position is that the test earthquake from Charleston propagated to the site, if propagated by a proper model, would very likely indicate a higher level of vibration. In looking at the Hermann model and figuring out why it has the geometry and size it does, one can see that the interpretation that Hermann gave applies to a total path and not the short term path.

Q. What do you mean by total path as opposed to short term path?

A. His model was from Bowman to Atlanta or ATL which contains velocities which are significantly different than they are on the coastal plain. His technique was a surface wave technique which takes an average velocity. The average velocity between those two points doesn't necessarily represent the individual velocities for any part of that path.

Q. You said that the position is that the test earthquake from Charleston propagated to the

site, if propagated by a proper model, would very likely indicate a higher vibration. What is your basis for saying it would very likely indicate a higher level of vibration?

A. Hermann's model includes a lower crustal layer of velocity, 6.6, which probably does not exist. That intermediate layer in the model would cause reflections and amplitudes at shorter ranges to be higher and would decrease the energy available for the post critical reflection. This is a case where a proper model should be used to see what the actual effect is.

Q. Have you done any modeling or any calculations to see what the actual effect is?

A. In this particular case, no. I have looked at amplitudes for my Ph.D. thesis but that is a long time ago and I based my conclusions on my experience. I do have a paper in BSSA which presents observed data for amplitude versus distance for smaller magnitude earthquakes, and that does show this effect.

Q. What paper is that -- is that listed on

documented historical seismic event that is relevant to the seismic design for the MOX Facility. Are you now saying the New Madrid event is more relevant to the seismic design than the Charleston earthquake?

A. No, I didn't say that at all. The statement was is it relevant. To some extent. New Madrid events are larger and they do have some relevance because they were felt in that area. I think to simplify that you would say the Charleston earthquake is the largest post event to have occurred in historical times. So it would be, in terms of design, it would be the most -- if you are going to limit it to earthquakes that have occurred in historical time, it would be the most severe.

Q. What would you say is the magnitude -- moment magnitude of the early 1800s New Madrid earthquake, the largest?

A. I have tried to stay out of that argument. Some people think it is lower and some higher. Some recent studies say it is lower. Arch Johnson presents probably the most definitive study

of that and I believe his numbers were in the 7.5 range.

Q. Then what is the moment magnitude of the Charleston earthquake in 1886?

A. Probably around 7.0.

Q. So because Charleston was a 7.0 and New Madrid is a 7.5, do you believe that the New Madrid is the most severe documented historical seismic event that is related to the seismic design of the MOX Facility?

A. Not the most relevant but the largest that is relevant.

Q. Although that is true, from what you said previously, you would agree that the Charleston, although a lower magnitude, contributes more to the seismic hazard of the Savannah River Site than the New Madrid?

A. Yes. The USGS and LLNL and EPRI studies -- or USGS studies, go through a process where they defragment the results and the defragmentation shows the relative contribution of various sources and when you do that for the

Q. It says that the spectra should be scaled up to an appropriate value of acceleration at the surface. Do you have a proposal what that appropriate value of acceleration should be?

A. No, I don't.

Q. Also on page four, in response to interrogatory number 3.2, does GANE agree that design earthquake with return interval of 10,000 years is acceptable for the MOX Facility and the response is yes. On that limited issue, do you have any reason to disagree with GANE's response?

A. I agree.

Q. What is your understanding of the spectral response -- what is the your understanding of what the surface horizontal spectrum is for the MOX Facility?

A. We are talking about the terms we talked about before, whether it is the hard rock or the natural surface.

Q. Surface, that is why I used the word surface. Not a thousand feet or 800 feet below the surface. I am talking about what is at the

peak ground acceleration, not depending on acceleration.

A. I don't know what it is exactly. It is a function -- it is an interpretation of a seismic data or in any case a number of runs of a seismic -- number of runs of a program using different input to decide what that should be.

Q. Let's move to the third supplemental interrogatory response, answer to interrogatory 3.30. Page five. The response to interrogatory number 3.30, GANE generally agrees that the approach taken by DCS in calculating the PSHA is appropriate and then with the inception of, et cetera, et cetera.

Do you agree with this statement?

A. You have taken -- DCS has taken a standard procedure. They have obtained some information about seismicity, although they didn't input them into the base value. They tried to formulate a spectrum for the base, for the hard rock equivalent, and they have attempted to propagate that to the surface to get the surface

acceleration. That basically is an appropriate way to do it. Are there other ways, possibly, but that is generally the approach that most seismologists take. The contention though is that some of the input along the way has not -- has been biased in one way or another.

Q. Let me rephrase and correct me if I am wrong. Basically what DCS did in its methodology to generate a seismic hazard in your opinion was okay, was appropriate, but what they used as inputs, you have concerns with some of those inputs?

A. Exactly.

Q. Okay. That is very helpful.

To these interrogatories, and I am referring to them all as a set, you stated that the only addition you would provide would be a single article that we have already identified. Are there any other documents upon which you plan to rely that we have not talked about?

A. I don't believe so.

Q. How much time did you spend preparing for

Q. What stuff is that?

A. The interrogatories and their answers.

Q. Did you do anything to prepare for your deposition?

A. For this deposition?

Q. Yes.

A. No. Turns out that I was pretty much on vacation and I didn't get the time I planned to so I didn't do it.

Q. Have you ever testified before the Nuclear Regulatory Commission?

A. No.

Q. Do you consider yourself to be an expert with detailed specialized knowledge of NRC's regulations?

A. No.

Q. How about that same question with respect to NRC guidance?

A. No.

Q. Have you ever had any interactions with the NRC other than in relation to the Livermore study?

A. Waste disposal in general.

Q. Any applications to nuclear facilities?

A. I have not pursued all the potential applications. If I had known this technique and had the equipment when I was first asked to deal with it in Southwest Georgia to deal with sheer wave velocity, I would have used it then.

Q. Do you have any experience with NRC regulations?

A. No.

Q. Are you aware that there are separate NRC regulations that deal with deterministic seismic analysis versus probabilistic seismic analysis?

A. I am aware that the original regulations were closer to a deterministic approach which in many cases became unreasonable or very difficult to manage and that the Lawrence Livermore studies and EPRI studies were largely initiated to get away from deterministic and move toward a probabilistic approach. I am not aware of -- have not read the regulations themselves. As to the history of why these were occurring, that is my understanding.

Q. What you are referring to about deterministic and the change to probabilistic, are you referring to that as applied to nuclear power plants or a broader range of facilities?

A. Major concern in developing this was the concern with respect to nuclear power plants. That was the driving motivation. It is a general topic and it applies to such things as seismic hazard and like this Lawrence Livermore/EPRI studies pioneered the technique which Art Frankel developed with the USGS into the new hazard maps which applies to everything.

Q. You have already told me that you haven't reviewed the NRC regulations in part 70 which apply to the MOX Facility but are you familiar with any NRC guidance documents?

A. Not in detail, no.

Q. Have you reviewed the standard review plan, which is an NRC guidance document new reg 1718, standard review plan for the MOX Facility?

A. No.

Q. Have you reviewed any other plans for any

other types of facilities?

A. No.

Q. Are you familiar with reg guide 1.60?

A. No.

Q. Have you ever looked at it?

A. I don't know.

Q. You don't know if you have ever looked at it?

A. Right.

Q. Do you have experience with the Department of Energy other than the work that you initiated in October of 2002?

A. It was a five-year grant that led up to that study.

Q. So I assume that five-year grant began sometime in 1997?

A. Yes -- yes.

Q. And what was the purpose of that grant?

A. That was the tomographic stuff.

Q. The tomographic conversion --

A. Of surface waves, yes.

Q. Other than that, have you ever been

choice of instrumentation. We chose an instrument that relied on phone line for communication. This was pre-long term reporting capabilities of instrumentation, and we chose an instrument that we thought we could get into the field -- we could order and have delivered and get into the field in a hurry. The contractor -- the company didn't quite follow through on what they said they could in the way of delivery time so it was delayed.

Q. Any experience with DOE regulations?

A. No.

Q. Any experience with DOE guidance documents?

A. No.

Q. Are you familiar with any of the DOE standards that were the basis of the 1997 PSHA?

A. No, don't think so.

Q. I am going to name DOE standard 1020. Does that ring a bell?

A. Numbers won't ring a bell.

Q. Entitled seismic design?

A. No.

something I felt needed to be done.

Q. Does the work you did on the intensity felt area of the Charleston earthquake contradict any of the work Bollinger did in the late 1970s regarding the intensity meso seisal zones from the Charleston 1886 earthquake?

A. I don't recall it contradicts his work, no. I may have looked at it a little more closer with some of the attenuation relationships. What I did in the attenuation relationship is developed something that accounted for the post critical amplitude of the seismic waves -- most critical reflection, and incorporated that into equations I used. I used his intensity interpretation directly. I did not modify it in any way.

Q. Have you ever developed a seismic response spectrum?

A. No, I haven't. I haven't in the sense of a spectrum that you would consider for design purposes. With my Ph.D. thesis, I looked very carefully at the spectra of the wave form and the way the spectra is developed and attenuated.

drew a big circle around the whole eastern United States and said you have a seven anyplace and gave a rate for it. That is one outlier. Then there is some -- to the extent that I have seen a number of papers -- Ben Howell wrote a paper some time ago on the fact that almost all of the major eastern United States earthquakes, at least according to this data at the time had occurred in areas where there had not been previous seismicity and that scared him. However, we note from Charleston and New Madrid, those areas have exhibited seismicity and we know Seattle has had tremendous earthquakes and people thought it was pretty quiet up there. Just from historical data, a lot has been learned about seismicity but not enough to know where the next one is.

Q. So wouldn't you agree that it is important to have outlier opinions in the PSHA?

A. I agree you have to evaluate those opinions as to whether they are radical or outliers in terms of whether they disagree with the general opinion of seismologists. I have to admit that

myself, when I talk about eastern United States major earthquakes, I am probably a little bit of an outlier in the sense that they are not due to existing faults but due to weaknesses in crusts which evolve in both the earthquake and the fault.

Q. Would you agree that a PSHA should incorporate the diversity of expert judgments into the analytical results by appropriately capturing the current state of knowledge of the expert community?

A. That sounds quite reasonable, yes.

Q. Are you familiar with the senior seismic hazard analysis committee which I will refer to as SHAC?

A. No.

Q. Are you familiar with any reports issued by SHAC?

A. I don't think so.

Q. So it is fair to say you have never used it as guidance?

A. No.

Q. What is your opinion of the underlying

MR. POLONSKY: Let's do it now.

(Discussion off the record.)

(Recess.)

BY MR. POLONSKY:

Q. I don't want to cut you off from a response you might have otherwise given. Is there anything that is pending on the table in your mind or should I move on?

A. No, you can move on.

Q. Would you agree that the Lawrence Livermore/EPRI PSHAs are the gold standard for capturing uncertainty in the parameters that comprise the PSHA?

A. What is a gold standard?

Q. The standard that someone would turn to if that they were designing a nuclear facility?

A. I have to put this in historical perspective. Lawrence Livermore started up with their study contracted by the NRC. It was an expert's opinion pulled together at the time. The experts had a wide diversity of opinions. EPRI funded by the power plants probably didn't trust

EPRI or Livermore work, that some sources of the uncertainties relate to the attenuation functions that were used and that is a part of the study I didn't get into. What do you mean?

A. I did not reproduce the attenuation. The Lawrence Livermore and EPRI, I was a seismology expert. They had a separate panel for attenuation. They accepted relationships from the seismology group and attenuation from the attenuation group. I was not a part of the attenuation group.

Q. GANE has stated that EPRI and Livermore were intended for first-guess work only. Do you agree with that statement?

A. I agree with the statement that the Lawrence Livermore and EPRI studies were intended to give a regional assessment of the hazard. That their application to a particular site was to be a first guess in the sense that any individual site should be reevaluated given the details of seismicity and details of attenuation relationships for that particular site. Seismicity and attenuation relationships used in EPRI and Lawrence

Livermore were regional and meant to be used in a wide area.

Q. What is your basis for that statement, just your understanding --

A. That is my understanding. I remember asking someone about that and I don't remember who and when. It was someone involved in the studies. Basically, I had concern way back then, how can you use these generalized relationships for specific sites and I remember asking someone and he said they were not intended for a final answer but that any new site would have to be evaluated based on recent information.

Q. Give me your definition of what a major earthquake is in your opinion. Can you define what small and large are for me in your opinion, and if we could give it the moment magnitude but just for the purposes of currency?

A. There is a term called micro earthquake which is generally believed to be anything that is not felt but may be recorded and that is about magnitude one or less in the western U.S.. They

might be magnitude two or less because people are less sensitive out there. I could say the ground motion is not as strong on the surface because they are deeper. A small earthquake is larger than a micro earthquake and we are talking about earthquakes that don't cause significant or extensive damage.

Q. So magnitude one or two to what?

A. On the order of three, three and a half.

Q. And a large earthquake?

A. Large earthquake is going to be three and a half to five or six.

Q. And then major was five and a half to anything above that?

A. Yes.

That is just sort of off the cuff. Occasionally we get e-mails saying we have to define these terms and here it is and they seem to differ. After you have gone through about six of these you don't remember which definition to work with.

Q. Is there a category above major?

Q. And you don't have an opinion on what exactly that peak ground acceleration should be for the horizontal spectrum for the MOX Facility?

A. No, but if you give me a good contract, I will compute it for you.

Q. Do you have an opinion of where the epi center tier of the 1886 Charleston earthquake was?

A. I have an opinion, yes.

Q. What is that opinion?

A. I have had recent conversations with Pradeep Talwani and I have seen his recalculated epi centers and I can therefore calculate where the main shock must have occurred -- must have occurred.

Q. Getting back to the question or its answer, but if you give me a good contract, I will compute it for you. Approximately how many hours do you think it would take you to compute it?

A. We are talking about hard rock or --

Q. Surface. Only talking about surface.

A. That would depend on some of the data, whether it was available or not. If there was a

in the location where the CAR assumed a repeat of the 1886 Charleston earthquake for purposes of a historical check, that being 120 kilometers south southeast of the Savannah River Site?

A. Mostly east. No, that would be realistic.

Q. Do you think that is conservative?

A. Do I think you erred on the positive side?

Q. We can get some things right.

A. I think it should be done correctly. I don't think you should throw in errors to make it look like a more severe case. I think it is probably realistic.

Q. Do you agree that it was appropriate to use the magnitude that was used for that historical check?

A. In terms of identifying it as the Charleston earthquake, that particular one, that would be adequate. It may or may not be adequate if one were looking at a comparison -- a direct comparison between Charleston seismicity and its

the site. I would include a surface layer of the sediments because they sometimes enhance or increase the reflections. I would include a thinning of that layer as you go toward the Savannah River Site, and I would probably see whether or not I can see evidence of other structures that might be included in that model along that path.

Q. Does the USGS take into account all the things you described?

A. No. They are looking for an average for the U.S.

Q. So for a MOX Facility, if they are not going to do their own brand-new PSHA, and they are going to take a PSHA, and you stated the USGS would be the PSHA you would use --

A. I said, of the group that is probably the best at this point because they include the Atkinson/Boore model as part of their analysis, at least one-third contribution.

Q. What PSHA should an applicant for a MOX Facility use?

A. I think they should redo it.

Q. I understand you think they should do it but of the PSHAs out there, what would they choose?

A. If they were forced to choose one and didn't want to take into consideration facts that may affect that one way or the other, I think I would go with the USGS at this point.

Q. Do you know whether NRC regulations require an applicant for a MOX Facility to redo a PSHA for a MOX Facility site?

A. No. It is just the understanding I had before from conversations that individual sites should be recomputed to take into account local conditions and variations.

Q. What does take "into account local conditions and variations" -- are those site-specific or do they go 200 kilometers?

A. They are probably site-specific and 200 kilometers is site-specific.

Q. Then what is the purpose of using a Livermore or EPRI PSHA if you have to look at everything that is 200 kilometers around the site?

MR. POLONSKY: Let's take a break.

(Discussion off the record.)

(Recess.)

BY MR. POLONSKY:

Q. Looking solely at the historical check of the 1886 Charleston earthquake, do you have an opinion as to whether or not the horizontal surface spectrum being used for the MOX Facility envelopes the ground motions associated with that historical check?

A. I believe that was a conclusion in the CAR, or some document I have seen. The check of the historical Charleston earthquake came up with a spectra that was less than -- or was enveloped by the MOX spectrum.

Q. So you agree that the horizontal surface spectra for the MOX Facility envelopes the ground motions associated with the deterministic check as calculated?

A. As calculated.

Q. I understand you may disagree with the inputs to that historical check?

Carolina coastal plain showing more activity in the last 6,000 years and over a wider area than previously known."

Do you agree with this item?

A. Basically, yes.

Q. What recent paleo seismic work is this referring to?

A. The Talwani/Schaeffer work and recent studies.

Q. And what recent studies were those?

A. I don't know the specific articles but there was two articles -- Seismological Research Letters that I believe I listed.

Q. Those were published in 2002; is that correct?

A. Yes.

Q. So they couldn't have been referred to here because this was dated August of 2001, this contention. Is it just talking about Talwani and Schaeffer?

A. This was put together not by me but the other previous consultant. When I came in later on

I looked at the literature and I found the articles that are in the Seismological Research Letters.

Q. The statement we just read from one of the revised contention, is it your opinion that it deals only with Talwani and Schaeffer?

A. When I was asked to review it and look at it, I had these other articles. So from my point of view, no. From the previous point of view, perhaps yes.

Q. The two additional articles that you are discussing, are they the discussing Hu, Gassman and Talwani papers?

A. Yes.

Q. And what do you believe is the relevance of those Hu, et al., papers to the seismic design of the MOX Facility?

A. They established a rate of activity for the Charleston seismic zone.

Q. How did they do that?

A. By looking at paleo seismic data.

Q. How did they look at paleo seismic data?

A. They looked for evidence of liquefaction

TRANSCRIPT OF PROCEEDINGS

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	
DUKE COGEMA STONE & WEBSTER	Docket No.: 0-70-03098-ML
(Savannah River Mixed Oxide Fabrication Facility)	ASLBP No.: 01-790-ML
	VOL. II

Continued Deposition of DR. LELAND TIMOTHY LONG

Pages 250 through 442

Washington, D.C.
June 26, 2003

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ERRATA SHEET

To the Deposition of Dr. Leland Timothy Long on June 26, 2003

The deponent, having a right to make any changes necessary, hereby makes the following changes in the deposition and states the reason for each change accordingly.

PAGE	LINE	CHANGE	REASON FOR CHANGE
254	8	delete "-- and locating"	incorrect transcription
255	15	change "see" to "say"	incorrect transcription
256	3	insert "However," before "it"	incorrect transcription
256	5	insert "not" before "available"	incorrect transcription
256	5	insert period after "time"	incorrect transcription
256	6	change "of the" to "The"	incorrect transcription
257	12	change "that was given a probability" to "all hypotheses were considered"	clarification
257	14	insert "and give it a probability" after "possibility"	grammatical correction
259	1	change "the" to "a"	incorrect transcription
259	2	change "definitive – the definition and depth of" to "definitive definition of"	incorrect transcription
263	21	change "A" to "'a'"	incorrect transcription
264	17-18	change "they used," to "the"	incorrect transcription
264	20	insert "to" before "take", "do", and "provide"	incorrect transcription
264	20	insert "an interpretation relating to the position of the" after "provide"	clarification
265	15	delete "well"	incorrect transcription
266	1	change "dating was" to "14 dates were"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
266	2	after 018.", insert "This indicated variations in radiation and production of C14."	clarification
266	3	change "there" to "in available C14"	clarification
266	4	insert "(uncalibrated earlier data)" after "errors"	clarification
267	5	change "and minor" to "or minus"	incorrect transcription
274	6	change "than" to "in the"	incorrect transcription
274	14	insert "to represent a point source," after "area"	incorrect transcription
274	15	insert "near" after "hazard"	incorrect transcription
274	15	change "central area – I went the other way" to "point source will err on the low side	grammatical correction
274	16	insert "to represent a point source" after "area"	incorrect transcription
274	17-18	change "be less at a greater distance" to "err on the high side"	clarification
274	18	substitute period for comma after "more"	incorrect transcription
274	19-20	delete "but – whereas the hazard at the earthquake would be decreased by a broader area"	incorrect transcription
274	22	delete "a combination --"	incorrect transcription
275	6-7	change "be a function of distance" to "depend more on"	grammatical correction
275	7	change "from" to "on the seismicity of"	clarification
275	8	insert comma after "So"	incorrect transcription
275	8	delete "it would have been something --"	incorrect transcription
275	9	insert "and" before "so"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
275	11	delete "a" and "strength or not"	grammatical correction
278	3	change "they" to "the soils"	clarification
278	5	change "G" to "g" in two places	incorrect transcription
281	7	insert "a sand to resist" after "of"	clarification
281	7	insert "blow" after "low"	incorrect transcription
281	8	insert "the" before "number"	incorrect transcription
281	13	change "constraint" to "constituent"	incorrect transcription
282	14	change "has not been" to "were"	incorrect transcription
282	15	change "which if it hasn't," to "which it hasn't, because"	Grammatical clarification
290	16	change "some" to "come"	incorrect transcription
292	11	change "summary" to "some"	incorrect transcription
293	17	change "temporarily" to "temporally"	incorrect transcription
297	4	change "leads to" to "needs"	incorrect transcription
301	5	change "even" to "whether"	incorrect transcription
301	6	delete "if"	incorrect transcription
301	8	change "on" to "or"	incorrect transcription
301	9	delete "Charleston plain --"	misspoke
301	10	delete "the essence"	grammatical correction
301	18	change "when computing it" to "used to compute the PSHA"	clarification
302	18	change "required" to "satisfied"	incorrect transcription
303	2	change "volcanics" to "volcanism"	incorrect transcription
302	3	insert "visiting the mountain" after "that"	Clarification

PAGE	LINE	CHANGE	REASON FOR CHANGE
305	13	change "it" to "earthquakes"	clarification
306	2	change "is in the zone," to "is not in a zone,"	incorrect transcription
306	12	change "distinguish that seismicity" to "understand that the seismicity"	incorrect transcription
306	13-14	change "probabilistic spectral – hazard assessment" to "PSHA"	incorrect transcription
306	15	insert "'a'" before "and"	incorrect transcription
306	15	change "B" to "'b'"	incorrect transcription
306	15	delete "how much --"	grammatical correction
306	16	change "event, and" to "event."	incorrect transcription
306	17	change "that is" to "The a and b values define"	grammatical clarification
306	17	change "analysis" to "relation"	incorrect transcription
306	21	change "at" to "above"	incorrect transcription
306	22	insert "because below that level"	clarification
307	5	change "B" to "b"	incorrect transcription
308	9	change "A" to "a"	incorrect transcription
308	12	insert "per unit time" after "area"	clarification
308	12	change "assign a" to "assign an 'a"	incorrect transcription
309	17	change "probability" to "weight"	incorrect transcription
309	17-18	delete "Now, you have a weight of one."	grammatical correction
309	19-20	delete "between which of those – if you have multiple zones in one area, you have to decide"	grammatical correction
309	21	change "each, and the" to "each. The"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
310	10	insert "and" before if	Grammatical correction
310	11	insert ", then " after area	Grammatical correction
312	6	change "size" to "site"	incorrect transcription
316	1	delete "whether that is 100 –"	incorrect transcription
320	7	insert "(i.e.," before "already"	Grammatical clarification
320	7	change "weakeness" to "weaknesses)"	grammatical clarification
321	10	change "a" to "the full thickness of the"	clarification
321	19	change "include" to "conclude"	incorrect transcription
323	13	change "is" to "as"	incorrect transcription
325	14	change "as" to "has"	incorrect transcription
326	3	change "at" to "as"	incorrect transcription
326	7	insert period after "magnitudes"	incorrect transcription
326	7-8	delete "and you will find maximum magnitudes in an area where the earthquake was two."	incomprehensive transcription
326	20	change "sites" to "areas"	incorrect transcription
326	22	delete "So that one"	incorrect transcription
327	1	change "expert – hypothetically" to "expert. Hypothetically"	incorrect transcription
327	4	delete "probability or"	incorrect transcription
328	3-4	delete "I don't know if there is an or on that."	incorrect transcription
333	15	change "plouisson" to "Poisson"	incorrect transcription
334	10	insert "of Seismological Research Letters (then Earthquake Notes)	clarification

PAGE	LINE	CHANGE	REASON FOR CHANGE
338	13	insert "thick" after "feet"	clarification
338	15	change "-- once you get to an area where" to "can be based on structure. The coastal plain sediments extend to an area"	grammatical correction
338	16	change "a fault" to "the fall"	incorrect transcription
338	16	change "line off of the" to "line. The"	incorrect transcription
338	18-19	change "sediments, and the" to "sediments. The"	grammatical clarification
339	1	change "volcanics or" to "volcanic rocks in"	incorrect transcription
339	1	insert "or Triassic" after "Jurassic"	incorrect transcription
339	3	insert "(to the east)" after "coast"	clarification
339	4	change "coastal" to "crustal"	incorrect transcription
339	5	change "reach" to "edge"	incorrect transcription
339	5	change "moved more toward" to "are more like"	incorrect transcription
339	6	insert "rocks" after "type"	incorrect transcription
339	6	insert "(Triassic)" after "Jurassic"	incorrect transcription
344	1	delete "they"	incorrect transcription
344	2	delete "-- that I mentioned"	incorrect transcription
347	21-22	change "explanation, scale or variant" to "explanation of scale invariance"	grammatical clarification
348	21	insert "large" after "his"	incorrect transcription
349	9	change "series" to "SEUSN"	incorrect transcription
350	8	change "refractal" to "fractal"	incorrect transcription
351	21	change "is what -- " to "depends on what is"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
351	21	insert period after "catalog"	incorrect transcription
351	22	change "the" to "The"	incorrect transcription
351	22	insert "(the existing catalogs) after "available"	clarification
351	22	change "he" to "were"	incorrect transcription
352	1	change "group" to "earthquakes"	clarification
352	2	delete "largest"	incorrect transcription
352	2	insert "of larger earthquakes" after "group"	incorrect transcription
352	2	change "ones and the" to "earthquakes"	incorrect transcription
352	6	delete "the contention that --"	incorrect transcription
356	8	delete "to"	incorrect transcription
358	14-15	change "We are looking at gaps and missing areas" to "These studies look at gaps and areas where earthquakes are lacking."	clarification
361	22	change "California" to "Carolina"	incorrect transcription
372	3	change "BRDL" to "Brittle-"	incorrect transcription
372	18	delete "to"	grammatical correction
372	19	change "densities" to "stresses"	misspoke
372	20	insert "largest" before "stresses"	incorrect transcription
379	4	change "Germonivch" to Germanovich	spelling Correction.
392	21	change "coastal" to "crustal"	incorrect transcription
392	21	change "work" to "works"	incorrect transcription
393	1	delete "so"	incorrect transcription
393	1	change "that is in" to "most of them pertain to areas closer to"	clarification

PAGE	LINE	CHANGE	REASON FOR CHANGE
393	7	change “years, but this” to “years. But, a crustal model”	clarification
394	1	change “that” to “what”	incorrect transcription
394	2	change “into all those other established for --” to “into, the range of all those other return periods established for those studies.”	grammatical clarification
394	3	insert “DCS” before “simply	incorrect transcription
394	3	change “posit” to “composite”	incorrect transcription
394	3	change “turn” to “return”	incorrect transcription
394	17	change “they” to “the data”	clarification
394	17	delete “, in terms of data”	incorrect transcription
394	18	delete dash	incorrect transcription
394	18	insert “data available today” after “more”	clarification
395	3	change “Macke” to “McKee (1977)”	clarification
395	3-4	delete “Long, Jones and Macke, I guess it is – or”	redundant
395	22	change “Halmond” to “Hawman”	incorrect transcription
396	2	change “blends” to “blasts”	incorrect transcription
396	7	change “Keene” to “Kean”	incorrect transcription
397	17	change “quote B unquote” to “‘b’”	incorrect transcription
397	22	change “to do -- that” to “to do with the model. That”	incorrect transcription
399	5	change “off” to “out”	incorrect transcription
400	4	change “thought” to “believed”	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
400	6-7	change "asperities or rigid spots on a fault" to "asperities (between rigid spots on a fault)	clarification
400	19	insert "earthquake" after "characteristic"	incorrect transcription
400	20	insert "recursion" before "relationship"	incorrect transcription
401	5	change "model, that" to "model? That"	incorrect transcription
401	7	insert ", and" after "earthquake"	incorrect transcription
402	19-20	delete "you have considered"	incorrect transcription
409	19	change "that" to "one"	incorrect transcription
409	21	change "estimates, and the" to "estimates. The"	incorrect transcription
409	22	insert "that for example" before "places"	incorrect transcription
410	2	change "ago" to "away"	incorrect transcription
411	6	change "methods, do" to "methods. Do"	incorrect transcription
411	7	change "interest, and if' to"interest? If'	incorrect transcription
411	11	change "where' to "(where"	incorrect transcription
411	14	change "earthquakes" to "earthquakes)"	incorrect transcription
411	14	change "say, does" to "ask is"	incorrect transcription
411	15	change "which" to "(which"	incorrect transcription
411	16	change "been, is that" to "been),"	incorrect transcription
413	19	change "freer see S" to "frequency"	incorrect transcription
416	16	insert quotation mark before "These"	incorrect transcription
416	20-21	insert brackets around "there is a Website here"	incorrect transcription
416	22	insert quotation mark after "SRS."	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
420	22	change "range" to "terrain"	incorrect transcription
423	16	change "about" to "a bit"	incorrect transcription
424	5	insert "exponential" before "attenuation"	clarification
426	6	change "derived" to "interpret"	incorrect transcription
427	4	change "ADL" to "ATL"	incorrect transcription
427	5	change "came" to "ended"	incorrect transcription
427	6	change "plain, two-something and" to "model. The lower crustal P-wave equivalent velocity was about"	clarification
427	7	change "thicknesses, not" to "thicknesses. It is not a result of"	clarification
427	8	delete "averaging – not"	incorrect transcription
427	8	change "of that factor" to "along the path from Charleston to the site"	clarification
428	14	change "one" to "computation"	clarification
428	14	delete "a"	incorrect transcription
428	15	change "straight --" to "one for a model where I would"	incorrect transcription
428	16-17	change "next one I would do is put an appropriate radiant in" to "next model I would compute is one with an appropriate velocity gradient in the model"	grammatical clarification
429	2	change "mobile" to "Moho"	incorrect transcription
429	15	change "it" to "Hermann's model"	clarification
429	18	delete "was that"	incorrect transcription
429	19	delete "two-layer crust"	incorrect transcription

PAGE	LINE	CHANGE	REASON FOR CHANGE
432	16	insert "have" after "you"	incorrect transcription
433	10	insert "not" after "have"	incorrect transcription
433	19	change "beta" to "made"	incorrect transcription
434	8	change "Mantel" to "Mantle"	incorrect transcription
434	9	change "Mantel" to "Mantle"	incorrect transcription
437	15	change "have you" to "you have"	incorrect transcription
439	12	change "metric" to "mafic"	incorrect transcription
439	13	inserrt "a" before "higher"	incorrect transcription
439	13	change "or" to "in the"	incorrect transcription

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Dr. Leland Timothy Long

considered or proposed by a participant on the expert panel in the Livermore study?

A. The answer is basically yes, it does refine the data, it does provide constraints on the data that were available to the experts at the time of the qualification on that that I gave was that some experts were so broad and inclusive that you might say that their response included anything that might possibly be discovered.

Q. So, for example, one expert may have placed a 7.5 earthquake anywhere on the Carolina coastal plain, not just limited to the three places Talwani and Schaeffer did?

A. That is right.

Q. So, for Livermore and probably EPRI, there are opinions that encompass the locations identified in the Talwani and Schaeffer paper?

A. That would be true. The impact on the study would be different though. The impact of a broad area which encompasses all these sites would be different than the distribution of sites that would be implicated by the Talwani and Schaeffer

paper.

Q. What is your basis for stating that people today -- let me rephrase that -- that experts today, if they were empaneled today -- let me rephrase it.

Would you believe that there would be today in a new PSHA study similar to Livermore or EPRI, at least one person who had the opinion that a 7.5 could occur anywhere on the South Carolina coastal plain?

A. I think that if it were formulated in an EPRI study where that was given a probability, a number of scientists would say that is a possibility.

Q. So the opinion here is not necessarily a new opinion about location of earthquakes since the opinion that an earthquake could occur anywhere on the coastal plain has been out there for 20 years?

A. That is true, yes. That idea has been around for a long time.

Q. So you are pointing to this one paper and GANE is stating that this paper shows that there is

seismic activity over a wider area than previously known?

A. I don't think it says that. It says the DCS didn't consider that distribution.

Q. Point 1 on the revised contention, under the paragraph "Likelihood of significant seismic event," the last sentence: "These assertions do not consider recent paleoseismic events on the South Carolina Coastal Plain showing activity in the last 6000 years, and over a wider area." The only paper cited is Talwani and Schaeffer?

A. The term previously known might be interpreted various ways. I think when you look at the studies that Duke performed, I believe they were concentrating on a Charleston epicenter. When you look at a panel of experts with very wide variations in opinions, those opinions will encompass any hypothesis or distribution you want to put in there.

Q. Does the Talwani and Schaeffer paper show more activity over a wider area than previously known, yes or no?

consider this, at what point do you stop?

A. I don't think you ever stop. I think at the last minute, you think you are all done, you have gotten approval, a new paper comes out and says there is an active fault underneath this building. I am not saying there is, but if someone says that, and we have new evidence that something is happening, it changes a lot.

Q. I agree with that statement, but that is identifying a known feature, a known fault. No one has identified any new feature in any of the papers you have identified. All that they have identified are new interpretations of the data or additional theories, and when people are identifying new theories and hypotheses, those are interesting to think about and they should be considered seriously by the expert community, but they are just another opinion in the range of opinions.

A. This article presents data which strongly suggests that there are other areas of activity. I think that is significant enough to consider some review. Now, it may or may not change any of the

results.

Q. And your position is that because it presents in your mind some new information, that it has to be looked at from a purely scientific perspective, you don't have an opinion as to whether it may or may not change?

A. If the changes that are presented suggest that there may be a problem in terms of the determination -- and by a problem, I mean maybe underestimated in some way -- then it should be looked at.

(The witness consulted with counsel.)

BY MR. POLONSKY:

Q. Dr. Long, if the Talwani and Schaeffer scenarios narrow the areas of earthquakes -- let rephrase that. If one of the scenarios by Talwani and Schaeffer narrows the area to three areas, Charleston, Bluffton and some northern part, wouldn't this produce a lower ground motion than the SRS in the PSHA than if the PSHA includes a broader seismic zone that can contribute to the damage?

companion articles. One goes into the technical aspects of how one determines soil properties and how they are going to liquefy. The other is associating liquefaction at various sites to ground motion, acceleration and G. That G is then converted to an estimate of magnitude.

Q. Do you agree with the methodology -- let me back up. For ease of use, can we refer to them as Hu, et al., 1, and Hu, et al., 2?

A. Okay.

Q. And for the record, I guess I have to clarify that Hu, et al., 1 is -- starts on page 964 of the eastern section seismological research letters, Volume 73, No. 6, November 2002, and runs to page 978. And Hu, et al., 2 begins on page 979 of the same volume and number and continues to page 991.

Do you agree with the methodology used in Hu, et al., 1, or do you have an opinion as to the methodology used in Hu, et al., 1?

A. That is really not my field. I would accept their work based on what I do know.

do you believe Hu et al. 1 is relevant to the seismic design for the MOX Facility?

A. It provides further estimates of magnitudes that are indicative of major earthquakes.

Q. Does Hu et al. 1 do that?

A. Hu et al. 2 provides --

Q. My question was regarding Hu et al. 1.

A. Hu, et al., 1 provides techniques, background techniques, as background type article.

Q. Do you know what they actually did as the basis for Hu et al. 1?

A. My understanding is that they ran a number of tests and looked at the properties of the soils.

Q. Do you have any opinion as to how soil properties can affect a later assessment of magnitude?

A. I have some idea. I have not gone in detail because I don't feel that is an area where I am an expert, nor do I need to know that material for assessment of seismicity. The basic conclusion

liquefaction. I think that what they did is a significant contribution, certainly to South Carolina seismicity, because they have pulled together, first of all, the basis for what the properties of soils are and what acceleration is required to cause liquefaction, and then they have applied that to a situation where they have determined accelerations and extrapolated estimated magnitudes on that basis. So I think that is a significant contribution.

Q. On page 977 of Hu, et al., 1, the last sentence of the conclusions, that sentence says, "The effect of aging of the source sands on the liquefaction potential of the SCCP requires further study." Do you know what that means or what they are hinting at?

A. Geologists learn early in their career that the strength or hardness of the rock is a function of age, that rocks change with age, that they condense, they compress, and they get sometimes stiffer and harder. The rate that that occurs varies, and I think they are saying when

that material has sat in place for X number of years, it may become more stable. I think they are saying that that aspect, that potential area of uncertainty leads to more investigation. They may also have been hedging some of their uncertainties.

Q. If there were an error in the estimation of the age of the soils such that the Hu, et al., 1, authors assumed newer soils as opposed to older soils, what is your opinion on how that would impact what the results of Hu, et al., 1, and Hu, et al., 2, is?

A. I don't know what their opinion is. My opinion is that an older soil would be a more stable soil and that with time it would take a higher acceleration to cause liquefaction, so if they assumed it was younger, then it would perhaps take a lesser acceleration to cause liquefaction. They do mention too the possibility that water levels vary. Water content is a critical factor in terms of liquefaction.

Q. Would you agree if less acceleration was required, that the magnitude assumptions in Hu, et

could have occurred north and south, in the areas of Bluffton or Georgetown, and those were included in the PSHA, as people suggested that there were large areas where Charleston-type earthquakes occurred on the coastal plain?

A. It is not whether they were included. I already said the range of opinions in that area were very diverse, very wide, and a lot of that had to do with the fact that a lot of the experts didn't know what was going to happen in the next 20 years in terms of scientific studies including liquefaction.

Q. If the NRC said it was acceptable to use EPRI or Livermore or a combination, would you agree that by using the EPRI or Livermore studies, that DCS would have satisfied the requirement by the NRC?

A. In a legal sense it would have required it, but perhaps not in a moral sense. I will give an example.

I was told that it was acceptable to visit Mount Saint Helens in April, two weeks before

it blew. In retrospect, I wouldn't have done that. There has been a lot learned in volcanics to say that would have been an obvious mistake and not one being made today.

I think we are dealing here with an acceptance of a study done -- Livermore and EPRI, they were done in the '70s. They included a wide, diverse group of opinions. They didn't include a lot of the opinions we know today. They included hypotheses and ideas that can be discounted today. I think that we have new data, new information that today we can insert into a PSHA that would refine and give a better or more confident result.

Q. Would you agree that if the Livermore and EPRI studies are wrong in your view, but are wrong on the conservative side, would they be acceptable to use?

A. I think you should establish that they are not in error. I think you should establish what is a correct value and determine whether or not your error or conservative values are above or below the correct value.

Q. Your assumption is that it should be correct, not more conservative, not less conservative?

A. Yes.

Q. We have had conversations about people choosing large areas for the location of the Charleston seismic zone in the Livermore and EPRI studies, and you stated -- what I am getting at today is that in some way today you drop an expert, you just wouldn't consider that opinion any more because the scientific community has refined its understanding about the location of the Charleston seismic zones since then, and if you got a panel of experts today and did the same thing, you would get a different result?

A. I think that is true.

Q. If you have that outlier person, and who is considered an expert, is part of the panel, how do you decide to drop an expert?

A. I think in many cases, perhaps most of the cases, the experts themselves would say, oops, I know more now, this is a better answer.

risk. Whether that is 100 -- I don't believe that is 100 percent correct, and I believe that Kafka, for example, has demonstrated that existing seismicity is not 100 percent reliable in terms of predicting new sites of earthquakes, at least the statistics he gave it was around 30 percent.

So we have new information. We have very definitive information now on the Charleston seismic zone and we have information on zones like Bowman and Bluffton and Georgetown that were also seismically active. If one were to revise then the probabilistic seismic hazard assessment and utilize this new information, then the results may change.

I don't think you can overlook the real contribution that those three studies have made. They did establish a technology. They showed how it should be done, and in essence they said if you want to now apply this to a specific local area, be sure the relationships are appropriate for that area. In other words, those studies couldn't be done for another country unless they put in all the parameters for that other country or continent.

Q. But they were specifically done for the United States?

A. They were done for the United States.

Q. Do you believe the EPRI and Livermore studies as they are right now without any changes can be used to site a nuclear facility?

A. I think that if you took those two studies and in each case where you wanted a nuclear facility you did a supplemental evaluation of the parameters that went in, you could determine whether or not the EPRI and Lawrence Livermore values were appropriate.

Q. Is Bluffton closer to SRS than Charleston?

A. I think they are about the same distance. Considering the dimensions of SRS, it would be plus or minus.

Q. Do you know why in the contention they state that Bluffton is closer?

A. No.

Q. Do you agree?

A. I think that was in there before I came

on.

Q. Do you agree that -- page 2 of the revised contention, second full paragraph, third sentence says the other scenario would put one magnitude six event near South Carolina only 100 miles from the SRS, and the others near Charleston and Georgetown. In other words, contrary to what the CAR says, major events may have occurred closer than thought to the Charleston seismic zone. Do you agree with this statement?

A. Not necessarily.

Q. What do you disagree with?

A. The term much closer. In the sense -- there are two aspects of the statement. One is perhaps a misinterpretation of the distance from Bluffton to the Savannah River Site --

Q. Can we focus on that, just distance, Bluffton's distance?

A. If you want to focus on Bluffton's distance, why don't we pull out a map and measure it? Do I believe it is a certain distance? Why not measure it?

Q. The years were only 1924 to the present, so it is making a generalized statistical statement. It is not saying an applicant for a MOX facility should take into account this paper and absolutely should incorporate this into their PSHA.

Would you agree that this paper is a first stab by Kafka at assessing whether there is a statistical relationship between prior seismicity and future seismicity?

A. Definitely. It is a pioneer paper in that respect although I could not tell you that other people have not attempted this. There has been a lot of work in California to try to use statistics to predict earthquakes. We are looking at gaps and missing areas.

Q. I can tell you with my background, this was very interesting to read. I found it fascinating, but at the same time I was putting my head in the position of DCS and trying to think what do I do with this paper as it applies to designing a MOX Facility, and I couldn't see applying it because it is so out there in the

earthquakes have occurred in Georgia, on a small scale, and admittedly you have trouble translating between scales on earthquakes, but if I go back and look at it, I would see every so often there is a surprise, and it may be that statistics might be 30 percent of new areas.

Q. Do you think the opinion of Kafka was taken into account by one of the opinions in the Livermore or EPRI studies?

A. In a very general sense it might have been included. I think, yes, there was at least one expert who said we have no idea where the major earthquakes will occur next. Does that have an effect? Yes. That expert would have one extreme view. Other experts had other views and they were averaged out.

I think Kafka has put some fairly definitive statistics on this problem and he said, look, whether you look in California, Turkey or the southeastern U.S., you have catalogs which when statistically analyzed suggest something like 30 percent of the largest events in the catalog occur

could occur anyplace and that 30 percent of the time they do occur just about anyplace except where they have occurred before. To take the observation that the South Carolina Coastal Plain is, according to the current seismic monitoring, in part aseismic is not inconsistent. That is consistent with Kafka's hypothesis.

Q. As an academic exercise, would you agree that Kafka specifically ignored geology and any known geologic features?

A. Yes.

Q. And the purpose of his paper was to isolate statistically without any consideration to geology?

A. Yes.

Q. If you have already addressed it, forgive me, but could you tell me how Kafka's paper addresses truly -- I won't say truly large -- addresses magnitude seven-or-greater earthquakes?

A. Kafka's paper treats catalogs from many areas of the world. Some of those catalogs cover a range of very large earthquakes.

five and a half. The rate of recurrence is small, but they could occur many places in the Piedmont or in the coastal plain where the pertubation for the earthquake would be below the coastal plain sediments.

What impact they would have on a facility would be dependent upon the response of that facility to various amplitudes and frequencies of vibration, and that would be for an engineer to answer.

Q. I think you previously testified that you are not an expert on those structural issues.

A. No. I don't evaluate structures for their vibrational response.

Q. Would a cluster --

A. Another paper here?

Q. I am sorry.

A. This is by Kaufman and long, "Velocity and structure of seismicity of southeastern Tennessee."

Q. And does it indicate when that was published?

the spectrum was not site-specific but was computed for the whole Savannah River Site, and I was under the impression that we were not pursuing the difference between the site response from nearby areas.

Q. That was my understanding too.

Off the record.

(Discussion off the record.)

MS. CURRAN: We will stipulate that GANE will withdraw the sentence on page 4 of the revised contention which states this spectrum is not site-specific but was computed for the whole of the Savannah River Site in 1997.

BY MR. POLONSKY:

Q. Dr. Long, the previous sentence is a quote of the CAR, of the original CAR, which says, "MFFF-designed earthquake is the existing SRS PCS-3 spectrum." Do you know whether the MOX Facility designed earthquake is the PC-3 spectrum?

A. I am not sure that that is here.

Q. Could you look at that page of the CAR? This is a revision date of 2001 and the page is

the contention states that the applicant asserts that the MFFF-design earthquake is the existing SRS PC-3 spectrum. Do you agree we didn't assert that, but the CAR states the technical basis for it is the existing PC-3 spectrum, but in fact the MOX Facility horizontal surface spectrum is a reg guide 1.6 spectrum scaled to 0.2 Gs?

A. I will agree to that.

MR. POLONSKY: Off the record.

(Discussion off the record.)

MS. CURRAN: We have stipulated that GANE will withdraw a sentence on page 4 of the revised contention which states that in the CAR, the applicant asserts that the MFFF design earthquake is the existing SRS PC-3 spectrum.

BY MR. POLONSKY:

Q. Dr. Long, the beginning of this paragraph, in the contention, on page 4, discusses the new reg 0800 standard review plan for nuclear power plants, cite section 2.5.6 from a revision dated 1997, and the contention then states this -- "GANE cites it for the proposition that licensed

else is there, and I would say, well, you can use the USGS, it is going to give you a good answer. You could use Lawrence Livermore. You could use EPRI. But then you would have to go back and look at what were the basic assumptions for the computations in those methods, do they apply to a particular site of interest, and if you have a site that has some potential anomalous feature one way or the other, you should appropriately factor that in.

When you look at Kafka's result, where 30 percent or so of the new larger earthquakes occur in areas where there have not been previous earthquakes, you have to say, does the USGS statistical technique which relies solely on placing earthquakes where they have been, is that appropriate, or should the USGS have taken a seismicity rate in which in the future 30 percent would occur anyplace.

Q. Would you use the USGS 2002 hazard maps as a basis for constructing a facility where you were concerned about annual probabilities of

exceedence of 10 to the minus 4?

A. That would be my first stop.

Q. That is where you would go?

A. That is where I would stop.

Q. What happens for -- same question, but for an annual probability of exceedence of 10 to the minus 5.

A. I think that you have to accept these maps at face value. They represent a database which is 200 years, maybe 100 years in some places, that is what the database is. If you are in Turkey or China, you can go back a couple thousand years, but in the Southeast U.S., you have 100 or 200 years of good continuous data. That is what your database is.

You are attempting to extrapolate that to very large time periods. That to me has a problem. I don't know an alternative except that Kafka has offered a solution, a statistical solution which could be factored into the U.S. computation, and I think that might even reduce the effect of Charleston.

continues, the June 2002 USGS hazard map gives an acceleration greater than 0.2G with a 2 percent probability of exceedence in 50 years at the Savannah River Site. This is equivalent to a return period of 2500 years. This suggests that the 10,000-year return period should require a acceleration greater than 0.2Gs.

Is that your response?

A. I believe it is.

Q. How did you calculate that it was a 2500-year return period?

A. Two percent -- a 2 percent probability of exceedence in 50 years. You write the approximation that is the product --

Q. I am sorry. I am not asking you how you calculated 2 percent of 50 to get to 2500 years. How did you identify on the USGS map that 0.2 G at the Savannah River Site has a 2 percent probability of exceedence in 50 years?

A. It is on the map. You can read it off the map. The contour lines are labeled.

Q. Where did you get the map?

A. Off the Web.
Q. Do you recall when you did that?
A. I have done that a number of times.
Q. Do you know what the assumptions are regarding the volume of soil above bedrock in the USGS hazard maps?
A. No.
Q. Go back to the revised contention, bottom of page 4. "In addition, the approach to the PSHA has been insufficiently conservative. In Table 1.3.6-7, the applicant estimates the return period for SAG equals 0.375 G at 5 Hz is 2700 years." And then you cite the WSRC reports that these are derived from.

"In contrast, the national seismic hazard mapping project," and you provide a Web site address, "estimates a return period of 1200 years for the same event at the SRS." I know you didn't write this, but looking at it now, is there any part of this that we don't need to discuss and that we can withdraw?
A. I would like to think about that.

Basically, the value that one pulls off the map from the URL is larger than the hazard value that was used from Savannah River plant.

MR. POLONSKY: Off the record.

(Discussion off the record.)

MS. CURRAN: We are stipulating that GANE will withdraw a sentence at the bottom of page 4 of the revised contention which states in Table 1.3.6-7 at page 1.3.6-39, the applicant estimates the return period for SAG (equals 0.375 G at 5 Hz) is 2700 years.

MR. POLONSKY: Off the record.

(Discussion off the record.)

MS. CURRAN: We have another stipulation that GANE is going to withdraw two sentences at the bottom of page 4 of the revised contention. These estimates are derived from Westinghouse Savannah River company reports, WSRC-TR-97-0085, and WSRC-TR-98-00263. In contrast, the national seismic hazard mapping project, URL -- there is a Web site here -- estimates a return period of 1200 years for the same event at the SRS.

MR. POLONSKY: And that spills onto page 5, so the only sentence remaining in the last paragraph is the first sentence of that paragraph.

MS. CURRAN: Right.

MR. POLONSKY: Off the record.

(Discussion off the record.)

BY MR. POLONSKY:

Q. Dr. Long, you stated that one of your concerns is that DCS relied on attenuation data inherent in the Livermore studies and we didn't take into account one of the more recent studies, one of which you cited to be the Atkinson and Boore study?

A. The Livermore and EPRI studies didn't take that into account, right.

Q. One of the statements you made in relation to the Atkinson-Boore paper was that it would increase something by a factor of two to four. Now, could you elaborate on what that factor is and what it increases?

A. One of the last figures of the Atkinson-Boore papers is a comparison of their

have data obtained on both rock and soil. The curves are fairly consistent at 5 Hz. The curve that exhibits the greatest amount of pertubation at 100 kilometer range is Atkinson-Boore. The others are much more closely related to attenuation. The data again showed there is a wide spread of values at 100, 150-kilometer region.

Do the single curves capture the data? I think that would be best answered by doing a statistical fit of some type and finding a statistical parameter that shows how well the lines go through the data, the scattering of data and the fact that there are two kinds of data, hard rock and soil, might make that a little bit difficult.

Q. Would it be your opinion that it would be improper to use Somerville, et al., or Toro, et al., ground attenuation models for the design of a facility?

A. It is my opinion that when you do the actual attenuation values -- unfortunately these curves don't have a lot of data in the 10, 20 or 100 to 80 kilometer range. They are looking mostly

at 100 to a thousand kilometers, greater distances, so there is a certain amount of ambiguity in the close-in range. Whether or not these curves fit the data in that range could be questionable. Your question was whether it was appropriate. I think one has to look at the situation.

Q. In the third GANE supplemental interrogatory response, 3.6, which is on page 3, toward the bottom of the response, it says the dominate component of the earthquake hazard at the MOX Facility comes from a repeat of the Charleston event at approximately the same distance of 80 to 150 kilometers. Therefore, attenuation curves should be corrected to reflect increased amplitude at the MOX facility site. This would correspondingly increase the hazard and reduce the return period."

Focusing just on the historical check of the 1886 earthquake, and I want to avoid the discussion of probalistic or PSHA for now, you stated yesterday that the Hermann crustal model, which I think is 1986, is inappropriate because it

historical check?

A. The predicted ground motion for the historical check would be less than it would be normally for a more correct crustal velocity.

Q. Do you know how much lower?

A. No.

Q. Could you gather a guess in percentage, 10 percent, 2 percent, 5 percent?

A. In the range of 10 to 50 percent.

Q. Ten to 50?

A. Yes.

Q. How would you go about determining exactly what that percent error was?

A. Well, the first one I would do is a straight -- take that intermediate layer off. The next one I would do is put an appropriate radiant in. And third, I would introduce structures that are appropriate for that path. I would introduce the coastal plain sediments in a wedge. I would introduce velocity anomalies that are consistent with the Triassic basins and I would put in a gradient in the lower part of the crust that would

be consistent with a transition from the crust to the mobile.

Q. Are you aware that the Hermann crustal model as published in 1986 was modified for the Savannah River Site?

A. It was modified by shallowing it. The two-layer version of it was maintained, and that was perhaps the most incorrect part.

Q. What do you mean by it was modified by shallowing it?

A. The depth of the Moho was made to equate to 29 to 30 kilometers.

Q. Do you know what else was done to modify the Hermann crustal model for SRS?

A. In detail -- we would have to go back and look at it and make a detailed comparison. Conceptually, the difference is Hermann's model had the two-layer crust, a two-layer crust was -- that two-layer crust with a thickness of close to 40 kilometers was modified for a 30-kilometer crust for that path from Charleston to the Savannah River plant.

Charleston event the RVT ground motions are sensitive to source, depth and distance.

Would you agree then that the path that was -- or the model that was used was modified to take into account the Moho bounce?

A. The Owens/Hermann model apparently does take into account, according to this, the Moho bounce. It was applied to a Hermann model and that contains an intermediate layer, and physically an intermediate layer is going to reflect the waves and starve the energy that is available for the Moho bounce. Unless you are fudging and making mistakes, you are not going to get rid of the physical problem of the Hermann model not giving you a proper attenuation and distance relation.

Q. But since you haven't done any studies, you don't know if the Owens/Hermann approximation as applied to the modified Hermann crustal model makes any significant difference than a path that you would choose specifically from Charleston to SRS?

A. I have done a number of studies starting

with my Ph.D. thesis on the attenuation or propagation of waves in the crust. Those studies included determination of amplitude as a function of distance using a number of techniques, and I know that certain models are physical models, in particular the layering model as presented by Hermann is going to give a different distance response than a layer model that does not contain an intermediate layer.

If these people are using correct formulations of elastic theory and making appropriate approximations, they are going to respond to the model in the same way any other propagation theory will.

Q. But the distance response might be off by one or two percent with all of the changes they made -- you wouldn't know because you haven't done any calculations; is that right?

A. I haven't done the calculations for this particular model.

Q. Let me go down further. Figure 10.1 shows the SRS site relative to the -- 1886