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(2)

November 8, 2004

Chief, Rules and Directives Branch
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Comments on Draft Appendix C to Regulatory Guide 1.200 (69 *Federal Register* 54707, September 9, 2004)

The Nuclear Energy Institute[1] offers the following comments on the subject *Federal Register* notice, which solicited public comments on the proposed Appendix C to Regulatory Guide 1.200. EPRI has prepared technical comments on the proposed Appendix on behalf of NEI, and these are attached and further discussed below.

We have significant concerns with the current draft of Appendix C. There remain important unresolved issues with respect to interpretation of the standard, consideration of seismic hazards analysis, and ongoing activities essential to this document. Therefore, we strongly recommend that NRC endorsement of the standard should be deferred.

Our principal concerns are detailed below:

- The pilot program to address Appendices A and B of Regulatory Guide 1.200, which address the ASME internal events PRA standard, is still underway. Experience to date has indicated issues of interpretation remain with respect to both the standard itself and NRC positions contained in Appendices A and B. Given that the ANS external events standard builds upon the ASME internal events standard, it is premature to finalize the regulatory position on the ANS standard until the ongoing pilot program is complete, and the regulatory positions on the ASME standard are fully clarified and understood. Following the conclusion of the existing pilot plant activities,

[1] NEI is the organization responsible for establishing unified nuclear industry policy on matters affecting the nuclear energy industry, including regulatory aspects of generic operational and technical issues. NEI members include all utilities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect/engineering firms, fuel fabrication facilities, materials licensees, and other organizations and individuals involved in the nuclear energy industry.

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E-RIDS = ADM-03
Add = A. Singh (AXS3)

and NRC communication of the results, Appendix C will additionally need its own pilot phase, and should initially be issued for trial use.

- The lack of a large volume or number of industry comments on Appendix C (beyond those attached to this letter) should not be interpreted as tacit endorsement of either the ANS standard or the regulatory positions. Appropriately, industry PRA technical resources needed to provide a full technical evaluation of the ANS standard and associated regulatory positions are currently focused on near-term activities associated with increasing NRC expectations related to PRA technical adequacy, risk applications, and reactor oversight process activities.

- We are concerned that the regulatory position appears to disavow use of seismic margins analysis (SMA) for most applications. While we agree that seismic risks must be addressed in applications, it is not apparent that development of a full seismic PRA is a prudent activity for many plants, given the competing needs to improve internal events, fire, and other PRAs of greater importance to regulatory decision making. SMA provides a useful approach for many regulatory applications and should be included in the scope of Regulatory Guide 1.200. Significant further discussion is needed prior to finalization of the associated regulatory positions.

- Based on our reviews, Appendix C and the ANS Standard appear to establish expectations for seismic PRAs that exceed those of any operating plant, and are impractical for implementation. While the comments provided in the attachments are examples only, we believe they are adequate to convey the significance of our concern.

- EPRI Report 1009074, *Trial Plant Review of an American Nuclear Society External Event Probabilistic Risk Assessment Standard* (September 2003), is attached. EPRI does not believe that the issues identified in this work were completely considered in the evaluation of the Standard or the development of Appendix C. In particular, even one of the most complete seismic PRAs in the nuclear power industry does not conclusively achieve capability Category 2 of the Standard. The report authors also believe that reviewers could have other interpretations of the Standard and alternatively conclude that additional requirements of the Standard are not met by the trial plants. In addition, the EPRI report did not consider the recent more restrictive seismic positions expressed in the Draft Appendix C with respect to Seismic Margin usage and with regard to the establishment of seismic hazard for a specific site. The language within the Draft Appendix C will add further concern relative to the conclusions of the report.

We thus request NRC consideration of the following:

1. Extend the comment period for Appendix C until after finalization of the ongoing pilot program for Appendices A and B, and NRC communication of the results. It is imperative that the regulatory positions on Appendices A and B are well understood before proceeding with Appendix C. At that time, industry will conduct a more comprehensive technical evaluation of the ANS standard and Appendix C.

2. Following the above, and resolution of issues identified, Appendix C should be issued for trial use, and a pilot implementation program conducted.

3. The final Appendix C should be issued following completion of the pilot program and communication of regulatory expectations, similar to the approach for the ASME internal events standard.

Our detailed comments are attached. Please contact me if you would like to discuss these comments further, or desire additional information.

Sincerely,

Anthony R. Pietrangelo

Anthony R. Pietrangelo

cc: Ms. Mary Drouin, NRC
Mr. Amarjit Singh, NRC
Mr. Mike Tschiltz, NRC

Attachments

1. EPRI comments on Appendix C to Regulatory Guide 1.200.
2. Examples of additional areas of concern with interpretations of the ANS standard.
3. EPRI Report 1009074, *Trial Plant Review of an American Nuclear Society External Event Probabilistic Risk Assessment Standard.*, September 2003.

EPRI

Trial Plant Review of an American Nuclear Society External Event Probabilistic Risk Assessment Standard

Technical Report

Trial Plant Review of an American Nuclear Society External Event Probabilistic Risk Assessment Standard

1009074

Final Report, September 2003

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The report is a corporate document that should be cited in the literature in the following manner:

Trial Plant Review of an American Nuclear Society External Event Probabilistic Risk Assessment Standard, EPRI, Palo Alto, CA: 2003. 1009074.

REPORT SUMMARY

This study examined a representative set of Seismic Probabilistic Risk Assessments (SPRAs) and Seismic Margin Assessments (SMAs) performed for U.S. nuclear plants and evaluated them against the American Nuclear Society's draft External-Event PRA Methodology Standard for conducting Probabilistic Risk Assessment of external events.

Background

The External-Event PRA Methodology Standard provides basic requirements for performing external event probabilistic risk assessments that would support future risk informed decisions. The Standard limits its requirements to performing a Level 1 analysis of the core damage frequency (CDF) and a limited Level 2 analysis of Large Early Release Frequency (LERF). The Standard provides requirements for a graded approach to risk assessment. For SPRA, it requires three "Capability Categories" representing three levels of detail. This Three Capability Category format is consistent with the internal events PRA standard developed by ASME. Guidance is not provided on the capability category appropriate for risk informed decisions. This is left to the judgment of the risk analyst. In the standard it is assumed that an internal event PRA is available or is being conducted in parallel with the external event PRA. The Standard defines the interfaces between internal and external event evaluations and also provides requirements for Seismic Margin Assessment (SMA). SMA results may be recast into a quantitative risk assessment format in support of risk informed decisions; however, the Standard does not specifically address how this is to be done.

Objectives

To evaluate selected existing SPRAs and SMAs against the Draft Standard to determine if the requirements of the Standard are generally being met by current practice as performed in Individual Plant Examination of External Events (IPEEE); to determine if there are any requirements in the Standard that need to be clarified or modified in order for licensees to develop and apply external event risk models to risk informed decisions.

Approach

The project team compared results of two SPRAs and one SMA to each of the requirements of the Standard to determine if the Standard's requirements were met and. in the case of SPRA, which of the Capability Categories were met. The two SPRA selected for the study assess an eastern U.S. site with average seismic hazard and a western U.S. plant with very high seismic hazard. The selected SMA was originally conducted as a Trial Plant Applications of the EPRI Seismic Margin Methodology.

Results

The two SPRAs meet the majority of the requirements of Capability Category 1, but there are variations with regard to their compliance to Capability Categories 2 and 3. The SMA generally meets the requirements of the Standard. The two SPRAs selected were conducted in accordance with the requirements of NUREG-1407 that set the procedural and submittal requirements for an IPEEE. The NUREG-1407 requirements are generally consistent with the requirements in the Standard for Capability Category I. Because of the difference in seismicity of the two SPRA sites studied, the high seismic zone plant study was more thorough and for the most part corresponded to Capability Category II. The site with the lower seismicity generally corresponded with the requirements of Capability Category I. Ultimately, enhancements to the SPRAs may be required to address some future risk informed applications, depending ultimately on the required Capability Category. The SMA selected was originally conducted as a trial plant application of the EPRI SMA methodology and did not include a few of the requirements in NUREG-1407 for IPEEE. For this reason, it was not in complete compliance with every detailed requirement of the Standard but was in compliance with all major subjects areas it did address.

EPRI Perspective

Existing SPRAs and SMAs can and should be used for future risk informed applications. Most SPRAs were developed for IPEEE and would meet the intent of the requirements of Capability Category I of the Standard. For many risk informed applications the existing models are adequate to demonstrate the change in risk that would result from a change in design requirements, seismic qualification method, construction practice, maintenance intervals, inspection intervals, or other practices. For some future applications, some refinements and enhancements may be necessary to quantify the change in risk from the issue or issues being addressed. However, existing SMAs may need to be augmented with an issue-focused specific probabilistic risk evaluation for some risk-informed applications. The degree that the SMA must be augmented will depend on the issue at hand and the relative CDF/LERF risk levels existing at the particular plant. Existing SMAs require additional effort in order to use their results for Capability Category I applications. Existing SMA capacity calculations can be developed into fragilities. A rudimentary plant logic model can then be developed to estimate the plant risk based on the seismic hazard and these fragilities. Some future risk informed applications may even ultimately require a complete Capability Category II risk model and evaluation similar to that required within a high quality SPRA.

Keywords

Earthquakes
Seismic Risk
Fragilities
Individual Plant Examination for External Events
Probabilistic Risk Assessment
Seismic Margin Assessment
Risk Informed

ABSTRACT

The American Nuclear Society has developed a draft "External-Event PRA Methodology Standard" that provides high level requirements (HLRs) and supporting technical requirements (STRs) for conducting Probabilistic Risk Assessment (PRA) of seismic events and other external events such as high winds and external flooding. The objective of the Standard is to provide basic requirements for performing external event risk assessments that would support risk informed decisions. The Standard limits its requirements to performing a Level 1 analysis of the core damage frequency (CDF) and a limited Level 2 analysis of large early release frequency (LERF). It is assumed the an internal event PRA is available or is being conducted in parallel with the external event PRA. The interfaces between the internal and external events evaluation models are defined. The focus of this report is on Seismic Probabilistic Risk Assessment (SPRA). In addition, the Standard provides requirements for Seismic Margin Assessment (SMA). SMA results may be recast into a quantitative risk format in support of risk informed decisions, thus the report also includes SMA.

For SPRAs, the Standard provides requirements for three Capability Categories or levels of detail. This is analogous to the ASME standard for internal event PRA and is a graded approach to risk assessment. Each risk-informed application must be evaluated on its own merit for supporting the decision to be made. The boundaries of the three Capability Categories are defined in a general sense and some overlap exists, thus, the compliance with a specific Capability Category can be somewhat subjective. There are no specific guidelines in the Standard regarding which Capability Category would be necessary for risk informed decisions in operating NPPs. This would depend on the particular issue being addressed.

In the case of SMA, the three Capability Category structure is not present in the Standard. There are a single set of requirements. SMAs do not transparently provide quantitative risk assessments values. The scope of a SMA covered by the Standard is limited to analyzing NPP seismic capacities by a deterministic methodology. As stated in the Standard, the philosophy is that the SMA results can be augmented with an issue-focused specific PRA evaluation to support an application. This would require some level of modeling and quantification to be conducted in a similar fashion to an SPRA.

All operating U.S. Nuclear Power Plants have performed internal event PRAs in response to the USNRC request for an Individual Plant Examination (IPE). A little less than half of the plants have performed SPRAs in response to the USNRC request for an Individual Plant Examination of External Events (IPEEE) while a little more than half of plants have performed a Seismic Margin Assessment for their IPEEE. Almost all of the SMAs conducted in the world to date have followed the EPRI methodology, thus the Standard considers/follows the EPRI methodology very closely and adds several supplemental requirements contained in NUREG-1407.

In general, Capability Category II would be the level of detail in a SPRA that would ultimately be required for critical risk informed decision-making. However, Capability Category I would, in many cases, be sufficient to determine changes in risk due to typical changes in plant licensing bases or in addressing Generic Safety Issues that are not highly sensitive to seismic issues. The augmentation of SMA with an issue-focused specific PRA should be conducted to meet the intent of Capability Category I of the Standard for the specific issue being considered. Use of the SMA results to address Capability Category II issues will typically require an expansion of the original scope of the SMA (beyond the 2 shutdown paths) and the development of some specific component fragilities. Capability Category III of the Standard has some requirements which follow along the lines of the Seismic Safety Margin Research Program and, in general, would likely only be considered in a research program regardless of whether the plant has an existing SPRA or an SMA.

The basic difference between Capability Category I and II in the Standard is that Capability Category II requires a more thorough seismic hazard analysis and a full uncertainty analysis of the risk quantification, whereas Capability Category I can rely more on generic or regional mean seismic hazard estimates and calculation of only the mean core damage frequency (CDF). For IPEEE, only a mean CDF estimate was required, therefore, almost all of the IPEEE SPRA submittals would comply with Capability Category I but not Capability Category II.

The objective of this study was to examine a representative/typical set of SPRAs and SMAs performed for U.S. NPPs and compare the procedures used to requirements in the Standard. The objective is two fold. First, it is to evaluate the selected studies performed relative to the requirements of the Standard for Capability Category I or II. Second, is to see if the requirements in the Standard are reasonable or require clarification relative to the current state of the art in performing SPRAs and SMAs.

Two SPRAs and one SMA were examined for comparison to the Standard and to determine their degree of compliance with the requirements of the Standard. The three plants selected for comparison of their seismic evaluations to requirements of the Standard were:

- San Onofre Nuclear Generating Station (SPRA)
- Surry Power Station (SPRA)
- Catawba Nuclear Station (SMA)

San Onofre Nuclear Generating Station (SONGS) is a Combustion Engineering Pressurized Water Reactor located on the Southern California coast in a high seismic region. SONGS was designed for a 0.67g Safe Shutdown Earthquake (SSE). Because of the high seismicity, SONGS was required in NUREG-1407 to conduct SPRA for IPEEE. This entailed a new seismic hazard study and detailed modeling of the plant systems.

Surry is a Westinghouse PWR located in a moderate seismic region in Virginia. It was designated in NUREG-1407 to be focused scope plant and had a choice of conducting SMA or SPRA. A SPRA was selected using the existing EPRI seismic hazard analysis for the site.

Catawba is a Westinghouse PWR with an ice condenser containment and is located in a region of moderate seismicity in South Carolina. It was designated in NUREG-1407 as a focused scope plant. The Catawba IPEEE submittal was based on a full scope Level 3 SPRA, however, Catawba also had previously undergone a trial plant review SMA using the initial EPRI SMA methodology. The Catawba trial plant SMA was selected for the comparison to the requirements of the Standard.

In conducting the comparison of the above studies to the requirements of the Standard it is important to note that the objective of the existing external event studies and the objective of the Standard are different. In the SONGS and Surry SPRAs, the objective was for the licensee to comply with the requirements of NUREG-1407, whereas the Standard is written to provide a graded scope of requirements for developing SPRA models for risk informed applications. The two SPRAs were found to generally comply with Capability Category I requirements of the Standard. Since SONGS was in a high seismic zone, significantly more effort was expended in the SPRA and, with the exception that a full uncertainty analysis was not conducted, the SONGS SPRA would basically meet the intent of the requirements for Capability Category II. Surry is in a much lower seismic zone and the systems modeling was much simpler, focusing on a few dominant contributors to CDF (in conformance with the applicable IPEEE requirements). The component capacity screening level for Surry was also at a much lower level. As such, the screening level tended to mask the significance of most of the plant components relative to CDF. For the most part, the Surry SPRA met the basic intent of Capability Category I but would likely require enhancement to be used in many risk informed applications.

The Catawba SMA was conducted before IPEEE requirements were published in NUREG-1407. The Catawba SMA followed the guidance of the EPRI SMA methodology but did not include an evaluation of seismic/fire interaction and containment performance as required in NUREG-1407 and the Standard. Other than those two omissions, the Catawba SMA met the basic requirements of the Standard.

There is one area of the Standard where a rigid compliance is somewhat subjective and was not specifically addressed in either SPRA. There are requirements to consider and evaluate the sensitivity of correlation and dependencies in the screening process, in the modeling and quantification process and in the final sensitivity analyses. Typically in SPRAs, components that are identical or very similar that appear in redundant trains of the same system are assumed to be 100% correlated; if one fails, the other fails. This negates any beneficial effect of redundancy. If the components are not alike and appear in the same train or in different trains of the same system, they are typically treated as uncorrelated. Other like and unlike components in different systems are typically treated as uncorrelated. Since the earthquake ground motion affects all components, there is some degree of response correlation that is not assessed. The standard alludes to the fact that generic correlations and dependencies can be used, if justified, for Capability Categories I and II. The treatment of correlation as described above can be considered to be a generic treatment but there was no attempt to justify this approach or to quantify the sensitivity in the two SPRAs addressed nor in most, if not all, of the IPEEE SPRAs. The quantification or justification in a rigorous sense is difficult since there is no consensus on a technical approach nor software available to the general public. It is not the charter of the Standard to provide specific methodology to meet Capability Category I and II. This is an area that will require some methodology development to fully clarify and implement the correlation and dependency requirements of the Standard in SPRAs.

A generic issue with Surry, as well as most SPRAs conducted for IPEEE, is that existing hazard analyses by EPRI or LLNL were used in the SPRAs. At the time of the studies it was assumed by SPRA analysts that the existing hazard analyses could be used without any further study to determine if new information could alter the results. Several places within the Standard address the issue of evaluating whether the hazard being utilized reflects the most current data/attenuation/methodology for developing the site UHS. The current wording in the draft standard indicates that the EPRI and LLNL hazard studies can be considered appropriate for use in support of Capability Category 1 and 2 risk informed applications as long as referenceable data doesn't exist that could materially change these seismic hazard results. The United States Geological Survey has recently assessed the seismic hazard in the U.S. and it is apparently higher in certain locations than that predicted by EPRI or LLNL. The studies conducted by EPRI and LLNL are considered to be more applicable to the NPP sites than the more generic regional hazard predictions by USGS, however, this difference now exists and the use of existing EPRI and LLNL hazard studies in risk informed applications may have to also address the difference in the USGS hazard results or justify that they are not applicable.

The existing EPRI and LLNL hazard studies define only the horizontal ground motion. The vertical ground motion is not specifically addressed. The SONGS site-specific seismic hazard analysis developed both horizontal and vertical ground motion. The Standard provides general requirements for developing the seismic ground motion at the site without differentiation as to the applicability to horizontal or vertical ground motion. The requirements in the Standard are assumed to apply equally to defining vertical as well as horizontal motion. Considering the basic concept of the Standard for a graded approach and considering that almost all of the existing SPRAs were conducted using EPRI and LLNL definitions of *horizontal* Uniform Hazard Spectra (UHS) and horizontal PGAPGA, it would be beneficial if the Standard would clarify what is acceptable for the three Capability Categories. It would seem logical to allow the development of only a horizontal PGA hazard and horizontal UHS for Capability Category I. However, the hazard analyst should also provide some guidance to the fragility and systems analysts on how to correlate the vertical ground motion to the defined horizontal ground motion. In this case, the LLNL and EPRI hazard studies would still fall short of meeting Capability Category I without some further guidance on the relationship of vertical to horizontal motion. For SONGs, the vertical ground motion was specifically defined although only a single attenuation equation was used for vertical motion. In that respect, the vertical ground motion did not contain the full uncertainty distribution that would be expected for capability Category II.

Another observation made is that the Standard requires the screening level to be high enough that the contribution to risk from screened out components is insignificant. The screening level must be based on a consideration of correlation and dependencies. SONGS screened at a level where the seismic induced failure rate of screened out components was more than two orders of magnitude lower that the calculated CDF whereas the Surry screening level, as well as the screening level in many other IPEEE SPRAs, resulted in failure rates of screened out components being more than 10% of the CDF. The Standard does not suggest the use of surrogate fragilities for screened out components, whereas, several IPEEE submittals use surrogate fragilities to some extent to attempt to capture the relative contribution to CDF of screened out components. The Standard, being a requirements document, and not a criteria or applications document, does not provide details on how to model screened out components but it could possibly provide some approximate target, at least for Capability Category I. The subjective opinion in this report is that the SONGS screening level was high enough that the lack of discussion on correlation was not important at least in meeting Capability Category I. On the other hand, the screening level for Surry is considered to be too low, thus the model as it exists, does not fully meet the intent of Capability Category I and would require some upgrading for usage in future risk informed applications.

Another requirement in the Standard that was not completely met in any of the studies reviewed is the requirement for peer review. The Standard refers to the general requirements in the ASME Standard for PRA (ASME, 2002) and provides additional specific requirements for SPRA and SMA. IPEEE required peer reviews but not in the depth required in the Standard. In the case of SONGS, the seismic hazard was peer reviewed by three independent experts. The systems analysis, including Human Reliability Analysis (HRA), was reviewed by knowledgeable in house staff that did not directly participate in the SPRA. Fragility analyses and walkdowns were performed jointly by the utility and EQE, a consulting company. The two teams reviewed each other although the reviewers were not independent of those doing the work. An independent consultant performed a focused review of the response analysis and some fragility analyses. The review teams and their conclusions are contained in the Tier 1 IPEEE report.

In the case of Surry, the peer review was conducted by a single consultant and focused primarily on the walkdown. Some sampling of fragility analyses was also conducted by the peer reviewer. The peer reviewer's report is included as an Appendix to the Tier 1 IPEEE report and the resolution of his findings are documented. There seems to be no peer review of the systems modeling including HRA. The EPRI hazard was used for the SPRA. The EPRI hazard study was comprehensive and was previously peer reviewed and was taken as a given input so no additional reviews of the hazard study were conducted in IPEEE. The overall level of peer review was judged insufficient to meet the intent of the Standard. Thus, some level of additional peer review would be recommended in support of any risk informed applications.

The Catawba SMA was conducted before the issuance of NUREG-1407 that required peer review. The objective of the Catawba SMA was a Trial Plant Review of EPRI NP-6041. The EPRI document did not require a peer review, therefore none was conducted.

As pointed out initially, the goal of the Standard is to provide requirements for SPRA that can be used in risk informed applications, whereas, the SPRAs conducted for IPEEE had a different goal and may, as a result, require enhancements for many risk informed applications. Existing SMAs can be transformed into a SPRA structure to obtain quantitative results for certain risk informed applications. The degree of systems and fragility modeling will depend upon the application and for some applications, the level of detail consistent with full SPRA may become necessary. In that case, the seismic capacity calculations can be utilized in the development of fragilities.

ACRONYMS

ALARA	As low as Reasonably Achievable
ANS	American Nuclear Society
CEUS	Central and Eastern United States
CUS	Central United States
CDF	Core Damage Frequency
CDFM	Conservative Deterministic Failure Margin
ECCS	Emergency Core Cooling System
ESFAS	Emergency Safety Features Actuation System
EUS	Eastern United States
FPS	Feet per Second
HCLPF	High Confidence of Low Probability of Failure
HLR	High Level Requirements
HRA	Human Reliability Analysis
IPE	Individual Plant Examination
IPEEE	Individual Plant Examination of External Events
LERF	Large Early Release Frequency
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
PGA	Peak Ground Acceleration
PRA	Probabilistic Risk Assessment
PSF	Performance Shaping Factor
PSHA	Probabilistic Seismic Hazard Analysis
PWR	Pressurized Water Reactor
RAI	Request for Additional Information
RLE	Review Level Earthquake
RRS	Required Response Spectrum
RRSc	Clipped Required Response Spectrum

ry	Reactor Year
Sa	Spectral Acceleration
SBLOCA	Small Break Loss of Coolant Accident
SDS	Seismic Damage State
SEL	Seismic Equipment List
SET	Seismic Event Tree
SEWS	Seismic Evaluation Work Sheets
SMA	Seismic Margin Assessment
SPRA	Seismic Probabilistic Risk Assessment
SPSA	Seismic Probabilistic Safety Assessment
SSCs	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
SSEL	Safe Shutdown Equipment List
SSI	Soil-Structure Interaction
SSMRP	Seismic Safety Margin Research Program
SSPS	Solid State Protection System
Standard	ANS External-Events PRA Methodology Standard, BSR/ANS 58.21
STR	Supporting Technical Requirements
TER	Technical Evaluation Report
TRS	Test Response Spectrum
TRSc	Clipped Test Response Spectrum
UHS	Uniform Hazard Spectra
USNRC	United States Nuclear Regulatory Commission
ZPA	Zero Period Acceleration

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1
INTRODUCTION

1.1 Background

The American Nuclear Society (ANS) has developed a draft "External-Event PRA Methodology Standard," (ANS 2002), hereafter referred to as the Standard. This Standard provides high-level requirements (HLRs) and supporting technical requirements (STRs) for conducting Probabilistic Risk Assessment (PRA) of seismic events and other external events such as high winds and external flooding. The USNRC is moving toward risk informed regulation (USNRC 2000) and the objective of the Standard is to provide basic requirements on performing external event risk assessments that would support risk informed decisions. The Standard limits its requirements to performing a Level 1 analysis of the core damage frequency (CDF) and a limited Level 2 analysis of large early release frequency (LERF). It is assumed the an internal event PRA is available or is being conducted in parallel with the external event PRA and the interfaces between the internal and external events modeling are defined. The focus of this report is on seismic probabilistic risk assessment (SPRA).

The types of risk-informed applications contemplated under the Standard are very broad and include applications related to design, procurement, construction, licensing, operations and maintenance. For SPRAs, the Standard provides requirements for three Capability Categories or levels of detail. This is analogous to the ASME standard for internal event PRA (ASME, 2002) and is a graded approach to risk assessment. An existing SPRA may span all three Capability Categories for some STRs, may meet only one of the three Capability Categories for a given STR, or may not technically meet any of the Capability Categories of one or more STRs. This would not necessarily mean that the existing study or model was not suitable for making risk informed decisions. Each risk-informed application must be evaluated on its own merit for supporting the decision to be made. The boundaries of the three Capability Categories are defined in a general sense and some overlap exists, thus, the compliance with a specific Capability Category can be somewhat subjective. For many STRs, the wording for each Capability Category is the same. Following the concept of a graded approach, it is implied in the Standard, as well as in the ASME Standard, that the level of detail in the evaluation should be in relation to the fundamental bases of meeting the Capability Category. In the case of SMA, the three Capability Category structure is not present in the Standard.

All U.S. Nuclear Power Plants have performed internal event PRAs in response to the USNRC request for an Individual Plant Examination (IPE). Many of the plants have performed seismic and fire PRAs in response to the USNRC request for an Individual Plant Examination of External Events (IPEEE). A little over half of plants have performed a Seismic Margin Assessment (SMA) for their seismic IPEEE submittal. SMA results, supplemented by quantitative PRA type applications of the results, may also be used to some degree in risk informed applications. Therefore, the Standard provides requirements for conducting SMAs. Almost all of the SMAs conducted in the world to date have followed the EPRI (1988 or1991) methodology, thus the Standard follows the EPRI methodology very closely and adds several supplemental requirements contained in NUREG-1407 (USNRC, 1991b) that was the procedural and submittal guidance specified by the USNRC for IPEEE SMAs and SPRAs.

There are no specific guidelines in the Standard regarding which Capability Category would be necessary for risk informed decisions in operating NPPs. This would depend on the particular issue being addressed. SMAs do not provide quantitative risk assessments values. The scope of a SMA covered by the Standard is limited to analyzing NPP seismic capacities by a deterministic methodology. As stated in the Standard, the philosophy is that the SMA results can be augmented with an issue-focused specific PRA evaluation to support an application.

In general, Capability Category II would be the level of detail in a SPRA that would ultimately be required for high quality of risk informed decision-making. However, Capability Category I would, in many cases, be sufficient to determine any changes in risk due to changes in plant licensing bases or in addressing Generic Safety Issues. The augmentation of SMA with an issue-focused specific PRA might be considered to meet the intent of Capability Category I of the Standard for the specific issue being considered even if a complete Capability Category I SPRA was not conducted. Capability Category III of the Standard follows along the line of the Seismic Safety Margin Research Program (USNRC, 1981) and, in general, would likely only be considered in a research program.

The basic difference between Capability Category I and II in the Standard is that Capability Category II requires a more thorough seismic hazard analysis and a full uncertainty analysis of the risk quantification, whereas Capability Category I can rely more on generic or regional mean seismic hazard estimates and only a calculation of the mean core damage frequency (CDF). For IPEEE, only a mean CDF estimate was required, therefore, almost all of the IPEEE SPRA submittals would comply with Capability Category I but not Capability Category II.

1.2 Objective

The objective of this study is to examine a select set of SPRAs and SMAs performed for U.S. NPPs and compare the procedures used to requirements in the Standard. The objective is two fold. First, it is to compare current SPRA practice in the selected studies relative to the requirements of the Standard for Capability Category I or II to determine the general compliance with the Standard and its objective. Second, is to see if the requirements in the Standard are reasonable relative to the current state of the art in performing SPRAs and SMAs.

1.3 Scope

The scope of this study was to examine two SPRAs and one SMA for comparison to the Standard and to determine their degree of compliance with the requirements of the Standard. If cases occur where the Standard is considered to be ambiguous in a STR or unrealistic relative to industry practice, it is to be noted for a point of clarification or recommended change.

The three plants selected for comparison of their seismic evaluations to requirements of the Standard are:

- San Onofre Nuclear Generating Station (SPRA)
- Surry Power Station (SPRA)
- Catawba Nuclear Station (SMA)

San Onofre Nuclear Generating Station (SONGS) is a Combustion Engineering Pressurized Water Reactor located on the Southern California coast in a high seismic region. SONGS was designed for a 0.67g Safe Shutdown Earthquake (SSE). Because of the high seismicity, SONGS was required by NRC (USNRC, 1991b) to conduct SPRA for IPEEE.

Surry is a Westinghouse PWR located in a moderate seismic region in Virginia. It was designated in USNRC (1991b) to be a 0.3g focused scope plant and had a choice of conducting SMA or SPRA. Virginia Electric and Power Company elected to conduct SPRA for their IPEEE submittal.

Catawba is a Westinghouse PWR with an ice condenser containment and is located in a region of moderate seismicity in South Carolina. It was designated in USNRC (1991b) to be a 0.3g focused scope plant. The IPEEE submittal was based on a full scope Level 3 SPRA, however, Catawba also had previously undergone a trial plant review SMA using the initial EPRI SMA methodology (EPRI, 1988). For this study, the trial plant SMA (EPRI, 1989b) was selected.

In the case of SONGS and Surry, the IPEEE Tier 1 submittals, USNRC requests for additional information (RAIs) and Utility responses to the RAIs were reviewed for comparison to the requirements of the Standard.

For Catawba, the SMA Trial Plant Review (EPRI, 1989b) was reviewed relative to the requirements for SMA in the Standard. In addition, the SPRA IPEEE submittal, RAIs and responses to RAIs were reviewed as supplemental information and insight on the capability of an SMA to be used in risk informed applications.

In conducting the comparison of the above studies and the requirements of the Standard it is important to note that the objective of the studies and the objective of the Standard are different. In the SONGS and Surry SPRAs, the objective was for the licensee to comply with the requirements of USNRC (1991a and 1991b) to: (1) develop an appreciation of severe accident behavior, (2) to understand the most likely severe accident sequences that could occur at its plant under full-power operating conditions, (3) gain a *qualitative* understanding of the overall likelihood of core damage and fission product releases, and (4) if necessary, to reduce the overall likelihood of core damage and fission product releases by modifying, where appropriate, hardware and procedures that would help prevent or mitigate severe accidents. The Standard is written to provide requirements for future risk informed applications. Per Regulatory Guide 1.174 (USNRC, 1988), *quantitative* assessments are required which will require some level of probabilistic analysis.

The format selected for the comparisons of NPP seismic evaluations to the requirements of the Standard is to reproduce the requirements of the Standard line by line and superimpose what was done in each of the NPP seismic assessments. Although repetitive, it provides a clear direct comparison of what was done in the seismic assessment relative to each STR of the Standard. The notes that apply to each STR in the Standard have been omitted in the interest of reducing the volume of this report.

The areas of the Standard that are not met completely by the cases reviewed are pointed out. In some cases it was determined that exactly meeting the STRs of the Standard was difficult using the current state of the art. In a few cases, some recommendations are made to clarify the intent of the Standard in the progression from one Capability Category to another or to change the STR.

2 SUMMARY OF HIGH LEVEL REQUIREMENTS OF THE STANDARD

The Standard provides high-level requirements and supporting technical requirements. The high level requirements for SPRA and SMA are summarized herein. In subsequent chapters, the supporting technical requirements are compared in detail to the work that was conducted in the seismic evaluations of the three selected NPPs.

2.1 Seismic Margin Assessment

In the mid-1980s, two different methodologies for the seismic margin assessment of nuclear power plants were developed. These are the so-called "NRC method" (Budnitz, et.al.,1985) and the "EPRI method." (EPRI, 1988). The EPRI methodology was updated in 1991 (EPRI, 1991a). There was little use made of the NRC method thus the high level requirements contained in the Standard are explicitly directed toward an analysis using the EPRI method, which employs success-path-type systems-analysis logic and deterministic seismic capacity evaluation methods. The EPRI method depicted in the Standard follows the revision to the EPRI SMA methodology in EPRI (1991a). The Catawba trial plant review was conducted using the initial EPRI SMA methodology (EPRI, 1988). They are essentially the same requirements with enhancements being added in the 1991 revision.

High Level Requirements for Seismic Margin Assessment

There are eight High Level Requirements under Seismic Margin Assessment, as follows:

Seismic margin assessment high level requirement A—review level earthquake (HLR-SM-A): A review level earthquake characterized by a ground motion spectrum SHALL be selected to facilitate screening of structures, systems and components and performance of seismic margin calculations.

Seismic margin assessment high level requirement B—success paths (HLR-SM-B): A minimum of two diverse success paths SHALL be developed consisting of structures and equipment that can be used to bring the plant to a safe stable state and maintain this condition for at least 72 hours following an earthquake larger than the RLE.

Seismic margin assessment high level requirement C—responses (HLR-SM-C): Seismic responses calculated for the Review Level Earthquake SHALL be median centered, SHALL be based on current state-of-the-art methods of structural modeling, and SHALL include the effects of soil-structure-interaction where applicable.

Seismic margin assessment high level requirement D—screening (HLR-SM-D):
The screening of components and subsequent seismic margin calculations SHALL incorporate the findings of a detailed walkdown of the plant focusing on the anchorage, lateral seismic support and potential spatial interactions.

Seismic margin assessment high level requirement E—failure modes (HLR-SM-E):
Seismic margin calculations SHALL be performed for critical failure modes of structures, systems and components such as structural failure modes and functional failure modes identified through the review of plant design documents, including analysis and test reports supplemented by earthquake experience data, fragility test data, generic qualification test data, and by a walkdown.

Seismic margin assessment high level requirement F calculations (HLR-SM-F):
The calculation of seismic margins (or so-called HCLPF capacities) SHALL be based on plant specific-data supplemented by earthquake experience data, fragility test data and generic qualification test data. Use of such generic data SHALL be justified.

Seismic margin assessment high level requirement G—success path margins (HLR-SM-G):
The plant seismic margin SHALL be reported based on the margins calculated for the success paths.

Seismic margin assessment high level requirement H—documentation (HLR-SM-H):
The Seismic Margin Assessment SHALL be documented in a manner that facilitates applying the SMA and updating it, and that enables peer review.

2.2 Seismic Probabilistic Risk Assessment

The technical requirements for SPRA have been developed based on a wealth of experience over the past twenty years, including a very large number of full-scope SPRAs for nuclear power plants, and a large number of methodology guidance documents and methodology reviews. The major elements of a SPRA are; seismic hazard analysis, systems analysis including quantification, and fragility evaluation.

Seismic PRA is an integrated activity requiring close interactions among specialists from different fields (for example, seismic hazard analysis, systems analysis, and fragility evaluation). Although the methodology for seismic PRA and the supporting data have evolved and advanced over the past twenty years, the analysis still requires expert judgment and extrapolation beyond observed data. The peer review requirement of the Standard is also directed in part toward assuring that judgment and extrapolation are within reasonable boundaries.

2.2.1 Seismic PRA: Technical Requirements for Probabilistic Seismic Hazard Analysis

Requirements for the probabilistic seismic hazard analysis (PSHA) address two situations. The first situation deals with cases where no prior study exists and the site specific PSHA must be generated anew. In the second situation, the PSHA analyst may have the option to use an existing study to form the basis for a site-specific assessment. For example, the Lawrence Livermore National Laboratory and Electrical Power Research Institute regional hazard studies (USNRC, 1994) and (EPRI, 1989a) for sites east of the Rocky Mountains can be used to develop site-specific PSHA for most of the CEUS sites, after certain checks or updates are made (see the requirements in HLR-HA-H below.)

The primary objective of the PSHA is to estimate the probability or frequency of exceeding different levels of vibratory ground motion, and the requirements described in the Standard address this objective in detail.

The "level" (complexity and efforts related to use of expert judgment, expert elicitation, integration, etc.) of hazard analysis depends on two primary considerations: (1) intended use of the SPRA (linked with the Capability Category needed for that application); and (2) the complexity of the seismic environment. When dealing with a particular issue that will affect the results of the PSHA, the USNRC/EPRI/DOE Senior Seismic Hazard Analysis Committee's so-called "SSHAC" report (Budnitz, et.al., 1997) lists the following factors which affect the choice of level for the hazard analysis.

- The significance of the issue to the final results of the PSHA.
- The issue's technical complexity and level of uncertainty.
- The amount of technical contention about the issue in the technical community.
- Important non-technical considerations such as budgetary, regulatory, scheduling, or other concerns.

Based on considerations of the above, with respect to the issues identified and other factors, the SSHAC report has identified and provided guidance for four "levels" of hazard analysis. When viewed in the context of the Standard's Capability Categories, the SSHAC Levels 1 and 2 will generally correspond to Category I, Levels 2 and 3 will generally correspond to Category II, and Levels 3 and 4 will correspond to Category III. Level 1 or 2 analysis, based primarily on the use of available information, by its very nature will contain more uncertainties and will need to be demonstrably adequate or conservative for the intended application. On the other hand, accurate characterization and reduction of uncertainties are deemed essential features of Category Capability III applications, requiring development of detailed site-specific information possibly including field investigations (Levels 3 and 4).

The LLNL (USNRC, 1993) and EPRI (EPRI, 1989a) seismic hazard studies are considered to be SSHAC Level 3 studies, and therefore, meet the requirements of the Standard for Capability Category II.

To illustrate further, using generic or regional hazard analyses or mean hazard estimates, as was often done in various IPEEE applications, would be examples of Capability Category I. Using a site-specific hazard analysis performed for a particular site (e.g. San Onofre) or using the LLNL and EPRI hazard analyses are examples of Capability Category II.

High Level Requirements for SPHA

There are ten High Level Requirements for Probabilistic Seismic Hazard Analysis:

***Seismic hazard analysis high-level requirement A—scope (HLR-HA-A)*:** The frequency of earthquakes at the site SHALL be based on a site-specific probabilistic seismic hazard analysis (PSHA) (existing or new) that reflects the composite distribution of the informed technical community. The level of analysis SHALL be determined based on the intended application and on site-specific complexity.

***Seismic hazard analysis high-level requirement B—data collection (HLR-HA-B)*:** To provide inputs to the PSHA, a comprehensive up-to-date data base including: geological, seismological, and geophysical data; local site topography; and surficial geologic and geotechnical site properties, SHALL be compiled. A catalog of historical, instrumental, and paleoseismicity information SHALL also be compiled.

***Seismic hazard analysis high-level requirement C—seismic sources and source characterization (HLR-HA-C)*:** To account for the frequency of occurrence of earthquakes in the site region, the PSHA SHALL consider all credible sources of potentially damaging earthquakes. Both the aleatory and epistemic uncertainties SHALL be considered in characterizing the seismic sources.

***Seismic hazard analysis high-level requirement D—ground motion characterization (HLR-HA-D)*:** The PSHA SHALL account for all credible mechanisms influencing estimates of vibratory ground motion that can occur at a site given the occurrence of an earthquake of a certain magnitude at a certain location. Both the aleatory and epistemic uncertainties SHALL be considered in characterizing the ground motion propagation.

***Seismic hazard analysis high-level requirement E—local site effects (HLR-HA-E)*:** The PSHA SHALL account for the effects of local site response.

***Seismic hazard analysis high-level requirement F—aggregation and quantification (HLR-HA-F)*:** Uncertainties in each step of the hazard analysis SHALL be propagated and displayed in the final quantification of hazard estimates for the site. The results SHALL include fractile hazard curves, median and mean hazard curves, and uniform hazard response spectra (UHS). For certain applications, the PSHA SHALL include seismic source deaggregation and magnitude-distance deaggregation.

***Seismic hazard analysis high-level requirement G—spectral shape (HLR-HA-G)*:** For further use in the SPRA, the spectral shape SHALL be based on a site-specific evaluation taking into account the contributions of deaggregated magnitude-distance results of the PSHA. Broadband, smooth spectral shapes, such as those presented in NUREG/CR-0098 (Newmark and Hall, 1978) (for lower-seismicity sites such as most of those east of the U.S. Rocky Mountains) may also be used taking into account the site conditions. The use of UHS may also be appropriate if it reflects the site-specific shape.

Seismic hazard analysis high-level requirement H—use of existing studies (HLR-HA-H): When use is made of an existing study for PSHA purposes, it SHALL be confirmed that the basic data and interpretations are still valid in light of current information, the study meets the requirements outlined in A through G above, and the study is suitable for the intended application.

Seismic hazard analysis high-level requirement I—other seismic hazards (HLR-HA-I): A screening analysis SHALL be performed to assess whether, in addition to the vibratory ground motion, other seismic hazards, such as fault displacement, landslide, soil liquefaction, or soil settlement need to be included in the SPRA for the specific application. If so, the SPRA SHALL address the effect of these hazards through assessment of the frequency of hazard occurrence and/or the magnitude of hazard consequences.

Seismic hazard analysis high-level requirement J—documentation (HLR-HA-J): The PSHA SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.

2.2.2 Seismic PRA: Technical Requirements for Systems Analysis

It is assumed in the systems-analysis requirements contained in the Standard that the seismic-PRA analysis team possesses a full-scope internal-events full-power Level 1 and Level-2-LERF PRA, developed either prior to or concurrently with the SPRA. It is further assumed that this internal-events PRA is then used as the basis for the SPRA systems analysis.

Systems analysis for SPRA generally consists of both adding some earthquake-related basic events to the internal-events systems model, and also "trimming" some aspects of that model that do not apply or can be screened out on a sound basis. Examples of trimming include eliminating the part of the model covering recovery from loss of offsite power, which is usually not feasible after a large earthquake; eliminating event trees that start with very unlikely events unrelated to earthquakes; and screening out of low-probability non-seismic failures and human-error events. Thus the seismic-PRA systems model is generally substantially simpler than the corresponding model for internal events, even though it also contains some added complexity related to earthquake-caused failures.

In special circumstances, it is acceptable to develop an ad-hoc systems model tailored especially to the SPRA situation being modeled, instead of starting with the internal-events model and adapting it. If this approach is used, it is especially important that the resulting model be consistent with the internal-events systems model regarding plant response and the cause-effect relationships of the failures. Further, it is then especially important that a peer review be undertaken that concentrates on these aspects. Whichever approach is used, either adapting the internal-events systems model or building an ad-hoc systems model, it is important that the systems model includes all important failures, including both failures caused by the earthquake and non-seismic failures and human errors.

High Level Requirements

There are six High Level Requirements for Systems Analysis, as follows:

Systems-analysis high-level requirement A—completeness (HLR-SA-A): The seismic-PRA systems models SHALL include all important seismic-caused initiating events that can lead to core damage or large early release, and SHALL include all other important failures that can contribute significantly to CDF or LERF, including seismic-induced SSC failures, non-seismic-induced unavailabilities, and human errors.

Systems-analysis high-level requirement B—adaptations based on the internal-events PRA systems model (HLR-SA-B): The seismic-PRA systems model SHALL be adapted to incorporate seismic-analysis aspects that are different from corresponding aspects found in the full-power, internal-events PRA systems model.

Systems-analysis high-level requirement C—plant fidelity (HLR-SA-C): The seismic-PRA systems models SHALL reflect the as-built and as-operated plant being analyzed.

Systems-analysis high-level requirement D—seismic equipment list (HLR-SA-D): The list of SSCs selected for seismic-fragility analysis SHALL include all SSCs that participate in accident sequences included in the seismic-PRA systems model.

Systems-analysis high-level requirement E—integration and quantification (HLR-SA-E): The analysis to quantify CDF and LERF frequencies SHALL appropriately INTEGRATE the seismic hazard, the seismic fragilities, and the systems-analysis aspects.

Systems-analysis high-level requirement F—documentation (HLR-SA-F): The seismic-PRA analysis SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.

2.2.3 Seismic PRA: Technical Requirements for Seismic Fragility Analysis

The seismic fragility of a structure, system or component is defined as the conditional probability of its failure at a given value of seismic motion parameter (e.g., peak ground acceleration, peak spectral acceleration at different frequencies, or floor spectral acceleration at the equipment frequency). The methodology for evaluating seismic fragilities of SSCs has been collected and is best documented in EPRI (1994) and is supplemented in EPRI (2003).

High Level Requirements

There are seven High Level Requirements under Seismic Fragility Evaluation, as follows:

Seismic fragility evaluation high level requirement A—realism (HLR-FR-A): The seismic fragility evaluation SHALL be performed to estimate plant-specific, realistic seismic fragilities of structures, systems and components whose failure may contribute to core damage and/or large early release.

***Seismic fragility evaluation high level requirement B—screening (HLR-FR-B)*:** If screening of high-seismic-capacity components is performed, the basis for the screening SHALL be fully described.

***Seismic fragility evaluation high level requirement C—response (HLR-FR-C)*:** The seismic fragility evaluation SHALL be based on realistic seismic response that the SSCs experience at their failure levels. Depending on the site conditions and response analysis methods used in the plant design, realistic seismic response MAY be obtained by an appropriate combination of scaling, new analysis and new structural models.

***Seismic fragility evaluation high level requirement D—failure modes (HLR-FR-D)*:** The seismic fragility evaluation SHALL be performed for critical failure modes of structures, systems and components such as structural failure modes and functional failure modes identified through the review of plant design documents, supplemented as needed by earthquake experience data, fragility test data, generic qualification test data, and a walkdown.

***Seismic fragility evaluation high level requirement E—walkdown (HLR-FR-E)*:** The seismic fragility evaluation SHALL incorporate the findings of a detailed walkdown of the plant focusing on the anchorage, lateral seismic support, and potential systems interactions.

***Seismic fragility evaluation high level requirement F—data sources (HLR-FR-F)*:** The calculation of seismic fragility parameters such as median capacity and variabilities SHALL be based on plant specific data supplemented as needed by earthquake experience data, fragility test data and generic qualification test data. Use of such generic data SHALL be justified.

***Seismic fragility evaluation high level requirement G—documentation (HLR-FR-G)*:** The seismic fragility evaluation SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.

2.3 Peer Review

In addition to the high level and supplemental technical requirements for conducting SMAs or SPRAs, the Standard sets requirements for peer review. Peer Reviews of SPRA or SMA are to be performed according to the requirements found in Section 6 of the ASME Standard for PRA (ASME, 2002), except where the specific requirements therein do not apply to the external events. In addition, specific additional peer-review requirements for SPRA and SMA are found in the Standard.

The purpose of peer-review is fundamentally to provide an independent review of the SPRA or SMA by experts who are independent of the SPRA or SMA project. The composition and qualifications of the peer review team are important and these aspects are covered in the ASME Standard and are incorporated in the External Event PRA Standard by Reference. Process issues, including the need for a peer-review team leader and the need for a peer-review methodology for the review are also covered in the ASME Standard.

The peer-review is to assess the PRA against the requirements in the standard to the extent necessary to determine if the methodology and its implementation meet the requirements of the

Standard. All aspects of all requirements need not be assessed; however, enough aspects are to be reviewed in order for the reviewers to achieve consensus on the adequacy of the methodologies and their implementation.

Tables 2-1 and 2-2 set forth the additional peer-review requirements specific to SPRA and SMA.

Table 2-1
Peer Review Requirements for Seismic PRA

(REQ. SPRA-PR-1): The peer review team SHALL have combined experience in the areas of systems engineering, seismic hazard, seismic capability engineering, and seismic PRAs or seismic margin methodologies. The reviewer(s) focusing on the seismic fragility work SHALL have successfully completed the SQUG Walkdown Screening and Seismic Evaluation Training Course (SQUG, 1993) or equivalent, or SHALL have demonstrated equivalent experience in seismic walkdowns.
(REQ. SPRA-PR-2): The peer review team SHALL evaluate whether the seismic hazard study used in the PRA is appropriately specific to the site and has met the relevant requirements of the Standard.
(REQ. SPRA-PR-3): The peer review team SHALL evaluate whether the seismic initiating events are properly identified, the SSCs are properly modeled, and the accident sequences are properly quantified. The review team SHALL ensure that the Seismic Equipment List is reasonable for the plant considering the reactor type, design vintage, and specific design.
(REQ. SPRA-PR-4): The peer review team SHALL evaluate whether the seismic response analysis used in the development of seismic fragilities meets the relevant requirements of the Standard. Specifically, the review SHOULD focus on the input ground motion (i.e., spectrum or time history), structural modeling including SSI effects, parameters of structural response (e.g., structural damping, soil damping), and the reasonableness of the calculated seismic response.
(REQ. SPRA-PR-5): The peer review team SHALL review the seismic walkdown of the plant in order to ensure the validity of the findings of the Seismic Review Team on screening, seismic spatial interactions, and the identification of critical failure modes.
(REQ. SPRA-PR-6): The peer review team SHALL evaluate whether the methods and data used in the fragility analysis of SSCs are adequate for the purpose. The review team SHOULD perform independent fragility calculations of a selected sample of components covering different categories and contributions to CDF and LERF.
(REQ. SPRA-PR-7): The peer review team SHALL evaluate whether the seismic quantification method used in the seismic PRA is appropriate and provides all the results and insights needed for risk-informed decisions. The review SHALL focus on the CDF and LERF estimates and uncertainty bounds, and on the dominant risk contributors.

Table 2-2
Peer Review Requirements for Seismic Margin Assessment

(REQ. SMA-PR-1): The peer review team SHALL have combined experience in the areas of systems engineering, seismic hazard, seismic capability engineering, and seismic PRAs or seismic margin methodologies. The reviewer(s) focusing on the seismic capability work SHALL have successfully completed the SQUG Walkdown Screening and Seismic Evaluation Training Course (SQUG, 1993) or equivalent or SHALL have demonstrated experience in seismic walkdowns.
(REQ. SMA-PR-2): The peer review team SHALL evaluate whether the selection of the RLE used in the SMA is appropriately specific to the site and has met the relevant requirements of the Standard.
(REQ. SMA-PR-3): The peer review team SHALL evaluate whether the success paths are chosen properly and reflect the systems and operating procedures in the plant, and that the preferred and alternative paths are reasonably redundant. The review team SHALL ensure that the Safe Shutdown Equipment List is reasonable for the plant considering the reactor type, design vintage, and specific design.
(REQ. SMA-PR-4): The peer review team SHALL evaluate whether the seismic response analysis used in the development of seismic margins meets the relevant requirements of the Standard. Specifically, the review SHOULD focus on the input ground motion (i.e., spectrum or time history), structural modeling including SSI effects, parameters of structural response (e.g., structural damping, soil damping), and the reasonableness of the calculated seismic response for the RLE input.
(REQ. SMA-PR-5): The peer review team SHALL review the seismic walkdown of the plant in order to ensure the validity of the findings of the Seismic Review Team on screening, seismic spatial interactions and identification of critical failure modes.
(REQ. SMA-PR-6): The peer review team SHALL evaluate whether the methods and data used in the seismic margin analysis of components are adequate for the purpose. The review team SHOULD perform independent HCLPF calculations of a selected sample of components covering different categories and contributions to plant margin.
(REQ. SMA-PR-7): The peer review team SHALL evaluate whether the seismic margin assessment method used is appropriate and provides all the results and insights needed for risk-informed decisions. The review SHOULD focus on the HCLPF capacities of components and success paths, and on the dominant contributors to seismic margins.

3
CATAWBA SEISMIC MARGIN ASSESSMENT

3.1 Overview of SMA

The SMA conducted for Catawba (EPRI, 1989b), was a Trial Plant Review to test the EPRI Seismic Margin Methodology (EPRI, 1988). It was performed prior to the publication of Generic Letter 88-20, Supplement 4 (USNRC, 1991a) and NUREG-1407 USNRC, 1991b) laying out the requirements for IPEEE. Consequently, it differed in some respects to the SMAs that were conducted for IPEEE. The Catawba SMA was equivalent to a full scope SMA as defined in NUREG-1407 as it included a full scope evaluation of relays, whereas NUREG-1407 placed Catawba in the focused scope bin and only required a search for low ruggedness relays. NUREG-1407 requested the IPEEE to include some additional evaluations that were not specifically addressed in the Catawba SMA although many were implicitly included. The additional IPEEE evaluations implicitly included in the Catawba SMA were:

- USI A-45, Shutdown Decay Heat Removal Systems: The Catawba SMA included all decay heat removal modes considering SBLOCA and no SBLOCA.
- USI A-17, Systems Interactions: Spatial systems interactions were included in the Catawba SMA. Also, seismic induced internal flooding was addressed as part of the systems interactions evaluation.
- USI A-40, Seismic Design Criteria: The issue of the seismic design of above ground tanks was specifically addressed in the Catawba SMA.
- Eastern U.S. Seismicity: Catawba was not one of the five Eastern U.S. sites identified by the USNRC as an outlier regarding the seismic design basis. Nevertheless, this issue was inherently addressed by examining the plant for an earthquake equal to twice the SSE.

Issues not specifically addressed included:

- NUREG/CR-5088 fire issues including GI-57, Inadvertent Actuation of Fire Suppression Systems and Seismic/Fire interaction: These two issues were not specifically addressed in the Catawba SMA.
- Containment Performance: The Trial Plant Review focused on safe shutdown as defined in EPRI (1988). The structures were found to be robust in the original SPRA (Duke, 1987) and were also screened out for the Trial Plant Review. The steam generators were found in the original SPRA to have a large capacity and were screened out in the Trial Plant Review, thus, containment bypass, due to steam generator tube rupture would not occur until high acceleration levels were reached. Failure of containment isolation was not addressed in the SMA. Many valves have lock in circuits and this could be a possible issue for isolation valves and their power supplies and controls. Catawba was a focused scope plant for IPEEE and the extent of the IPEEE relay review for containment isolation was limited to a search for low capacity relays.

Catawba had previously conducted a SPRA (Duke, 1987), thus, the actual IPEEE submittal was an updated version of that study (Duke, 1994), that factored in the findings of the Trial Plant SMA, and results of additional walkdowns to address the fire issues and to include both units.

The Trial Plant Review was performed with some overlap in the development of the initial version of EPRI NP-6041 (EPRI, 1988). As a result, some changes were made in recommended procedures and in the format of the walkdown documentation. In Revision 1 to EPRI NP-6041 (EPRI, 1991a), some changes were made to criteria for development of a HCLPF for equipment qualified by testing that have some effect on the conclusions of the Trial Plant Review.
In the Trial Plant Review, the scale factor for determining a HCLPF was calculated as:

$$SF = TRS/1.3(RRS)$$

Where, TRS is the test response spectrum for the equipment, RRS is the required response spectrum at the base of the equipment and SF is the scale factor to multiply times the earthquake level that defines the RRS for the seismic margin earthquake. If the RRS had a narrow banded peak, the 1.3 factor in the denominator could be reduced to unity if the bandwidth of the peak was less than a 20% frequency shift.

In Revision 1 to EPRI NP-6041, a more complex derivation of the HCLPF was included. For equipment qualified by testing the scale factor was calculated as:

$$SF = TRSc/RRSc$$

Where, in this case, TRSc is a clipped and factored TRS and RRSc is a clipped RRS. A detailed procedure for determining the clipping factors was introduced. For most cases of the Catawba equipment qualified by testing, the TRS was broad banded and the clipping factor would have been unity. The TRSc is defined in Revision 1 of EPRI-NP-6041 to be:

$$TRS_c = TRS\ (F_{ms})/F_k$$

Where F_{ms} is a broadband frequency factor and F_k is a knock down factor to provide a factor of safety between the test level and the HCLPF. F_{ms} is an effective increase factor on the TRS if it is broad banded multi axis input and the component of interest is primarily sensitive to a single axis narrow banded frequency. Since the applications at Catawba were primarily for cabinets that included numerous devices, the F_{ms} factor would be unity. F_k, for demonstrating function during the shaking, would be 1.2. Since many of the Catawba electrical and control circuits had a lock in design, function during the shaking was a requirement, thus $F_k = 1.2$. Overall then, the Trial Plant Review treatment of equipment qualified by testing was conservative by a factor of 1.3/1.2 = 1.08 relative to the requirements in Revision 1 to EPRI NP-6041. The only cases in the Catawba SMA where devices were assessed individually was in the main control boards. The in-structure response in the boards was calculated to determine the RRS for comparison to device TRS.

Another difference in the Revision 1 Vs original version of EPRI NP-6041 was the definition of the screening levels. In the 1988 version, screening tables were based on peak ground acceleration. The three screening levels were < 0.3g PGA, 0.3 to 0.5g PGA and >0.5g PGA. In the 1991 revision, the comparable screening tables defined the screening levels in terms of spectral acceleration (Sa). Spectral acceleration is a much better indicator of damage to structures and components that respond in the amplified acceleration range of the input response spectra.

The three levels of screening were < 0.8g Sa, 0.8g to 1.2g Sa and > 1.2g Sa defined at 5% damping. For standard spectral shapes, the two screening levels are comparable. These screening levels are to be compared to the RLE horizontal ground motion spectrum. The RLE selected for the Catawba trial Plant Review was a Sequoyah 84th percentile site-specific spectral shape anchored to 0.3g PGA. The RLE defined for Catawba for IPEEE in NUREG-1407 was a NUREG/CR-0098 median amplification spectral shape anchored to 0.3g PGA. The Catawba RLE spectrum contained more amplification than the NUREG/CR-0098 spectral shape. It was much closer to the SQUG bounding spectrum that has a 5% damped peak spectral acceleration of 0.8g and a PGA of 0.33g. Figure 3-1 compares the three spectra. It can be seen that the 10 Hz fundamental frequency of the Catawba auxiliary building, the RLE spectral acceleration is about 7% higher than the NUREG/CR-0098 spectrum specified for IPEEE.

New in-structure spectra were developed for the auxiliary building. The direct generation method was initially used. In some locations at high elevation, the demonstration of relay function during the RLE became difficult. Consequently, a new analysis using the time history method was conducted. The time history from the 1978 Tabas, Iran earthquake was used since the resulting response spectral shape was a close match to the Catawba RLE spectral shape. It was scaled to 0.3g PGA and modified to provide a vary close match to the RLE spectrum. The time history method produced about a 20% reduction in in-structure spectra in the critical locations of concern.

In the Catawba Trial Plant Review, almost all components met the 0.3g screening level. A few cabinets containing essential relays were demonstrated to have a HCLPF of 0.25g using the conservative RLE definition and the criteria for developing HCLPFs from test data in the 1988 original edition of EPRI, NP-6041. Relative to the 1991 Revision 1 to EPRI NP-6041 and the NUREG/CR-0098 spectral shape specified for IPEEE, the Catawba results were conservative by a factor of (1.08)(1.07) = 1.156, thus, using IPEEE criteria, the governing relays would have a HCLPF of 1.156(0.25g) = 0.29g. There is likely some additional conservatism that could be squeezed out of the overall process to demonstrate a plant level HCLPF of 0.3g.

In the Catawba IPEEE submittal, the SPRA did not include a relay evaluation since the plant was placed in the focused scope bin and only required a search for low ruggedness relays. Only one case was found where low ruggedness relays existed and they were used only in a maintenance and testing mode. They were isolated from the circuit when the diesel generators receive a signal for an emergency start, thus low ruggedness relays were not a concern.

The walkdowns and screening conducted for the Catawba SMA generally went at a slower pace than the typical IPEEE walkdown. The principal reason was that it was a trial Plant Review and very detailed examinations were conducted, especially in containment, to determine the feasibility of verifying the caveats on the walkdown sheets (later termed Seismic Evaluation Work Sheets, SEWS). Of particular interest was the feasibility of inspecting every possible source of SBLOCA. The initial walkdown of containment was before plant start up so it was free of contamination and pressure to minimize radiation exposure. This confirmed a previous conclusion that one of the shutdown paths had to include the possibility of a SBLOCA. The time and exposure that the walkdown team would be subjected to in assuring that a SBLOCA would not occur was not considered to be cost beneficial or to comply with ALARA guidelines. The safe shutdown paths selected for Catawba for the no LOCA case and including a SBLOCA are shown in Figures 3-2 and 3-3.

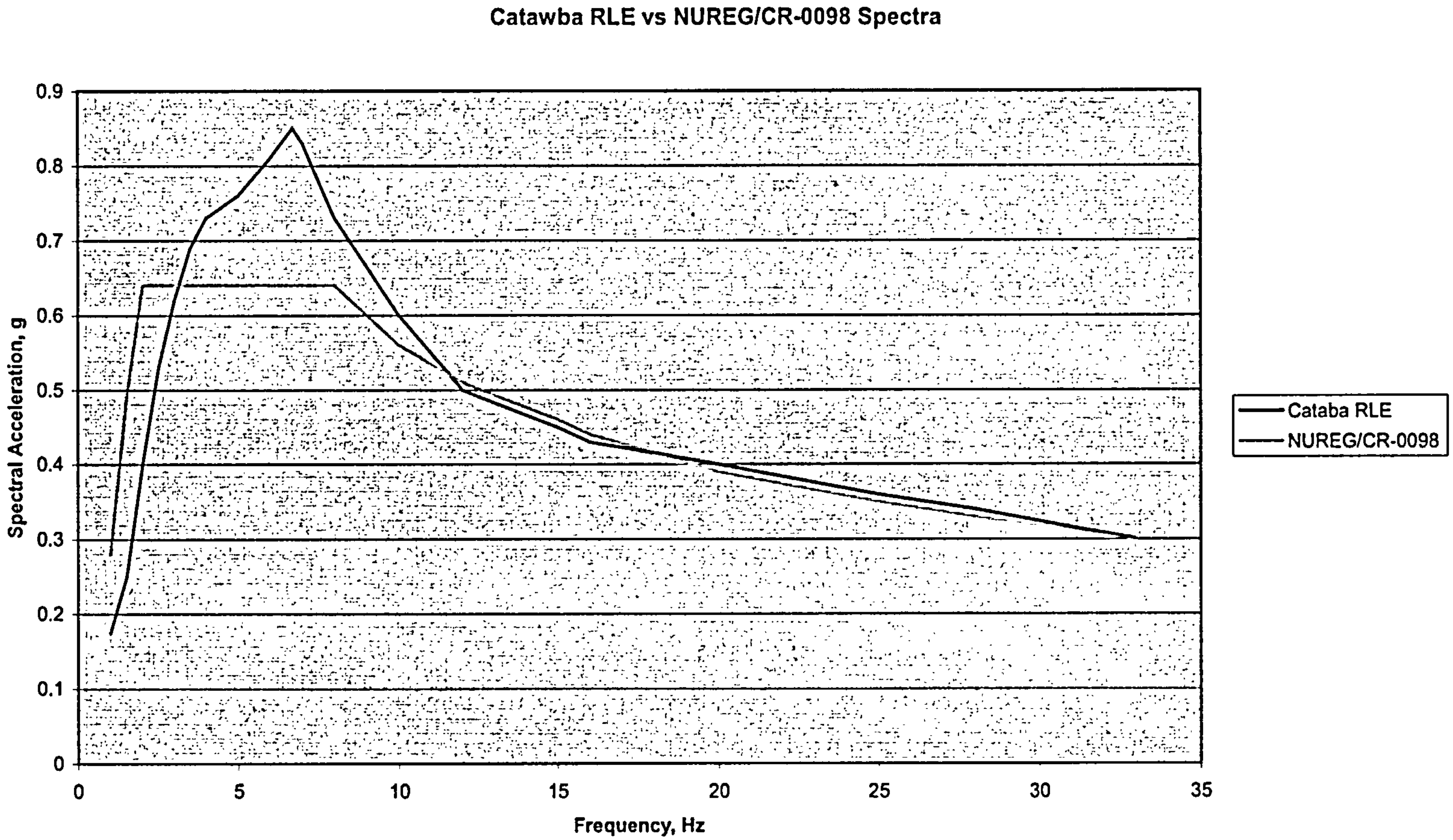


Figure 3-1
Catawba RLE Vs NUREG/CR-0098 Spectra

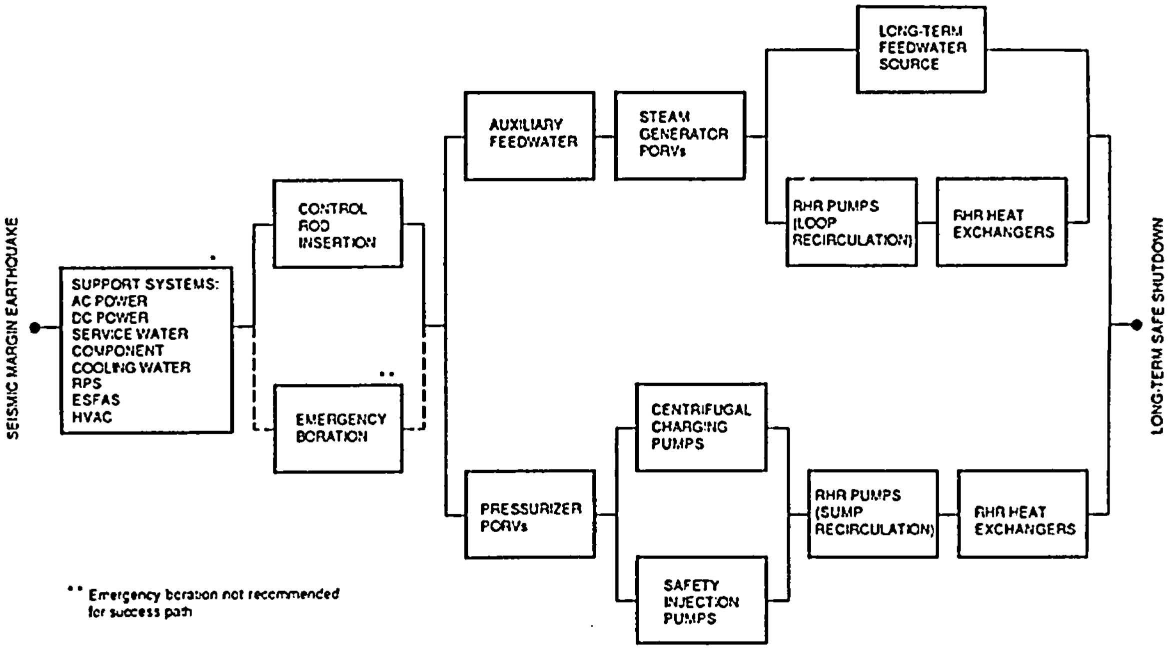


Figure 3-2
Catawba Success Path Logic Diagram – No Reactor Coolant System Leakage

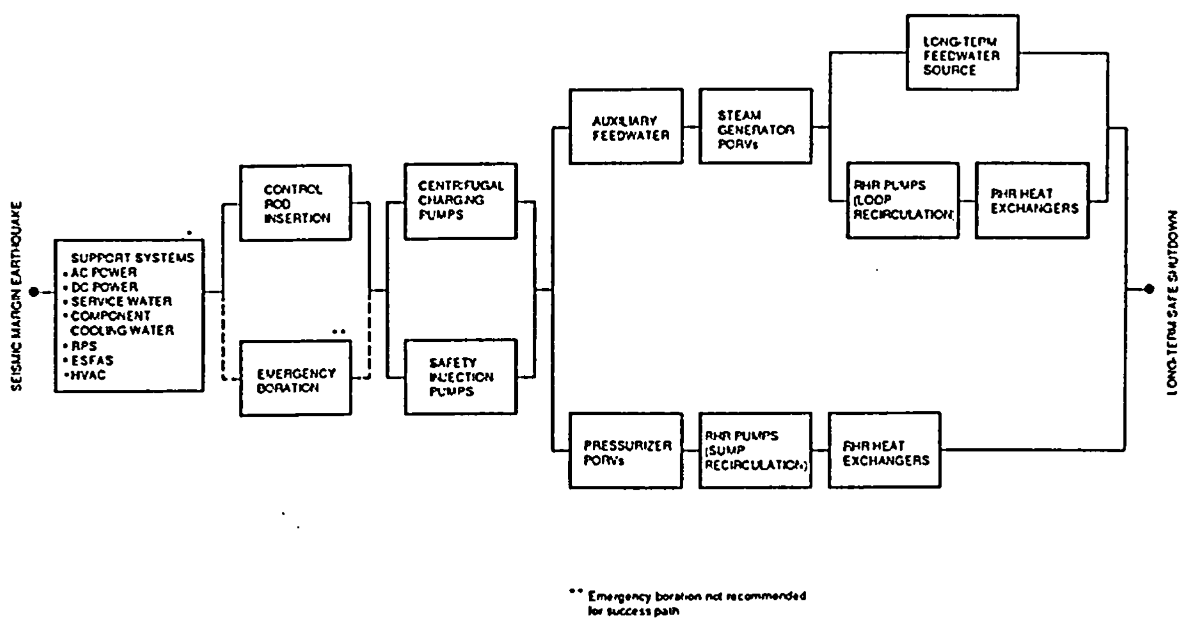


Figure 3-3
Catawba Success Path Logic Diagram – Small Break LOCA or Reactor Coolant Pump Seal Leakage

The documentation format and contents suggested in EPRI (1988) are different than that in NUREG-1407. The Trial Plant Review final report EPRI (1989b) contains generally more information and significantly more detail than required for an IPEEE Tier 1 report for IPEEE.

3.2 Comparison of the Catawba Trial Plant Review to the Requirements of the Standard

In Table 3-1, the Catawba Trial Plant SMA is compared to the requirements of the Standard on a line-by-line basis. The requirements of the Standard are reproduced and a description of the activity for Catawba is inserted. It is noted that for SMA, there are no capability categories as for the case of SPRA.

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA

Seismic Margin Assessment High Level Requirement A: Review Level Earthquake (HLR-SM-A): A review level earthquake characterized by a ground motion spectrum SHALL be selected to facilitate screening of structures, systems and components and performance of seismic margin calculations.	
Requirement	**Commentary**
(REQ. SM-A1) SELECT a Review Level Earthquake (RLE) as an earthquake larger than the Safe Shutdown Earthquake (SSE) for the plant.	**Note SM-A1:** The seismic margins methodology is designed to demonstrate sufficient margin over the SSE to ensure plant safety and to find any "weak links" that might limit the plant's capability to safely withstand a seismic event larger than the SSE. The review level earthquake is used to screen components based on generic seismic capacity. Screening is done in an SMA to optimize the resources needed and to focus attention on more critical and potentially seismically weak components. (EPRI, 1991) contains useful guidance on the selection of the RLE. The seismic margin method typically utilizes two review or screening levels geared to peak ground accelerations of 0.3g and 0.5g. Based on the guidance given in NUREG-1407 (NRC, 1991a), most plants in the Central and Eastern United States have selected 0.3g peak ground acceleration as the RLE for their SMAs. For some sites where the seismic hazard is judged to be low (i.e., less than 10^{-4} per year at SSE), a reduced-scope margin assessment relying mainly on a walkdown has been considered acceptable. NUREG-1407 further states that an RLE of 0.5g should be used for sites in the Western United States except for the California coastal sites, for which the seismic-margin methodology is not acceptable.
EPRI NP-6041 suggests that the RLE be defined at the 84th percentile level. The Catawba Trial Plant Review RLE was selected as a Sequoyah site-specific 84th percentile spectral shape anchored to 0.3g PGA. The 0.3g PGA is twice the Catawba SSE PGA. The amplification of the Sequoyah PGA is greater than for the Catawba SSE, thus the RLE demand is greater than twice the SSE demand and greater than the demand selected by NRC for IPEEE (see Figure 3-1). This requirement of the Standard is met.	
(REQ. SM-A2) CHARACTERIZE the Review Level Earthquake by a ground motion spectrum appropriate for the site conditions.	**Note SM-A2:** Based on the guidance in NUREG-1407 (NRC, 1991a), seismic margin assessments have been done using the 5% damped NUREG/CR-0098 (Newmark and Hall, 1978) median rock or soil spectrum anchored at 0.3g or 0.5g (depending on the RLE for the site). Alternative approaches for selecting the RLE spectrum are described in (EPRI, 1991). The shape of the RLE ground motion spectrum is needed to develop seismic responses of structures and equipment for the calculation of seismic margins.
The Sequoyah site-specific spectral shape was chosen as a representative ground motion spectral shape for site conditions similar to Catawba. It is very similar in shape to the SQUG bounding spectrum based on actual earthquake experience used for resolution of USI A-46 and similar to the NUREG/CR-0098 spectral shape specified by the USNRC in NUREG-1407 for IPEEE SMA. The Uniform hazard spectral shapes that result from EPRI and LLNL PSHA (EPRI, 1989a) and (LLNL, 1993) are quite different. They have much less energy in the lower frequency range, thus are less damaging. As shown in Figure 3-1, the Catawba RLE spectral amplification is greater than the NUREG/CR-0098 spectral shape selected by NRC for IPEEE, thus is more conservative.	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

Requirement	Commentary
Seismic Margin Assessment High Level Requirement B: Success Paths **(HLR-SM-B): A minimum of two diverse success paths SHALL be developed consisting of structures and equipment that can be used to bring the plant to a safe stable state and maintain this condition for at least 72 hours following an earthquake larger than the RLE.**	
(REQ. SM-B1) SELECT a primary success path and an alternative success path, one of which is capable of mitigating a small LOCA. In the success paths, INCLUDE systems whose function is to prevent severe core damage and their support systems.	**Note SM-B1:** A set of components that can be used to bring the plant to a stable hot or cold condition and maintain this condition for at least 72 hours is known as a "success path." Based on the selected success paths, a SSEL (Safe Shutdown Equipment List) is then developed for subsequent screening, walkdown, and margin evaluation. It is advisable to compare the SSEL for reasonableness with comparable SSEL lists compiled for seismic margin assessments at other similar nuclear power plants.
There were two main success paths selected with two branch paths for each that can lead to hot or cold shutdown and sustain the condition for up to 72 hours. One main path can mitigate a small LOCA. In the main small LOCA path, the loss of coolant is made up by the charging system and long term cooling is achieved by removing heat through secondary side cooling via the auxiliary feedwater system and ultimately by RHR closed loop recirculation or long term feedwater. In the other LOCA subpath, the primary system pressure is reduced via the pressurizer PORVs and makeup of coolant loss and core cooling is provided by safety injection and RHR sump recirculation. In the no LOCA main path, the preferred cooling scheme is by the auxiliary feedwater system and ultimately by either long term feedwater or RHR closed loop recirculation. The alternate branch to this, in the event of loss of auxiliary feedwater, is primary system depressurization via the pressurizer PORVs, coolant makeup and core cooling via charging or safety injection and long term RHR sump recirculation. Figures 3-2 and 3-3 show the Catawba success paths. These success path schemes satisfy the requirements of the Standard.	
(REQ. SM-B2) ENSURE that the success paths have the following properties: they are those for which there is a high likelihood of an adequate seismic margin; they are compatible with plant operating procedures; and they have acceptable operational reliability.	**Note SM-B2:** It is desirable that, to the maximum extent possible, the alternative path involves operational sequences, systems, distribution systems (i.e., piping, raceways, duct and tubing), and components different from those used in the primary path. (EPRI, 1991) contains useful guidance on the selection of success paths, on the use of Success Path Logic Diagrams in their selection, and on how "acceptable operational reliability" is defined for the SMA review. Generally, the approach is to choose one success path that can mitigate sequences that start with a loss of offsite power transient, and the other success path that can mitigate a small LOCA. Also, the SSCs are generally to be selected to enhance diversity, and to avoid those with low reliability. See NUREG-1407 (NRC, 1991b) for further guidance.
All of the procedures required for the alternate success paths are included in the operator procedures and incorporate reliable equipment that is maintained and tested to assure operation on demand. There are no unusual operator actions required. This requirement of the Standard was met.	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

<table>
<tr><th>Requirement</th><th>Commentary</th></tr>
<tr><td>(REQ. SM-B3) ASSUME that offsite power has failed and is not recoverable during the 72-hour period of interest following the RLE.</td><td>Note-SM-B3: Earthquake experience has shown that offsite power is almost always lost after any earthquake larger than the SSE. Because of the potential damage to the electric grid and the region surrounding the plant, it is judged that the offsite power may not be recovered for up to 72 hours. Therefore the selected success paths should be able to provide core cooling and decay heat removal for at least 72 hours following the earthquake, without recourse to offsite power. Although no credit for offsite power is taken in the SMA, one also must be aware of possible adverse effects if offsite power remains available or is restored. In the internal event PRA, the analyst assumes that there would be a successful scram given the loss of offsite power. The probability of mechanical binding of control rods is deemed low, hence there is no need to examine if the reactor protection system will function. However, in the case of SMA, the analyst should verify if the reactor protection system works and if the control rod could drop given the potential for seismic induced deformation of the reactor internals and failure of the control rod drive mechanism. Further, the power conversion system (e.g., the main condenser) SHOULD be assumed as not available for heat sink function and any equipment powered by non-vital AC is also considered unavailable.</td></tr>
<tr><td colspan="2">Offsite power is assumed to be lost and not recoverable during the safe shutdown scenarios. All safe shutdown paths rely on emergency power from the diesel generators for a period of 72 hours or more. The ability to achieve a successful reactor scram was verified by examining the structural integrity of the reactor internals and control rod drive system as well as the solid-state protection system (SSPS) and the Emergency Safety Features Actuation System (EFSAS). This requirement of the Standard is met.</td></tr>
<tr><td>(REQ. SM-B4) In the SMA, ANALYZE at least seismically initiated transient events and small seismically induced primary coolant leakage events (referred to as "small LOCA").</td><td>Note SM-B4: A detailed walkdown within the containment, to verify that all small instrumentation or impulse lines can withstand the RLE and that there are no potential spatial interactions resulting in their failure to add up to an area of 25 mm diameter, would lead to excessive radiation exposure of the walkdown team. Therefore, it is considered prudent and expedient to concede that a small LOCA will occur after an RLE, and to include the required mitigation systems in the success path (see REQ. SA-B9).</td></tr>
<tr><td colspan="2">The standard assumptions of loss of off-site power, turbine trip and reactor scram are assumed in the safe shutdown scenarios. One of the main shutdown paths includes a small LOCA from breakage of a small pipe or instrument line or from primary pump seal leakage. This requirement of the Standard is met.</td></tr>
</table>

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

<table>
<tr><th>Requirement</th><th>Commentary</th></tr>
<tr><td>(REQ. SM-B5) If one element in the Success Path Logic Diagram (SPLD) represents a multi-train system, MEASURE safety function success at the system level, not at the train level.</td><td>Note SM-B5: If one train of a system is judged to be seismically rugged (exclusive of a train-specific spatial interaction failure), then all trains of that system are considered rugged if the equipment items are identical. (EPRI, 1991) states further that this assumption is valid if the train-wise layout is similar, although train-specific systems interaction problems may invalidate this assumption.</td></tr>
<tr><td colspan="2">Catawba has two train safety systems. Each safe shutdown path has two trains in the front line systems that define the safe shutdown paths. One of the trains is capable of performing the safe shutdown function and the same train must be functional throughout the shutdown scheme. One of the two train support systems are also required for all safe shutdown paths. Thus, both trains of every front line system and support system that appear in the safe shutdown paths are evaluated. No specific assignment of Train A support systems was made to Train A front line systems. This is implied and if a train specific interaction were noted, it would have to be fixed to maintain two separate shutdown paths. Note that Catawba has a separate safe shutdown facility but no credit was taken for redundancy afforded by that facility due to the fact that it is not seismically qualified. The procedures and logic employed in the selection of safe shutdown paths for the Catawba SMA meet this requirement of the Standard.</td></tr>
<tr><td>(REQ. SM-B6) ENSURE that non-seismic failure modes and human actions identified on the success paths have low enough probabilities so as not to affect the seismic margin evaluation. USE a documented method for assuring this.</td><td>Note SM-B6: Non-seismic-caused component system unavailabilities are not explicitly addressed in a SMA by quantifying them, but they are identified and avoided on the success paths where necessary. This issue is covered implicitly in the EPRI SMA guidance (EPRI, 1991) by the requirement therein to avoid unreliable equipment. This should be reasonable for systems that have multiple and redundant trains but should be treated with caution for a single-train with recognized high unavailability. The screening criteria cited in the NRC's IPEEE guidance, NUREG/CR-5679 (Budnitz, Moore, and Julius, 1992), addressing both single-train and multi-train systems, MAY be used as guidance.</td></tr>
<tr><td colspan="2">The instrumentation available to the operators in the control room and the procedures they had been trained in were verified by review of the plant design documents and interviews with operations personnel. The most common non-seismic failure mode that leads to a contribution to core damage is the random failure of the emergency diesel generators either to start on demand or continue to run. Almost all SMAs must rely on operation of the diesel generators, which have reasonably good reliability. Other components in the success paths are highly reliable. There were no human actions required outside of the control room or actions for which the operators were not trained in order to achieve the safe shutdown by the paths selected. This requirement is considered to have been met.</td></tr>
</table>

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

<table>
<tr><th>Requirement</th><th>Commentary</th></tr>
<tr><td>(REQ. SM-B7) EVALUATE the potential effects of seismically induced relay and contactor chatter as well as the operator actions that may be required to recover from any such effects.</td><td>Note SM-B7: Guidance on evaluation of relay chatter effects is given in (EPRI, 1991b), NUREG-1407 (USNRC, 1991b) and (Hardy and Ravindra, 1990).</td></tr>
<tr><td colspan="2">Relay and contactor chatter was evaluated as a two-step process. Complete seismic qualification documentation was available and was used to develop HCLPFs for function of devices in cabinets. This was done at the cabinet level which was the basis of qualification. An exception to this was for the devices in the main control boards. There, the device test level was compared to the calculated demand in the control boards. In cases, where the HCLPF was not shown to be at least 0.3g PGA, the circuits were evaluated and many relays were screened out on the basis that there was no consequence of relay chatter. A few cabinets containing relays were found to have a HCLPF less than 0.3g but at least 0.25g. No further evaluation was carried out. GERS were in a state of development at the time of the study and were not of use. The relay study is considered to have complied with the requirements of NUREG-1407 for a full scope SMA and meets the requirements of the Standard.</td></tr>
<tr><td>(REQ. SM-B8) As part of the SMA, EXAMINE systems, structures and components needed to prevent early containment failure following core damage.</td><td>Note SM-B8: NUREG-1407 (USNRC, 1991b) identifies these functions. These functions are containment integrity, containment isolation, prevention of bypass, and some specific systems depending on the containment design (for example, igniters or ice baskets). The purpose of this examination is to evaluate whether these SSCs have enough seismic margin to function at earthquake levels above the design basis.</td></tr>
<tr><td colspan="2">The SMA did not address containment performance. The containment structural integrity, including the ice condensers and major primary system components, were examined and found to exceed the RLE. This also ruled out containment bypass due to steam generator tube rupture. Early failures from interfacing systems LOCA or failure of containment isolation were not addressed. The containment performance requirement of IPEEE in NUREG-1407 was in addition to the requirements of EPRI NP-6041 and was incorporated into the Standard. In this respect the Catawba SMA did not completely address this technical requirement.</td></tr>
</table>

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

Seismic Margin Assessment High Level Requirement C: Responses	
(HLR-SM-C): Seismic responses calculated for the Review Level Earthquake SHALL be median centered, SHALL be based on current state-of-the-art methods of structural modeling and SHALL include the effects of soil-structure-interaction where applicable.	
Requirement	**Commentary**
(REQ. SM-C1) ENSURE that seismic responses calculated for the Review Level Earthquake are median centered, are based on current state-of-the-art methods of structural modeling, and include the effects of soil-structure-interactions where applicable.	**Note SM-C1:** The median centered responses are calculated using EPRI-NP-6041 (EPRI, 1991). Here, "median centered" means that medians are being used to establish distributions, and not that medians represent best estimates for single value calculations.
Catawba is a rock site and structures are founded on rock or concrete fill extending to rock. New in-structure spectra for the RLE were developed for the auxiliary building that housed almost all of the safe shutdown equipment. The stress level in the auxiliary building was low so appropriate lower damping values were used in the response analysis. The original design basis model was used. This was a lumped mass stick model that appropriately modeled the eccentricities of the structure. The initial analysis was by direct generation. There was some conservatism in this analysis and for a few critical areas where essential electrical and control equipment were located, new spectra were developed using the time history method. The time history analysis is considered to be median centered. For other structures, scaling was conducted by comparing the RLE to the SSE spectrum at the fundamental frequency of the structure. Scaling was reasonable since the structures were founded on rock and the RLE and SSE spectral shapes were similar. The development of structural response is considered to meet the requirements of the standard.	
(REQ. SM-C2) Depending on the site conditions and response analysis methods used in the plant design, realistic seismic responses MAY be obtained by a judicious combination of scaling, new analysis and new structural models.	
New analysis and scaling was conducted as described under REQ.SM-C1 above. The analysis and scaling is considered to meet this requirement of the Standard.	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

Requirement	Commentary
(REQ. SM-C3) For soil sites or when the design response analysis models are judged not to be realistic and state-of-the-art, or when the design input ground motion is significantly different from the site-specific input motion, PERFORM new analysis to obtain realistic structural loads and floor response spectra.	**Note SM-C3:** Further details about the basis for this requirement can be found in (ASCE, 1998).
New analysis was conducted for the auxiliary building. Spectra were scaled for other buildings. The auxiliary building model was considered to be realistic and accounted for eccentricities. The site is a rock site and the RLE and SSE spectra were similar in shape thus scaling is justified. This requirement of the Standard is considered to have been met.	
(REQ. SM-C4) ENSURE that soil structure interaction analysis is median centered using median properties at soil strain levels corresponding to the RLE input ground motion. CONDUCT at least three SSI analyses to investigate the effects on response due to uncertainty in soil properties. ENSURE that one analysis is at the median low strain soil shear modulus and additional analyses at the median value times $(1+C_v)$ and the median value divided by $(1+C_v)$, where C_v is a factor that accounts for uncertainties in the SSI analysis and soil properties. If adequate soil investigation data are available, ESTABLISH the mean and standard deviation of the low strain shear modulus for every soil layer. ESTABLISH the value of C_v so that it will cover the mean plus or minus one standard deviation for every layer. For the minimum value of C_v USE 0.5. When insufficient data are available to address uncertainty in soil properties, USE C_v at a value not less than 1.0.	
Catawba structures are founded on rock, thus this requirement is not applicable.	
Note SM-C4: Further details about the basis for this requirement can be found in (ASCE, 1998).	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

<table>
<tr><td colspan="2">Seismic Margin Assessment High Level Requirement D: Screening

(HLR-SM-D): The screening of components and subsequent seismic margin calculations SHALL incorporate the findings of a detailed walkdown of the plant focusing on the anchorage, lateral seismic support and potential spatial interactions.</td></tr>
<tr><td>Requirement</td><td>Commentary</td></tr>
<tr><td colspan="2">(REQ. SM-D1) If SSCs on the SSEL are screened out on the basis of their generic high seismic capacity exceeding the RLE, CONFIRM the basis for such screening through a walkdown. (See REQ. SM-H4.)</td></tr>
<tr><td colspan="2">Many components were prescreened on the basis of the conservative seismic qualification. They were subsequently walked down and compared to the screening criteria of EPRI NP-6041to confirm the prescreening. This requirement of the Standard is considered to have been met.</td></tr>
<tr><td colspan="2">(REQ. SM-D2) CONDUCT a detailed walkdown of the plant, focusing on equipment anchorage, lateral seismic support and potential systems spatial interactions. The purposes of such a walkdown are to find as-designed, as-built, and as-operated seismic weaknesses in the plant and to ensure that the seismic margins are realistic and plant-specific.</td></tr>
<tr><td colspan="2">Three detailed walkdowns were performed. The effort totaled about 73 man-days including plant systems engineering support and was considered to be a thorough walkdown evaluation in accordance with EPRI NP-6041 referenced in the Standard and in NUREG-1407. The walkdown is documented in EPRI (1989b). The requirements of the Standard were met.</td></tr>
<tr><td colspan="2">(REQ. SM-D3) CONDUCT the walkdown consistent with the guidance given in (EPRI, 1991a).</td></tr>
<tr><td colspan="2">The walkdown guidance of EPRI (1988) was followed. There is virtually no difference except for the definition of screening level. EPRI (1988) screening was on the basis of PGA and EPRI (1991a) screening is on the basis of spectral acceleration. For standard spectral shapes such as NUREG/CR-0098, the SQUG GIP Reference Spectrum or the similar Catawba RLE, the screening levels are approximately equivalent. This requirement of the Standard is considered to have been met.</td></tr>
<tr><td>(REQ. SM-D4) If components are screened out during or following the walkdown, PROVIDE an anchorage evaluation justifying such a screening.</td><td>Note SM-D4: Normally an anchorage calculation is required to support the screening. In some cases, the analyst MAY use judgment in deciding the adequacy of anchorage. Such judgments SHOULD be documented. For details and scope of anchorage evaluation, the reader is referred to (EPRI, 1991) and (Czarnecki, 1987).</td></tr>
<tr><td colspan="2">For components selected for further evaluation, which included several cases of concern regarding anchorage, the anchorage was evaluated. In most cases, the components, including their anchorage were screened based on walkdown observations and judgment and reviews of seismic qualification reports. Since the plant was new and seismic qualification documentation was readily available, anchorage screening was easily accomplished in most cases without doing new calculations. The procedure used to screen components, including their anchorage, is considered to have met this requirement of the Standard.</td></tr>
</table>

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

<table>
<tr><th>Requirement</th><th>Commentary</th></tr>
<tr><td>(REQ. SM-D5) FOCUS the walkdown on the potential for seismic induced fire and flooding following the guidance given in NUREG-1407 (NRC, 1991b).</td><td>Note SM-D5: Normally, if the walkdown team identifies a potential seismic-induced fire issue or a seismic-induced-flooding issue, it should be reviewed by the plant personnel, and is either dismissed on a defined basis or remedied if necessary. Only rarely is the SMA analysis team faced with the task of quantifying a seismic margin for seismic induced fire and/or flooding issues. However, if this is needed, the assessment must quantify the relevant HCLPF capacities and integrate these with the systems-analysis aspect as in any other aspect of SMA.</td></tr>
<tr><td colspan="2">The potential for seismic induced flooding was assessed during the walkdowns. Seismic /fire interaction was not addressed in the Catawba Trial Plant Review. This is a requirement added by NRC for IPEEE. This requirement was not completely met in the Catawba SMA.</td></tr>
<tr><td>(REQ. SM-D6) In the walkdown, EXAMINE potential sources of spatial interaction (e.g., II/I issues, impact between cabinets, flooding and spray) and consequences of such interactions on SSCs contained in the SSEL, and INCORPORATE them into the analysis as appropriate.</td><td>Note SM-D6: A "II/I issue" refers to the condition wherein a non-seismically qualified object could fall on and damage a seismically qualified item of safety equipment.</td></tr>
<tr><td colspan="2">Seismic spatial interactions including flooding and spray and cabinet impact were addressed during the walkdown and in subsequent calculations for outliers identified during the walkdown. A few upgrades were made by the plant before startup as a result of identifying potential spatial interactions. This requirement of the Standard was met.</td></tr>
</table>

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

Seismic Margin Assessment High Level Requirement E: Failure Modes	
(HLR-SM-E): Seismic margin calculations SHALL be performed for critical failure modes of structures, systems and components such as structural failure modes and functional failure modes identified through the review of plant design documents including analysis and test reports supplemented by earthquake experience data, fragility test data, generic qualification test data, and by a walkdown.	
Requirement	**Commentary**
(REQ. SM-E1) IDENTIFY realistic failure modes of screened-in structures, distribution systems and components that interfere with the operability of equipment during or after the earthquake through review of plant design documents and the walkdown.	
In addition to a few issues identified that required maintenance or minor upgrades, there were 36 structures/components identified during the walkdowns and design document reviews that required a strength evaluation, a functional evaluation or both. In addition, there were systems interactions and flexibility issues identified during the walkdowns that required additional evaluation. In most cases, existing plant design documentation was used to focus on the governing failure modes. In the case of functionality, most resolution of functionality was based on achieved test levels. In these cases, no specific failure mode is identified, the goal is to demonstrate no failure by virtue of testing. This requirement of the Standard is considered to have been met.	
(REQ. SM-E2) CONSIDER all relevant failure modes of structures (e.g., sliding, overturning, yielding, and excessive drift), equipment (e.g., anchorage failure, impact with adjacent equipment or structures, bracing failure, and functional failure) and soil (i.e., liquefaction, slope instability, excessive differential settlement), and EVALUATE the HCLPF capacities for the critical failure modes.	**Note SM-E2:** The concept of HCLPF capacity as an indicator of seismic margin was introduced in (Budnitz et al., 1985). Examples of calculations of HCLPF capacities for a selected set of SSCs can be found in (Kennedy et al., 1989). Detailed and more prescriptive guidance on methods for calculating HCLPF capacities of SSCs under different critical failure modes can be found in (EPRI,1991) and (EPRI, 1994). Past seismic SMA reviews and seismic PRAs MAY also be used as guidance.
Structures other than the Nuclear Service Water Pond dam, were screened out. EPRI NP-6041 allows the screening out of major structures if the design meets certain conditions. The steel containment must be keyed to the foundation to prevent rocking or sliding. Screening of other structures requires that they meet ductile detailing requirements of ACI 318-71 or later and that they are designed for at least 0.1g PGA by dynamic analysis. Duke Energy, was the designer/constructor of the major structures and performed reviews of drawings and design criteria to demonstrate compliance with EPRI NP-6041 screening criteria. The structures met the screening guidelines for 0.5g PGA. The structures are founded on rock, thus are not susceptible to sliding at the screening level or to soil type failures. The control room ceiling was found to be secured by safety wires that prevented falling and large lateral motion, thus met the screening criteria of EPRI NP-6041 for up to 0.5g PGA. The Nuclear Service Water Pond Dam required a plant specific dynamic analysis to verify its stability during a RLE. Existing calculations were reviewed or new calculations were performed for equipment and spatial interactions identified for further evaluation. The requirements of the Standard were met by the reviews of design documents and drawings and by performing supplemental calculations to verify that the screening criteria referenced by the Standard were met and that the governing failure modes were addressed.	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

Seismic Margin Assessment High Level Requirement F: Calculations **(HLR-SM-F): The calculation of seismic margins (or so-called HCLPF capacities) SHALL be based on plant-specific data supplemented by earthquake experience data, fragility test data and generic qualification test data. Use of such generic data SHALL be justified.**	
Requirement	**Commentary**
(REQ SM-F1) BASE the component seismic HCLPF capacities on plant specific data supplemented as needed by earthquake experience data, fragility test data and generic qualification test data.	
The component HCLPF capacity was determined to exceed 0.3g PGA in almost all cases by scaling from the original seismic qualification documentation, supplemented by specific calculations or by comparing the RLE demand to the achieved test level. Earthquake experience data or generic test data such as GERS were not used nor were they necessary. These requirements of the Standard were met by the plant specific assessments conduced.	
(REQ. SM-F2) DERIVE the HCLPF capacities for all components and structures that are screened in based on plant-specific information, such as site-specific seismic input, anchoring and installation of the component or structure, spatial interaction and plant-specific material test data.	**Note SM-F2:** The component HCLPF capacities can be calculated using the Conservative Deterministic Failure Margin (CDFM) method proposed by Kennedy (EPRI, 1991). Note that the HCLPF capacity is calculated assuming that only normal operating loads are present at the time of the seismic margin earthquake. In the case of BWRs, the SRV response is combined with the seismic response.
Plant specific seismic input was defined by new in-structure spectra developed for the RLE. The evaluations were based on plant specific design reports and as built conditions. Functionality was generally demonstrated by comparison of the new RLE demand to the achieved test levels. HCLPF capacities were not necessarily determined if it was demonstrated that the HCLPF exceeded 0.3g. These requirements of the Standard are considered to have been met.	
(REQ. SM-F3) DEVELOP seismic HCLPF capacities for SSCs that are identified in the internal-events-PRA systems model as playing a role in the LERF part of the PRA analysis (see REQ. SA-A1).	**NOTE SM-F3:** Generally the concern is the seismically induced early failure of containment functions. NUREG-1407 (NRC, 1991a) describes these functions as containment integrity, containment isolation, prevention of bypass functions, and some specific systems depending on the containment design (e.g., igniters, suppression pools, or ice baskets).
The Catawba trial plant review did not include a specific evaluation of containment performance as required in IPEEE. Most of the large early release sources of failure, such as failure of the containment and failure of major NSSS equipment, were, however, included in the SMA evaluation. LERF was implicitly included, although this specific requirement of the Standard was not met.	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

Seismic Margin Assessment High Level Requirement G: Success Path Margins	
(HLR-SM-G): The plant seismic margin SHALL be reported based on the margins calculated for the success paths.	
Requirement	**Commentary**
(REQ. SM-G1) REPORT plant seismic margin based on the margins calculated for the SSCs on the success paths.	
The minimum HCLPF of SSCs on the SSEL was for relays in some of the SSPS and area termination cabinets in the auxiliary building at elevation 577 feet and above. The minimum HCLPF was 0.25g and was based on a comparison of the RRS to the TRS at the base of the cabinets. No attempt was made to develop transmissibility of the cabinets to the individual relay locations in the area termination cabinets. There were 15 total relays in 9 circuits, with HCLPF less than 0.3g, where chatter could be detrimental. Since the purpose of the study was a trial plant review, no further effort was expended to determine the capacities of the individual relays. In one case, the HCLPF of batteries in the diesel generator building would have been lower than the 0.25g derived for a few controlling relays. The batteries in their racks did not have spacers between the batteries nor between the batteries and the end rails. They had actually been tested in this configuration but, since the configuration was an outlier, it could not be determined that any capacity beyond the SSE was present. This condition was scheduled for upgrading and a HCLPF was not determined. The minimum HCLPF, thus the plant level HCLPF, was reported as 0.25g based on a few relays and contingent on the diesel generator batteries being upgraded. Note that in Section 3.1, it is shown that using the requirements in Revision 1 to EPRI NP-6041 and using the ground motion spectrum specified for the IPEEE RLE in NUREG-1407, that the HCLPF would have been about 0.29g. This requirement of the Standard has been met.	
Note SM-G1: The various individual HCLPF capacities are combined by using the so-called "min-max" method, described in (Prassinos et al., 1986).	
(REQ. SM-G2) REPORT the seismic margin for the plant after all SMA-related seismic upgrades have been done.	
The plant level HCLPF was based on a few relays with a HCLPF of 0.25g, contingent on some upgrading of diesel generator battery racks and fixing a few minor interaction, construction and maintenance issues. No attempt was made to determine the HCLPFs of the items slated for upgrade. This requirement of the Standard is considered to have been met.	
Note SM-G2: If the plant seismic margin is not judged high enough, the EPRI guidance (EPRI, 1991) recommends performing a limited-scope seismic PRA, which would focus on the particular function that is questionable, to try to demonstrate an acceptable risk. This approach would have merit if the limiting SSC were in an alternate parallel path, but would have limited benefit if it were required to support all success paths. If this approach were taken, most of the systems work done during the SMA would be directly applicable. Seismic hazard curves and equipment fragilities would need to be developed, but much of the plant modeling work would have been done.	

Table 3-1
Comparison of SMA Requirements in the Standard to the Catawba Trial Plant SMA (Continued)

<table>
<tr><th colspan="2">Seismic Margin Assessment High Level Requirement H: Documentation
(HLR-SM-H): The Seismic Margin Assessment SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.</th></tr>
<tr><th>Requirement</th><th>Commentary</th></tr>
<tr><td colspan="2">(REQ. SM-H1) MEET the general documentation requirements in Section 7.</td></tr>
<tr><td colspan="2">The documentation was done in accordance with the requirements of EPRI NP-6041(EPRI, 1988). EPRI (1991a) and NUREG-1407 (USNRC, 1991b) are cited in the Standard as examples for guidance. There is no difference between the EPRI (1988) and EPRI (1991a) documentation requirements so in this respect, the general requirements of the Standard are met. General requirement (REQ.DOC-6) of the Standard requires that the peer review and disposition of the peer review comments be included in the documentation. EPRI NP-6041 does not require a peer review, thus there is no documentation of this. The Catawba Trial Plant Review did have a review of walkdown findings performed by an independent expert. This independent review is included in the documentation, thus the requirement is partially fulfilled. In general, the documentation of the Catawba Trial Plant Review (EPRI, 1989b) was much more comprehensive than the Tier 1 reports submitted for IPEEE. The intent of this requirement of the Standard has been met by reporting the work that was conducted.</td></tr>
<tr><td colspan="2">(REQ. SM-H2) DESCRIBE the methodologies used to quantify the seismic margins or HCLPF capacities of SSCs, together with key assumptions.</td></tr>
<tr><td colspan="2">The documentation describes the evaluation of all SSCs that were not screened out. The evaluation of systems interaction issues and flexibility issues identified by walkdown and screened in SSCs is discussed in detail in the report (EPRI, 1989b). This requirement of the Standard is met.</td></tr>
<tr><td colspan="2">(REQ. SM-H3) PROVIDE a detailed list of SSC margin values that includes the method of seismic qualification, the dominant failure modes(s), the source of information, and the location of each SSC. For each analyzed SSC, PROVIDE the parameter values defining the seismic margin (i.e., the HCLPF capacity and any other parameter values such as the median acceleration capacity and the beta values), and the technical bases for them.</td></tr>
<tr><td colspan="2">The margin values (HCLPF values) are not specifically tabulated. For each SSC that was not screened out, a detailed description of the process used to assure that the HCLPF was above 0.3g PGA is provided. In most cases, one could derive HCLPFs from the information presented but this was not done. This was similar to many of the IPEEE submittals. The goal was to demonstrate that the SSC had a HCLPF that exceeded the RLE, not to derive specific values. In this respect, the requirement of the standard is not completely met but the intent was met by providing a detailed description of the evaluation of all SSCs that were not screened out.</td></tr>
<tr><td colspan="2">(REQ. SM-H4) If SSCs on the SSEL are screened out on the basis of their generic high seismic capacity exceeding the RLE (see (REQ. SM-D1)), DOCUMENT the basis for such screening.</td></tr>
<tr><td colspan="2">The initial screening was conducted on the basis of a review of design documents and the walkdown observations and comparison to the requirements in EPRI NP-6041 for screening at 0.3g. The walkdown sheets (SEWS) are contained in the Appendices to the Trial Plant Review Report (EPRI, 1989b) and document the basis for screening. This requirement of the Standard was met.</td></tr>
<tr><td>(REQ. SM-H5) DOCUMENT different aspects of the SMA, such as the selection of the RLE, the development of success paths and SSEL, the seismic response analysis, the screening, the walkdown, the review of design documents, the identification of critical failure modes for each SSC, and the calculation of HCLPF capacities for each screened-in SSC.</td><td>Note SM-H5: The documentation requirements given in (NRC, 1991b) and (EPRI, 1991) MAY be used as guidance.</td></tr>
<tr><td colspan="2">The documentation is in accordance with EPRI, 1991 and contains the information requested in the Standard.</td></tr>
</table>

3.3 Summary of Catawba SMA Compliance with the Standard

3.3.1 Compliance with the Standard

The Catawba SMA was conducted in accordance with the methodology and criteria depicted in EPRI (1988). The revised EPRI methodology document (EPRI, 1991a) retains the same methodology but adds more detail. The Catawba SMA would generally comply with the revised EPRI methodology document. The Standard generally follows EPRI (1991a) but adds additional requirements imposed by NRC in NUREG-1407 for IPEEE that address containment performance, seismic/fire interaction and Peer Review that were not addressed in the Catawba SMA. It is noted that the Catawba IPEEE submittal was based on a SPRA, but much of the work conducted in the Trial Plant SMA was incorporated into the SPRA, principally the walkdown screening and findings and the results of calculations supporting the SMA. In the IPEEE submittal the containment performance, seismic/fire interaction and Peer Review requirements of NUREG-1407 were addressed.

The specific requirements of the standard that were not met by the Catawba SMA are:

1. **REQ.SM-B8** – As part of the SMA, EXAMINE systems, structures and components needed to prevent early containment failure following core damage.

   This requirement was not specifically addressed but much of the requirement was implicitly met by the fact that the containment, containment internal structure and primary system were shown to have a large capacity. However, no attempt was made to examine the containment isolation system.

2. **REQ.SM-D5** – FOCUS the walkdown on the potential for seismic induced fire and flooding following the guidance in NUREG-1407.

   The walkdown did focus on seismic induced flooding but did not attempt to address seismic induced fire.

3. **REQ.SM-F3** – DEVELOP seismic HCLPF capacities for SSCs that are identified in the internal-events-PRA systems model as playing a role in the LERF part of the PRA analysis (see REQ.SA-A1).

   No specific attempt was made to investigate large early release. The focus was per the EPRI methodology document (EPRI, 1988) to assess safe shutdown paths to assure that core damage would not occur as a result of a RLE occurring at the site.

4. **REQ.SM-H1** – MEET the general documentation requirements in Section 7.

   The documentation of the Catawba SMA in EPRI (1989b) met all of the general requirements in Section 7 of the Standard except **REQ.DOC-6** that requires that the Peer Review report be included in the documentation and the disposition of the Peer Review comments be documented. A formal Peer Review, as required in the Standard, was not conducted of the Catawba SMA, hence this requirement was not met.

5. **REQ.SM-H3** – PROVIDE a detailed list of SSC margin values that includes the method of seismic qualification, the dominant failure mode(s), the source of information, and the location of each SSC. For each analyzed SSC, PROVIDE the parameter values defining the seismic margin (i.e. the HCLPF capacity and any other parameter values such as the median acceleration capacity and the beta values) and the technical bases for them.

   This requirement is not completely met but the intent of the requirement is considered to have been met. There is not a list of calculated HCLPF values for the screened-in components in the SMA report. The demonstration that the capacity of each of the screened-in components is greater than the RLE and the evaluation of the potential systems interactions and flexibility issues identified for resolution is well documented, but for almost all of the cases, actual HCLPF values were not calculated. The most common solution was to compare the RLE demand with the design demand used by the equipment vendor and demonstrate that the RLE demand was less, thus the HCLPF was implied to be greater than 0.3g pa. In other cases, the documented resolution was to identify a combination of design margin and the ratio of RLE demand to design demand to demonstrate that the component would still retain a margin relative to the design limits if subjected to the RLE, thus the HCLPF would exceed 0.3g PGA. The only HCLPFs reported were for the controlling case of relays in a cabinet qualified by testing. That controlling HCLPF was 0.25g PGA.

6. **Peer-Review** – Section 5 of the Standard, summarized in Section 2.3 of this report, requires a comprehensive peer-review of SMAs. General peer-review requirements are contained in the ASME PRA Standard (ASME, 2002) and specific peer-review requirements for SMA are summarized in Table 2-2 of this report. The Catawba SMA was a trial plant review of the EPRI SMA methodology (EPRI, 1988) which does not require a peer review, hence the peer-review requirements of the Standard were not met.

3.3.2 Assessment of the Standard

In general, the Catawba Trial Plant Review easily meets the requirements of the Standard with the exception of the containment performance, seismic/fire interaction and Peer Review requirements stated above. There are no SMA requirements in the Standard that appear to be ambiguous or unreasonable. It is assumed in the Standard, though not required, that an internal event PRA is available to aid in developing the SSEL and identifying items that could lead to containment failure, particularly large early release. All operating U.S. NPPs have internal event PRAs so this assumption is reasonable. In fact, almost all NPPs outside of the U.S. that have conducted SMAs or are conducting SMAs, have or are preparing internal event PRAs. The requirements of the Standard could be met without having an internal event PRA. It would just take more effort to develop the SSEL and to identify and include those items important to containment integrity.

4
SAN ONOFRE NUCLEAR GENERATING STATION SPRA

4.1 Overview of SPRA

The San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 are 1070 and 1080 MWe Combustion Engineering PWRs. The units are located on the Pacific Coast in Southern California about half way between Los Angeles and San Diego. The plant is primarily owned and is operated by Southern California Edison Co. (SCE). Unit 1 at the site is no longer in service. Units 2 and 3 are essentially identical and have provisions for limited sharing of AC power systems and the cooling water intake structure. The plants also share a common control complex, radwaste facilities, instrument air/nitrogen and emergency heating, ventilation and air conditioning systems. Other than noted above, the two units operate as independent entities. The plants began operation in 1983 and 1984 respectively.

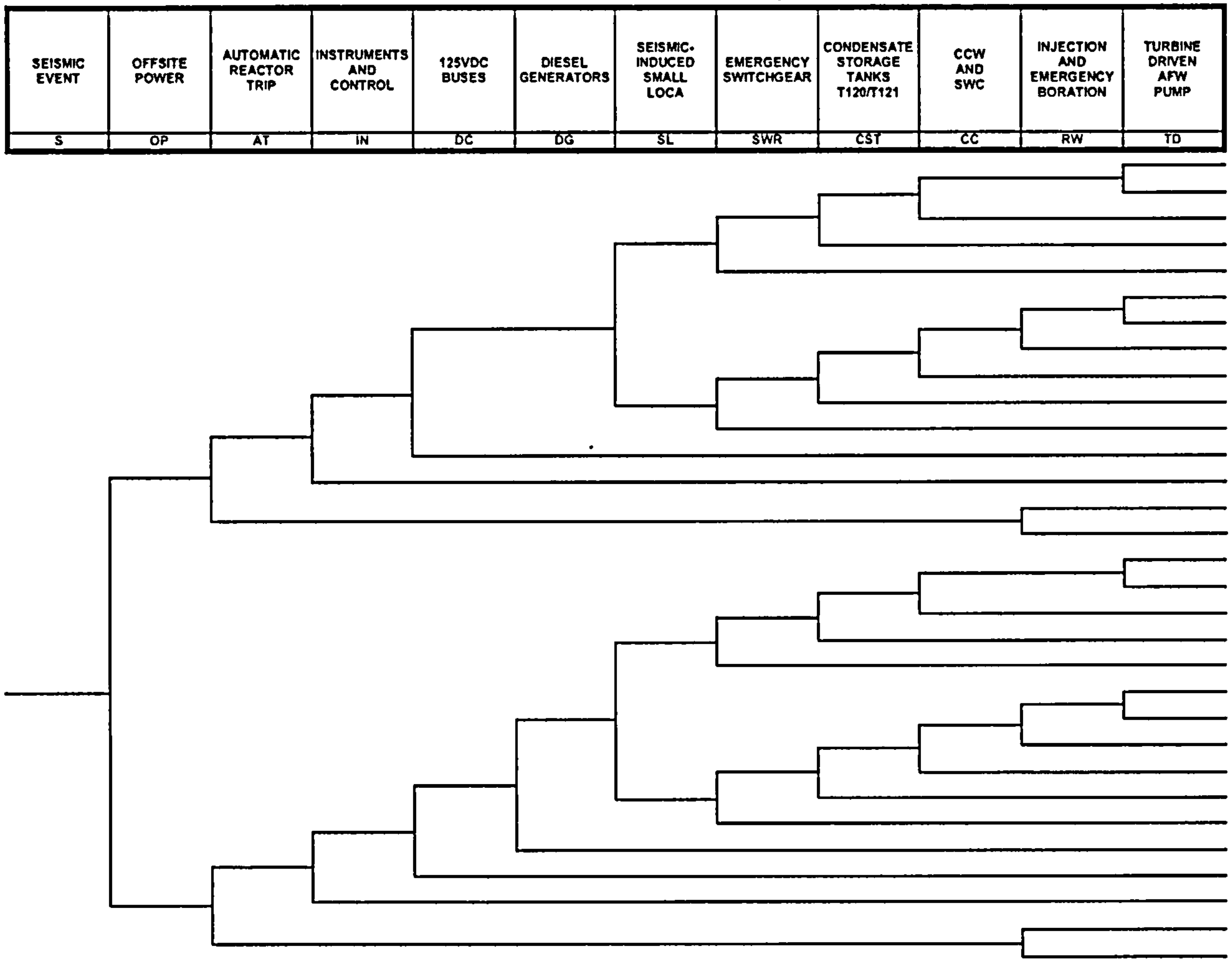
The two units were designed for a Design Basis Earthquake (DBE) of 0.67g peak ground acceleration. The ground motion spectral shape for the DBE was not a Regulatory Guide 1.60 spectral shape. It had a broad flat peak of 1.5g spectral acceleration from 1 Hz to 5 Hz. The two units are founded on deep soil deposits characterized as stiff well graded sands.

Because of the high seismicity at the site, NUREG 1407 required the plant to conduct a Seismic PRA for satisfaction of IPEEE. The SPRA (SCE, 1995) was completed in accordance with the methods described in NUREG/CR-2300 (USNRC, 1983). The EPRI and LLNL hazard studies (EPRI, 1989a) and (USNRC, 1994) did not include West Coast sites, thus SCE was required to perform a site specific seismic hazard assessment. This hazard study was conducted by a team of seismic hazard consultants and was reviewed by a panel of independent experts. The fragilities of structures and components, including relays that could not be screened out on the basis of seismic ruggedness or function, were developed by SCE in-house engineers and consultants.

The systems response to seismic events was modeled overall as a seismic event tree (SET) shown in Figure 4-1. The SET was used to determine accident sequences that either led directly to core damage or to degraded plant states. The degraded plant state sequences were then transferred to the IPE event trees to quantify the additional non seismic failures (random and human error) that would lead to core damage. The systems modeling and seismic risk computation was conducted by the SCE in-house PRA team. The total seismic induced core damage frequency (CDF) was calculated to be 1.7 E-5/reactor year. The CDF was dominated by seismic induced failure of offsite power followed by seismic induced failure of emergency switchgear and instrumentation/control systems. The two sequences that included these failures contributed 58% of the CDF. A significant contribution to CDF (about 22%) came from the next two accident sequences that included seismic induced loss of offsite power and random loss of Emergency Diesel Generators and random loss of Auxiliary Feedwater (AFW).

SONGS 2/3 SEISMIC EVENT TREE

SAN ONOFRE IPEEE – UNITS 2 & 3



NUMBER	SEQUENCE DESIGNATION		
1	S		
2	S-TD		
3	S-CC		
4	S-CST		
5	S-SWR		
6	S-SL		
7	S-SL-TD		
8	S-SL-RW		
9	S-SL-CC		
10	S-SL-CST		
11	S-SL-SWR		
12	S-DC		
13	S-IN		
14	S-AT		
15	S-AT-RW		
16	S-OP		
17	S-OP-TD		
18	S-OP-CC		
19	S-OP-CSI		
20	S-OP-SWR		
21	S-OP-SL		
22	S-OP-SL-TD		
23	S-OP-SL-RW		
24	S-OP-SL-CC		
25	S-OP-SL-CST		
26	S-OP-SL-SWR		
27	S-OP-DG		
28	S-OP-DC		
29	S-OP-IN		
30	S-OP-AT		
31	S-OP-AT-RW		
Total Frequency: 0 00E+00			

Figure 4-1
SONGS 2/3 Seismic Event Tree

Core damage scenarios greater than 1E-7/ry were evaluated in a Level 2 seismic PRA analysis for potential containment and containment system vulnerabilities. Based on a comparison with IPE results, there were no significant additional seismic induced large early release source terms and no seismic induced containment bypass sequences. There were also no additional seismic induced containment bypass, containment isolation or other containment failure modes. Late release was increased by the earthquake, primarily due to the low probability of long term recovery of support systems.

The overall approach utilized in developing the seismic hazard and seismic response of structures and equipment followed along the lines of the SPRA conducted for Diablo Canyon.

4.2 Seismic Hazard Evaluation

In probabilistic seismic hazard studies, the PGA and spectral acceleration (Sa) at several vibration frequencies are developed. The analysis consists of identifying seismic faults and area sources, determining the distribution of the magnitude of earthquakes that can occur at each source and using attenuation equations to propagate the earthquake effects to the site. Since there are several sources and several attenuation equations with uncertainty in all of the parameters, a logic tree approach is utilized to define the earthquake at the site in a probabilistic format. Typically the spectral accelerations at several periods (reciprocal of vibration frequency) and the PGA are calculated for the site as a function of frequency of occurrence. The spectral acceleration calculations are usually only carried out to the 1E-5 frequency of occurrence as was done in the LLNL and EPRI studies for the Central and Eastern U.S. The PGA is typically carried out to much lower frequencies such as 1E-8/year. Thus, a PRA analyst using the EPRI or Livermore hazard results, must base the computation of CDF on PGA frequency of occurrence in order to define the earthquake out to a high enough level of ground motion (low frequency of occurrence) that will cover the range of the fragility curves that are the most important contributors to risk.

The hazard at Diablo Canyon was developed with emphasis on spectral acceleration rather than peak ground acceleration. It is suggested in EPRI (1994) that specifying the hazard as a spectral acceleration vs. frequency of occurrence, as opposed to PGA vs. frequency of occurrence, is a much better measure of the ground motion input that is damaging to structures and equipment. This approach was also taken for the SONGS SPRA. Anchoring the fragilities to PGA introduces additional uncertainty due to the variability between PGA and spectral acceleration in a frequency range where structures respond, typically less than 5 Hz for soil sites and less than about 10 Hz for rock sites. If the hazard is defined as spectral acceleration in a frequency range where the major structures have their dominant vibration modes, this source of uncertainty between PGA and Sa can be significantly reduced. The Diablo Canyon Seismic PRA defined the seismic hazard as an average spectral acceleration over a frequency range where the major structure's dominant frequencies occurred. This same definition of the earthquake hazard was incorporated in the SONGS SPRA. For SONGS, the hazard was defined as the average spectral acceleration between 1Hz and 10Hz vs. frequency of occurrence.

4.3 Structural Response

In most SPRAs, the best estimate of response of structures is calculated in a deterministic manner. In some cases, scaling of design response is conducted if the structures are founded on hard rock and the ground motion response spectrum defined for the SPRA is similar in shape to the design ground motion response spectrum. For soil sites, it is recommended to conduct new analysis. Any factors of conservatism inherent in a deterministic analysis and the associated uncertainties in the deterministic analysis are applied to the major variables that contribute to the overall response to develop a so-called structural response factor and its variability. This structural response factor signifies the degree of conservatism in the calculated structural response relative to the input motion ground response spectrum. The major variables that affect response are spectral shape of the ground motion spectrum, soil shear modulus, damping of soil and structure, modeling (uncertainty in frequency and mode shape), combination of modal responses and combination of earthquake components. The standard suggests, but does not require, that probabilistic response be conducted for Capability Categories I and II. Capability Category III requires probabilistic response.

Probabilistic response analysis was conducted for the SONGS SPRA to develop probabilistic in-structure response spectra and probabilistic structural loads. Twenty-six simulations were conducted using a Latin Hypercube sampling technique. The probabilistic response utilized 26 different time histories that were scaled so that their average spectral acceleration from 1 to 10 Hz was equal to the average spectral acceleration of the site specific UHS defined at one times the SSE and at two times the SSE (two separate probabilistic response analyses were conducted). Other variables important to response were soil stiffness, soil damping, structural stiffness and structural damping. Values within the distribution on these variables were randomly combined with the time histories. Statistical analysis was then performed on the resulting structural response parameters and probabilistic spectra were defined at the 50th and 84th percentile levels. Corresponding probabilistic loads were developed for earthquake levels equal to the SSE and two times the SSE. This is a far more accurate method to determine the median response and the variability about it than a deterministic analysis with assumed variability about the median deterministic response.

4.4 Modeling of System Response and Quantification

The starting point in a SPRA is the internal events PRA model. SONGS had completed the IPE and the internal events PRA model for IPE was utilized. The IPE model was the basis for developing the seismic equipment list (SEL). About 600 components were placed on the SEL to be walked done and evaluated relative to a predetermined screening level. Many of the initiating events in the IPE model were excluded from the seismic model based on ruggedness screening by seismic walkdowns, review of seismic qualification calculations and specific fragility calculations. The initial effort was to construct a seismic event tree (SET) that would represent the initiating events and accident sequences that were not screened. Initiating events and individual components were screened from the PRA if their seismic induced failure rate was less than 1E-7/y. All front line systems and support systems that were not screened out were included in the SET. Containment bypass, interfacing systems LOCA and containment failures were also examined and modeled if they were deemed to be credible in the seismic failure scheme.

The SET was used to identify and quantify sequences where seismic events lead to either (1) direct core damage or (2) degraded plant states. The degraded plant state sequences were then transferred to IPE event trees to identify and quantify additional non-seismic failures (random failures and Human Reliability failures) that could lead to core damage.

In addition, relay performance was included in the analysis. The evaluation of relays followed the guidance in EPRI (1991b). The circuits for some 1300 relays were examined and the relays were categorized as chatter acceptable (CA), chatter unacceptable (CU) and operator action required (OA). Some 191 relays were categorized as CU and 27 as OA. Fragilities were developed for the CU relays. For relays that were categorized as OA, the Human Reliability Analysis in the IPE model was modified by applying Performance Shaping Functions (PSF). These PSFs were multipliers applied to the internal events operator action failure rates. The PSFs were selected considering whether the action was in the control room or out of the control room and considered the time available for the OA. They were not selected as a function of the earthquake level. The level was assumed to be high enough that maximum operator stress would result. The failure of operator actions was evaluated and included in the nodal equations going into the SET.

Boolean expression were developed for each node of the SET. The quantification of seismic induced failure frequencies for each seismic damage state (SDS) was conducted by a discrete probability distribution sampling process. The successes, failures and Boolean intersects were treated in the quantification.

4.5 Comparison of SPRA Requirements in the Standard to the SONGS IPEEE SPRA Submittal

4.5.1 Development of Seismic Hazard

Table 4-1 is a reproduction of the High Level and Supplemental Technical Requirements in the Standard for development of the seismic hazard. A brief description of the methodology utilized in the development of the seismic hazard for the SONGS SPRA is compared to each of the Supplemental Technical Requirements and a determination is made as to the Capability Category that was met.

4.5.2 Systems Analysis

Table 4-2 is a reproduction of the high level requirements and supplemental technical requirements in the Standard. The methodology used in the SONGS SPRA systems modeling and risk quantification is compared in Table 4-2 to the supplemental technical requirements. A determination is made of which capability category was met.

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard

<table>
<tr><td colspan="4">Seismic Hazard Analysis High-Level Requirement A: Scope

(HLR-HA-A): The frequency of earthquakes at the site SHALL be based on a site-specific probabilistic seismic hazard analysis (PSHA) (existing or new) that reflects the composite distribution of the informed technical community. The level of analysis SHALL be determined based on the intended application and on site-specific complexity.

Note: The need for determining the composite distribution is discussed in (Budnitz et al., 1997.) Existing LLNL (USNRC, 1993) and EPRI (EPRI, 1989a) hazard studies and many hazard studies conducted for plant-specific PRAs also meet this overall requirement, subject to updating as necessary. (See Requirement HLR-HA-H below.)</td></tr>
<tr><th>Index No. HA-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-A1</td><td>In performing the PSHA, BASE it on, and MAKE IT CONSIST of, the collection and evaluation of available information and data; consideration of the uncertainties in each element of the PSHA; and a defined process and documentation to make the PSHA traceable.</td><td colspan="2">In performing the PSHA, BASE it on, and MAKE IT CONSIST of, the collection and evaluation of available information and data; evaluation of the uncertainties in each element of the PSHA; and a defined process and documentation to make the PSHA traceable.</td></tr>
<tr><td colspan="3">Songs PSHA utilized three expert teams to derive the seismic sources, derive ground motion attenuation functions and to perform historical seismicity analysis. In addition a peer review team of three experts was involved throughout the project to critique the studies and results. This activity is considered to meet requirements of Capability Category III.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

<table>
<tr><th>Index No. HA-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-A2</td><td colspan="2">As the parameter to characterize both hazard and fragilities, USE the spectral accelerations, or the average spectral acceleration over a selected band of frequencies, or peak ground acceleration. In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are of interest and are dominant contributors to the PRA results and insights.</td><td>As the parameter to characterize both hazard and fragilities, USE the spectral accelerations, or the average spectral acceleration over a selected band of frequencies. In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are of interest and are dominant contributors to the PRA results and insights.</td></tr>
<tr><td colspan="3">The SONGS PSHA defined the seismic hazard at the site in terms of average spectral acceleration over the frequency range from 1 Hz to 10 Hz. The amplified horizontal response is generally in the range of 1 ½ to 8 Hz for the Diesel Generator Building foundation and from 1 ½ to 5 Hz for the Auxiliary Building. The amplified vertical response is in a range of 4 to 15 Hz. Fragilities, thus seismic risk quantification is anchored to horizontal ground motion and a range of about 1 ½ to 8 Hz would envelope all structures. Spectral accelerations were computed in the SPHA at 1, 2.5, 5, 10 and 25 Hz. The average of the range from 2.5 to 5 Hz would have been better for the auxiliary building alone whereas the range of 5 to 10 Hz would have been better for the diesel building alone. Taking the average over the range of 1 to 10 Hz enveloped the amplified horizontal response of all building of interest but in this case, by using the average spectral acceleration over a wide frequency range, it is not clear that there is any improvement over referencing the fragilities to PGA. Uniform hazard ground motion spectra were also defined for the horizontal and vertical directions corresponding to the frequency of the SSE and two times the SSE. This is considered to meet requirements of Capability Category II. For Capability Category III, it would seem that the hazard for each building and components within the building would need to be defined at the fundamental modal frequency of the building or as the average of a narrow frequency band about the fundamental mode of each building. This would then require a more complicated quantification of the risk than is normally done by referencing all fragilities to one hazard parameter.</td></tr>
<tr><td rowspan="2">HA-A3</td><td colspan="3">In developing the PSHA results, whether they are characterized by spectral accelerations, peak ground accelerations or both, EXTEND them to large enough values (consistent with the physical data and interpretations) so that the final numerical results, such as core damage frequency, reflect accurate estimates of risk, and the delineation and ranking of seismic-initiated sequences are not affected.</td></tr>
<tr><td colspan="3">The PSHA curves, averaged from 1 Hz to 10 Hz, were extended to 1E-8/y frequency of occurrence. The mean frequency of occurrence of the spectral acceleration averages that corresponded to the screening value of 8g Sa was 1E-8/y. 8g Sa was determined in sensitivity studies to be a threshold where the failure rate of components was less than 1E-7/y, thus, the hazard was extended to the point where components with median capacities above this value were not included in the model. This is considered to meet the requirements of all capability categories.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

<table>
<tr><th>Index No. HA-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>HA-A4</td><td colspan="3">SPECIFY a lower bound magnitude for use in the hazard analysis, such that earthquakes of magnitude less than this value are not expected to cause significant damage to the engineered structures or equipment.</td></tr>
<tr><td></td><td colspan="3">A minimum moment magnitude, m_o, of 5.0 was selected as a value frequently used in other SPHA studies as an energy level of earthquake that is not damaging to engineered structures. Since SONGS was designed for a high (0.67g) peak ground acceleration, it is believed that it is applicable to SONGS. This lower bound magnitude selection is considered to be is applicable to all Capability Categories.</td></tr>
<tr><td colspan="4">Seismic Hazard Analysis High-Level Requirement B: Data Collection
(HLR-HA-B): To provide inputs to the PSHA, a comprehensive up-to-date data base including geological, seismological, and geophysical data; local site topography; and surficial geologic and geotechnical site properties SHALL be compiled. A catalog of historical, instrumental, and paleoseismicity information SHALL also be compiled.</td></tr>
<tr><th>Index No. HA-B</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>HA-B1</td><td>In performing the PSHA, BASE it on available or developed geological, seismological, and geophysical data bases that reflect the current state-of-the-knowledge, and that are used by experts/analysts to develop interpretations and inputs to the PSHA.</td><td colspan="2">In performing the PSHA, BASE it on available and developed comprehensive geological, seismological, and geophysical data bases that reflect the current state-of-the-knowledge, and that are used by experts/analysts to develop interpretations and inputs to the PSHA.</td></tr>
<tr><td></td><td colspan="3">Songs PSHA utilized three expert teams to derive the seismic sources, derive ground motion attenuation functions and to perform historical seismicity analysis. In addition a peer review team of three experts was involved throughout the project to critique the studies and results. The data bases for California are one of the most comprehensive in the world. This activity is considered to meet requirements of Capability Category III.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

<table>
<tr><th>Index No. HA-B</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-B2</td><td>ENSURE that the data base and information used are adequate to characterize all credible seismic sources that may contribute to the frequency of occurrence of vibratory ground motion at the site, considering regional attenuation of ground motions and local site effects. If the existing PSHA studies are to be used in the SPRA, ENSURE that any new data or interpretations that could affect the PSHA are adequately incorporated in the existing data bases and analysis.</td><td colspan="2">ENSURE that the size of the region to be investigated and the scope of investigations is adequate to characterize all credible seismic sources that may contribute to the frequency of occurrence of vibratory ground motion at a site, considering regional attenuation of ground motions and local site effects. If the existing PSHA studies are to be used in the SPRA, ENSURE that the investigations are of sufficient scope to determine whether there are new data or interpretations that are not adequately incorporated in the existing data bases and analysis.</td></tr>
<tr><td colspan="3">The SONGS PSHA utilized all available data and two expert geotechnical organizations to define the sources of known active faults and area sources and defined attenuation functions that were applicable to predicting the ground motion at the site at the surface of the deep soil column. In addition, a peer review team of three experts was utilized to assure the thoroughness of the data and the interpretations of the data. This is considered to meet the requirements for all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-B3</td><td>As a part of the data base used, INCLUDE a catalog of historically reported, geologically identified, and instrumentally recorded earthquakes. USE(USNRC, 1997b) requirements or equivalent.</td><td colspan="2">As a part of data collection, COMPILE a catalog of historically reported, geologically identified, and instrumentally recorded earthquakes. USE (USNRC, 1997b) requirements or equivalent.</td></tr>
<tr><td colspan="3">In the SONGS PSHA, three earthquake catalogues were used. (1) Ellsworth (USGS) who studied all events with M >6 and determined epicentral locations and magnitude estimates; (2) National Oceanic and Atmospheric Administration that included earthquakes in Southern California prior to 1932 and (3) California Institute of Technology that includes events in Southern California in 1932 and later years. These are the most comprehensive catalogues available. They included some 6793 main shock events and 7051 aftershock events. This is considered to meet requirements of all three Capability Categories.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

<table>
<tr><td colspan="4">Seismic Hazard Analysis High-Level Requirement C: Seismic Sources and Source Characterization
To account for the frequency of occurrence of earthquakes in the site region, the seismic sources with the PSHA's hazard model SHALL consider all credible sources of potentially damaging earthquakes. For the purpose of characterizing the occurrence rates for those seismic sources, all earthquakes greater than magnitude 3 SHALL be considered. Both the aleatory and epistemic uncertainties SHALL be considered in characterizing the seismic sources.</td></tr>
<tr><th>Index No. HA-C</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-C1</td><td colspan="3">In the PSHA, CONSIDER all potential sources of earthquakes that affect the probabilistic hazard at the site. BASE the identification and characterization of seismic sources on regional and site geological and geophysical data, historical and instrumental seismicity data, the regional stress field, and geological evidence of prehistoric earthquakes.</td></tr>
<tr><td colspan="3">The SONGS PSHA considered all known faults and area sources that could have an effect on the hazard at the site. This is considered to meet requirements for all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-C2</td><td colspan="3">ENSURE that any expert elicitation process used to characterize the seismic sources is compatible with the level of analysis discussed in Req. HA-A, and FOLLOW a structured approach.</td></tr>
<tr><td colspan="3">The three teams involved in the PSHA for SONGs are all recognized experts. The PSHA was state of the art and thoroughly reviewed by a team of peer review experts. The interpretation of data, selection of sources and attenuation functions was considered to meet all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-C3</td><td>The seismic sources are characterized by source location and geometry, maximum earthquake magnitude, and earthquake recurrence. ENSURE that the total uncertainties in these characterizations are accounted for.</td><td colspan="2">The seismic sources are characterized by source location and geometry, maximum earthquake magnitude, and earthquake recurrence. INCLUDE the aleatory and epistemic uncertainties explicitly in these characterizations.</td></tr>
<tr><td colspan="3">Aleatory and Epistemic uncertainties were considered in the seismic source characterization in the PSHA. This is considered to meet requirements for all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-C4</td><td colspan="3">If an existing PSHA study is used, SHOW that any seismic sources that were previously unknown or uncharacterized are not significant, or INCLUDE them in the update of the hazard estimates.</td></tr>
<tr><td colspan="3">The SONGs PSHA was a new study. This requirement is not applicable.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

<table>
<tr><th colspan="4">Seismic Hazard Analysis High-Level Requirement D: Ground Motion Characterization

(HLR-HA-D): The PSHA SHALL account for all credible mechanisms influencing estimates of vibratory ground motion that can occur at a site given the occurrence of an earthquake of a certain magnitude at certain location. Both the aleatory and epistemic uncertainties SHALL be considered in characterizing the ground motion propagation.</th></tr>
<tr><th>Index No. HA-D</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-D1</td><td colspan="3">ACCOUNT in the PSHA for (a) all credible mechanisms governing estimates of vibratory ground motion that can occur at a site, and for (b) regional and site-specific geological, geophysical, and geotechnical data and historical and instrumental seismicity data (including strong motion data).</td></tr>
<tr><td colspan="3">The attenuation equations selected for the SONGS PSHA were for predicting the ground motion at the surface for deep stiff soil sites similar to SONGS. Five attenuation equations were used for the horizontal earthquake prediction. Each equation was weighted by experts based upon their expert opinion as to how well the equation fit the data for California earthquakes. A single attenuation equation was used for the prediction of vertical ground motion spectral shape. This is considered to meet requirements for all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-D2</td><td colspan="3">ENSURE that any expert elicitation process used characterize the ground motion is compatible with the level of analysis discussed in Req. HA-A, and FOLLOW a structured approach.</td></tr>
<tr><td colspan="3">The attenuation equations used were selected and weighted by experts and peer reviewed by experts. This process is considered to comply with the requirements for all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-D3</td><td>ENSURE that all of the uncertainties in the ground motion characterization are accounted for.</td><td colspan="2">ADDRESS both the aleatory and epistemic uncertainties in the ground motion characterization in accordance with the level of analysis identified for REQ. HA-A.</td></tr>
<tr><td colspan="3">Aleatory and Epistemic uncertainties were considered in the PSHA. This is considered to meet requirements for all Capability Categories.</td></tr>
<tr><td rowspan="2">HA-D4</td><td colspan="3">If an existing PSHA study is used, SHOW that any ground motion models or new information that were previously unused or unknown are not significant, or INCLUDE them in the update of the hazard estimates.</td></tr>
<tr><td colspan="3">The SONGs PSHA was a new study. This requirement is not applicable.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

<table>
<tr><th colspan="4">Seismic Hazard Analysis High-Level Requirement E: Local Site Effects

(HLR-HA-E): The PSHA SHALL account for the effects of local site response.</th></tr>
<tr><th>Index No. HA-E</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-E1</td><td>DEMONSTRATE that the PSHA accounts for the effects of site topography, surficial geologic deposits, and site geotechnical properties on ground motions at the site.</td><td colspan="2">ACCOUNT in the PSHA for the effects of site topography, surficial geologic deposits, and site geotechnical properties on ground motions at the site.</td></tr>
<tr><td colspan="3">The attenuation equations used were appropriate for predicting the ground motion at the surface for deep stiff soil sites. Thus, local site response is inherently contained in the attenuation equations. A single attenuation equation was used for prediction of the vertical motion at the site. This is considered to meet the requirements of at least Capability Category II.</td></tr>
<tr><td rowspan="2">HA-E2</td><td>ENSURE that all of the uncertainties in the local site response analysis are accounted for.</td><td colspan="2">ADDRESS both the aleatory and epistemic uncertainties in the local site response analysis.</td></tr>
<tr><td colspan="3">Aleatory and Epistemic uncertainty were included in the attenuation analysis using 5 attenuation equations that predicted the horizontal site response at the surface of deep stiff soil. Vertical response predictions utilized one attenuation equation. The aleatory and epistemic uncertainty is included in the site response predictions. This is considered to meet the requirements of at least Capability Category II.</td></tr>
</table>

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

Seismic Hazard Analysis High-Level Requirement F: Aggregation and Quantification			
(HLR-HA-F): Uncertainties in each step of the hazard analysis SHALL be propagated and displayed in the final quantification of hazard estimates for the site. The results SHALL include fractile hazard curves, median and mean hazard curves, and uniform hazard response spectra (UHS). For certain applications, the PSHA SHALL include seismic source deaggregation and magnitude-distance deaggregation.			
Index No. HA-F	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-F1	In the final quantification of the seismic hazard, INCLUDE mean estimates. ADDRESS how this accounts for uncertainties.	In the final quantification of the seismic hazard, INCLUDE and DISPLAY the propagation of both aleatory and epistemic uncertainties.	
	The SONGS PSHA was performed using a logic tree analysis considering multiple sources and magnitudes, several attenuation equations and the aleatory and epistemic uncertainty in all of the input parameters. The process results in a suite of hazard curves for the site. Statistics were performed on the suite of hazard curves to derive a mean, median and several fractile values. This requirement is considered to be met for all capability categories.		
HA-F2	In the PSHA, INCLUDE appropriate sensitivity studies and intermediate results to identify factors that are important to the site hazard and that make the analysis traceable.		
	The process of developing the PSH for SONGS included sensitivity studies for input parameters and of the results. The intermediate and final results were peer reviewed by independent expert. All Capability Category requirements are considered to have been met.		

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

Index No. HA-F	Capability Category I	Capability Category II	Capability Category III
HA-F3	DEVELOP the following results as a part of the quantification process, compatible with needs for the level of analysis determined in HLR-HA-A: • Mean hazard curves for peak ground acceleration and spectral accelerations; • Mean UHS.	DEVELOP the following results as a part of the quantification process, compatible with needs for the level of analysis determined in HLR-HA-A: • Fractile and mean hazard curves for each ground motion parameter considered in the PSHA; • Fractile and mean UHS.	DEVELOP the following results as a part of the quantification process, compatible with needs for the level of analysis determined in HLR-HA-A: • Fractile and mean hazard curves for each ground motion parameter considered in the PSHA; • Fractile and mean UHS; • Magnitude-distance deaggregation for the median and mean hazard; • Seismic source deaggregation; • Mean magnitude and distance.
	The SONGS PSHA included sensitivity studies to determine the distance and magnitude that contributed most to the site response for the frequency of occurrence of the SSE and two times the SSE. The dominant distance and magnitude were reported for 1 Hz and 10 Hz. The dominant sources were also identified for low level ground motion and for higher level ground motion. Mean magnitude and distance were not reported in the IPEEE submittal. The predicted ground motion at the site was not modified as a result of the deaggregation. The study is considered to meet Capability Category II.		

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

Seismic Hazard Analysis High-Level Requirement G: Spectral Shape			
(HLR-HA-G): For further use in the SPRA, the spectral shape SHALL be based on a site-specific evaluation taking into account the contributions of deaggregated magnitude-distance results of the PSHA. Broad-band, smooth spectral shapes, such as those presented in NUREG/CR-0098 (Newmark and Hall, 1978) (for lower-seismicity sites such as most of those east of the U.S. Rocky Mountains) MAY also be used taking into account the site conditions. The use of existing UHS is acceptable unless evidence comes to light that would challenge these UHS spectral shapes.			
Index No. HA-G	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-G1	ENSURE that the spectral shape used in the SPRA reflects or bounds the site-specific considerations.	BASE the response spectral shape used in the SPRA on site-specific evaluations performed for the PSHA. REFLECT or BOUND the site-specific considerations.	BASE the response spectral shape used in the SPRA on site-specific evaluations performed for the PSHA, and REFLECT or BOUND the characteristics of spectral shapes associated with the mean magnitude and distance pairs determined in the PSHA for the important ground motion levels.
	The SONGS PSHA produced fractile and mean Uniform Hazard Spectra for the frequency of occurrence of the SSE and two times the SSE. These spectral shapes were not changed to reflect differences that might result from deaggregation of magnitude or distance. The median spectral shape for two times the SSE was used in the probabilistic response analysis of the structures. Capability Category II requirements were met.		

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

Index No. HA-H	Capability Category I	Capability Category II	Capability Category III
Seismic Hazard Analysis High-Level Requirement H: use of Existing Studies			
(HLR-HA-H): When use is made of an existing study for PSHA purposes, it SHALL be confirmed that the basic data and interpretations are still valid in light of established current information, the study meets the requirements outlined in A through G above, and the study is suitable for the intended application.			
HA-H	[There are no Supporting Requirements here.]		
	The SONGS PSHA was a new study. This STR is not applicable.		
Seismic Hazard Analysis High-Level Requirement I: Other Seismic Hazards			
(HLR-HA-I): A screening analysis SHALL be performed to assess whether, in addition to the vibratory ground motion, other seismic hazards, such as fault displacement, landslide, soil liquefaction, or soil settlement need to be included in the SPRA for the specific application. If so, the SPRA SHALL address the effect of these hazards through assessment of the frequency of hazard occurrence and/or the magnitude of hazard consequences.			
Index No. HA-I	**Capability Category I**	**Capability Category II**	**Capability Category III**
	[There are no Supporting Requirements here.]		
	Ground failures due to liquefaction, bearing failure, lateral spread or earthquake induced settlement were evaluated. In addition an evaluation was made of liquefaction of filled cavities, offshore conduit blockage and stability of cut slopes. These evaluation were conducted by deterministic means for a ground motion spectral acceleration corresponding to 5.4g average spectral acceleration. The frequency of occurrence of this average spectral acceleration corresponds to the frequency at two times the SSE. This requirement is met for all Capability Categories.		

Table 4-1
Comparison of ANS Standard Methodology to SONGS SPRA Methodology for Development of the Seismic Hazard (Continued)

Seismic Hazard Analysis High-Level Requirement J: Documentation (HLR-HA-J): The PSHA SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.			
Index No. HA-J	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-J1	MEET the general documentation requirements in Section 7.		
HA-J2	MEET the documentation guidelines of (NRC, 1997a) for PSHA, including a description of the specific methods used for source characterization and ground-motion characterization, and of the scientific interpretations that are the basis for the inputs and results. If an existing PSHA is used, CHECK its documentation to ensure that it is adequate to meet the spirit of the requirement here.		
	Only a summary documentation of the hazard study contained in the IPEEE submittal was reviewed. The complete SPHA documentation is referenced and appears to be well documented and peer reviewed by independent experts. This study was state of the art. *The documentation requirements for STRs HA-J1 and HA-J2 are considered to have been met.*		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis

<table>
<tr><td colspan="4">Systems-Analysis High-Level Requirement A: Completeness

(HLR-SA-A): The seismic-PRA systems models SHALL include all important seismic-caused initiating events that can lead to core damage or large early release, and SHALL include all other important failures that can contribute significantly to CDF or LERF, including seismic-induced SSC failures, non-seismic-induced unavailabilities, and human errors.</td></tr>
<tr><th>Index No. SA-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">SA-A1</td><td colspan="3">ENSURE that all significant earthquake-caused initiating events are included in the seismic-PRA systems model.</td></tr>
<tr><td colspan="3">IPE initiating events, including secondary events that could result from earthquakes such as seismic induced fire and internal flooding, were examined to determine if they should be included in the seismic event tree. Containment bypass events such as interfacing systems LOCA, catastrophic failure of the reactor vessel and steam generator were also examined. Most of the IPE initiating events, such a large LOCA, reactor vessel rupture, steam generator rupture, etc. were screened out on the basis of seismic ruggedness, thus low probability of occurrence. The screening threshold was a failure rate less than 1E-7/y. This corresponded to approximately 8g spectral acceleration. Events such as uncomplicated reactor trip, loss of offsite power and small LOCA could not be screened out and were included in the seismic event tree. The initiating events modeled are considered to meet all Capability Categories.</td></tr>
<tr><td rowspan="2">SA-A2</td><td colspan="3">In the initiating-event selection process, DEVELOP a hierarchy to ensure that every earthquake greater than a certain defined size produces a plant shutdown within the systems model.</td></tr>
<tr><td colspan="3">The construction of the SET was done considering the hierarchy of equipment capacity and the consequences of failure. The first node in the SET was loss of offsite power which can occur at low acceleration levels. The next node was a potential seismic induced ATWS resulting from potential damage to the reactor internals that would not meet the screening level 1E-7/y. The next nodes in the SET represented failure of support systems such as instrumentation and control, loss of 125v DC power, loss of emergency diesel generators, etc. that could lead directly to core damage. Other nodes such as loss of CCW and loss of salt water cooling were placed ahead of ECCS since ECCS is dependent on CCW and salt water cooling. Thus, the SET was constructed in a logical hierarchy structure and meets all Capability Categories of the Standard.</td></tr>
</table>

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Index No. SA-A	Capability Category I	Capability Category II	Capability Category III
SA-A3	ENSURE that the PRA systems models reflect all significant earthquake-caused failures and all significant non-seismic-induced unavailabilities and human errors. The analysis MAY group earthquake-caused failures if the leading failure in the group is modeled.		
	The construction of the SET shown in Figure 4-1 considered all credible initiating events in the IPE model as well as potential seismic induced events such as seismic induced fire and flood, seismic spatial systems interactions, inadvertent actuation of fire protection systems, containment bypass, relay malfunction, etc. For those sequences that did not lead to direct core damage, the resulting plant damage state sequences were transferred to IPE event trees to identify and quantify the additional non-seismic failures (random failures and human error) that could lead to core damage. Relay chatter that required operator action was also included for these damage state analyses. Performance shaping factors (PSF) that increase the human error failure rate due to the operator stress from the earthquake were applied to the human reliability analysis. The modeling is considered to have included all credible earthquake induced failure modes and non seismic failure modes and to have met the requirements for all Capability Categories.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement B: Adaptations Based on the Internal-Events Pra Systems Model			
(HLR-SA-B): The seismic-PRA systems model SHALL be adapted to incorporate seismic-analysis aspects that are different from corresponding aspects found in the full-power, internal-events PRA systems model. ***Note*:** While the most common procedure for developing the seismic-PRA systems model is to start with the internal-events systems model and adapt it by adding and trimming, in some circumstances it is acceptable instead to develop an ad-hoc seismic-PRA systems model tailored especially to the situation being modeled. If this approach is used, it is especially important that the resulting model be consistent with the internal-events systems model regarding plant response and the cause-effect relationships of the failures. Further, it is then especially important that a peer review be undertaken that concentrates on these aspects. See Section 3.7.2.1 and also the NOTE at REQ. SA-A3 for further commentary.			
Index No. SA-B	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-B1	*In each of the following aspects of the seismic-PRA systems-analysis work, SATISFY the corresponding requirements in the ASME internal-events, full-power PRA standard (ASME, 2002), except where they are not applicable, or where this Standard includes additional requirements. DEVELOP a defined basis to support the claimed non-applicability of any exceptions. The aspects governed by this requirement are:* 1. Initiating-event analysis 2. Accident-sequence analysis 3. Success-criteria analysis 4. Systems analysis 5. Data analysis 6. Human-reliability analysis 7. Use of expert judgment When the ASME requirements are used, FOLLOW the Capability-Category designations in that Standard, and for consistency USE the same Capability Category in this analysis.		
	The methodology followed that in NUREG/CR-2300 as did the internal events PRA conducted for IPE. No attempt was made to compare the IPE model with the ASME standard. The IPE model was reviewed by USNRC and is considered to be a thorough representation of the plant response to initiating events. The seven subjects cite in the Standard are considered to be adequately carried forward from the IPE model to represent the response of the plant to seismic events, coupled with random failures and human error. This requirement is considered to have been met for all Capability Categories.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Index No. SA-B	Capability Category I	Capability Category II	Capability Category III
SA-B2	In the HRA (human reliability analysis) aspect, CONSIDER that additional post-earthquake stresses can increase the likelihood of human errors or inattention, compared to the likelihood assigned in the internal-events HRA when the same activities are undertaken in non-earthquake accident sequences. Whether or not increases in error probabilities are used, JUSTIFY the basis for this decision about what error rates to use.		
	Performance shaping factors (PSF) were applied to the human reliability analysis human error rate in the IPE. The performance shaping factors that were multipliers on internal event human error failure rate, were selected as a function of whether the operator action took place in the control room or outside of the control room. Operations outside of the control room were assigned higher PSFs. The time available for operator action was also considered in developing PSFs. Operators' actions that had to be performed in short times were assigned significantly higher PSFs. The PSFs were not varied with the level of earthquake as in some assessments. Since SONGS was designed for a high seismic level, the demand for operator recovery action would only be required when high seismic levels of ground shaking had occurred, therefore, conservative values, consistent with high levels of earthquake ground motion, were used. This requirement is considered to have been met for all Capability Categories.		
SA-B3	PERFORM an analysis of seismic-caused dependencies and correlations, in a way so that any screening of SSCs appropriately ACCOUNTS FOR those dependencies and correlations. The analysis MAY use generic dependency and correlation values if justified.		PERFORM an analysis of seismic-caused dependencies and correlations, in a way so that any screening of SSCs appropriately ACCOUNTS FOR those dependencies and correlations. USE plant-specific dependency and correlation values throughout.
	The SONGS SPRA treated dependencies in the same manner as other SPRAs. Components that are alike that are in redundant safety trains are considered to be totally dependent and components that are not alike in the same train, in redundant trains or in separate systems are considered to be independent. Correlations and dependencies were not specifically addressed in the screening process. *In the screening of components, the screening failure rate was set at 1E-7/year corresponding to about 8g spectral acceleration at the ground level. Theoretically, for a series of screened components that are uncorrelated that appear in OR gates, the system failure rate could be higher than the screening level. However, if the screening level is set sufficiently low (in this case, two orders of magnitude lower than the computed CDF), the correlation would have little effect on the overall results. The generic correlation and low failure rate used in screening are considered to met the intent of Capability Category I and likely Capability Category II.*		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Index No. SA-B	Capability Category I	Capability Category II	Capability Category III
SA-B4	ENSURE that any screening of human-error basic events and non-seismic-failure basic events does not significantly affect the PRA's results.		
	For seismic accident sequences that did not lead directly to core damage, the IPE model was used to evaluate the contribution of random and human error failures that could lead the degraded state to core damage. Human error performance shaping factors were applied to account for increases stress on operators. Thus, all non-seismic failures in the seismic accident sequences that did not lead to direct core damage were included with appropriate modifications for increased human error due to operator stress. This requirement is met for all Capability Categories.		
SA-B5	CONSIDER the effects of the chatter of so-called low-ruggedness relays.	CONSIDER the effects of the chatter of relays and similar devices.	
	A full scope relay evaluation was performed. All relays in circuits of the power or I&C systems that were modeled were identified. By evaluating the consequences of relay chatter, most of the relays were considered to be chatter acceptable (CA). One hundred ninety one (191) of 1300 that were considered were determined to be chatter unacceptable (CU). Twenty seven (27) relays required operator action (OA) if they were to chatter. Relays that were CU were included in the SET nodal equations and fragility curves were developed for them. The human reliability analysis conducted included OA to mitigate the effects of relays requiring operator action. Performance shaping factors were applied to the human error rates from the IPE model. All possible detrimental effects of relays were included in the model and in the risk quantification. The evaluation of relays in the SONGS SPRA is considered to meet the requirements of all Capability Categories.		
SA-B6	In the systems-analysis models, for each basic event that represents a seismically-caused failure, INCLUDE the complementary "success" state where applicable to a particular SSC.		
	The nodal equations included successes as well as failures. This is considered to meet the requirement of al Capability Categories.		
SA-B7	CONSIDER the possibility that a large earthquake can cause damage that blocks personnel access to safety equipment or controls, thereby inhibiting operator actions that might otherwise be credited.		
	The IPEEE Tier 1 submittal does not specifically describe walkdowns to assess the path that operators must take to recover from relay chatter effects. The walkdowns did assess seismic fire interaction and seismic induced internal flood, and seismic spatial interactions. The number of locations requiring operator action are limited. To account for possible plant damage interfering with operator actions outside the control room, the PSFs were increased significantly above the PSFs for OA in the control room. The intent of the requirement is considered to have been met for at least Capability Category I.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Index No. SA-B	Capability Category I	Capability Category II	Capability Category III
SA-B8	CONSIDER the likelihood that system recoveries modeled in the internal-events PRA may be more complex or even not possible after a large earthquake, and ADJUST the recovery models accordingly. Conservative recovery values MAY be used.	CONSIDER the likelihood that system recoveries modeled in the internal-events PRA may be more complex or even not possible after a large earthquake, and ADJUST the recovery models accordingly.	
	Operator action recoveries were modified using PSFs to account for operator stress and possible inaccessibility to areas in the plant where the operator would be required to go for recovery action. The modeling of this operator recovery action is considered to conform to at least Capability Category I.		
SA-B9	CONSIDER including an earthquake-caused "small-small LOCA" as an additional fault within each sequence in the seismic-PRA model.		
	In the SET hierarchy, small LOCA appears after events that lead directly to core damage. Safety injection is required after small LOCA. There are no accident sequences that do not lead directly to core damage that do not contain small LOCA, thus addition of small-small LOCA is inherently included in the SET. The modeling meets the requirements of all Capability Categories.		
SA-B10	In the SPRA walkdown, INCLUDE the potential for seismic-induced fires and flooding following the guidance given in NUREG-1407.		
	A specific walkdown was conducted to evaluate the seismic ruggedness of fire and flood sources. The walkdown also included the inadvertent actuation of fire protection systems. It was determined that no safety related equipment would be impacted by fire or flood sources, including inadvertent actuation of fire protection systems. This requirement was met for al Capability Categories.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement C: Plant Fidelity (HLR-SA-C): The seismic-PRA systems models SHALL reflect the as-built and as-operated plant being analyzed.			
Index No. SA-C	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-C1	To ensure that the systems-analysis models reflect the as-built, as-operated plant, JUSTIFY any important conservatisms or other distortions introduced by demonstrating that they do not significantly alter the seismic-PRA's validity for applications.		
	The SPRA model was applicable to both units and utilized the IPE model to development the list of active equipment in the pant safety systems. Additional passive equipment that could fail in a seismic event was added to the seismic equipment list. Both units were walked down to assure that the model reflected the plant in its as-built state and identify any differences between the two units. Any potential weaknesses or interactions observed during the walkdowns were either identified for upgrading or were included in the systems modeling. The development and verification of the SEL, and the resulting modeling of the plant response to earthquakes, is considered to meet this technical requirement for all Capability Categories.		
Systems-Analysis High-Level Requirement D: Seismic Equipment List **(HLR-SA-D): The list of SSCs selected for seismic-fragility analysis SHALL include all SSCs that participate in accident sequences included in the seismic-PRA systems model.**			
Index No. SA-D	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-D1	USE the PRA systems model as the basis for developing the SEL ("Seismic Equipment List"), which is the list of all SSCs to be considered by the subsequent seismic-fragility evaluation task.		
	The IPE model was used to identify the equipment important to the internal events PRA model. Equipment added to the list included passive equipment whose failure could result in failure of essential safety systems and cabinets of I&C devices included in the IPE model. Note that the IPE modeling was on a device level whereas the seismic qualification of devices and development of seismic fragilities were on a cabinet level. In addition, a comprehensive relay list was developed and those relays that were determined to be chatter unacceptable or operator action required, were added to the SEL. This procedure is considered to meet all requirements for all Capability Categories.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

<table>
<tr><th colspan="4">Systems-Analysis High-Level Requirement E: Integration and Quantification
(HLR-SA-E): The analysis to quantify core-damage frequency (CDF) and large-early-release frequency (LERF) SHALL appropriately integrate the seismic hazard, the seismic fragilities, and the systems-analysis aspects.</th></tr>
<tr><th>Index No. SA-E</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">SA-E1</td><td colspan="3">In the quantification of CDF and LERF, PERFORM the integration using the seismic hazard, fragility and systems analyses.</td></tr>
<tr><td colspan="3">The integration of the hazard and fragilities was performed using a discrete probability sampling process. The computer code used for this integration utilized Boolean expressions for each seismic accident sequence and properly treats successes, failures and Boolean intersects. This technical requirement is considered to have been met for all Capability Categories.</td></tr>
<tr><td rowspan="2">SA-E2</td><td>In quantifying CDF and LERF frequencies, PERFORM the quantification on a cut-set-by-cut-set or accident-sequence-by-accident-sequence basis (or for defined groups of these), as well as on a comprehensive/integrated basis.
Broad groupings MAY be used.</td><td colspan="2">In quantifying CDF and LERF frequencies, PERFORM the quantification on a cut-set-by-cut-set or accident-sequence-by-accident-sequence basis (or for defined groups of these), as well as on a comprehensive/integrated basis.</td></tr>
<tr><td colspan="3">The integration was performed for each accident sequence in the SET. Results for each sequence were computed and summed to determine the total CDF and LERF. The procedure meets the requirements of all Capability Categories.</td></tr>
<tr><td rowspan="2">SA-E3</td><td colspan="3">In the analysis, USE the quantification process to ensure that any screening of SSCs does not affect the results, taking into account the various uncertainties.</td></tr>
<tr><td colspan="3">Sensitivity studies were conducted to determine the effects of excluding nodes in the SET. The contribution of excluded nodes was determined to be less that 1E-7/y which was the initial exclusion target for excluding basic events. Sensitivity studies were also included to assess the impact of unacceptable relay chatter and operator recovery. Only one operator action sensitivity study resulted in an increase in CDF of any significance. That was for a case of the operator failure to reset and start the diesel generators. This had an impact of one order of magnitude on the calculated CDF. Almost 40% of the CDF is attributed to loss of offsite power and seismic failure of essential motor control centers. The motor control center median capacity was about 56% of the screening level capacity. Other sequences that contained vital components, with capacity much less than the capacity corresponding to the screening level, contributed much less to CDF. It is concluded that this requirement of the Standard is met for all Capability Categories.</td></tr>
</table>

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Index No. SA-E	Capability Category I	Capability Category II	Capability Category III
SA-E4	In the integration/quantification analysis, ACCOUNT for all significant dependencies and correlations that affect the results. The analysis MAY use generic dependency and correlation values if justified.		In the integration/quantification analysis, ACCOUNT for all significant dependencies and correlations that affect the results. USE plant-specific dependency and correlation values throughout.
	The correlations and dependencies incorporated in the modeling were generic as used in almost all SPRAs except the LLNL SSMRP study. Identical or similar components that have the same function in redundant trains of safety systems are assumed to be 100% correlated. If one fails, the other fails. Dissimilar components in the same train, redundant trains or different systems are considered to be uncorrelated. This has the conservative effect of nullifying any redundancy afforded by dual or triple safety trains. By treating the components in series in an essential system as totally uncorrelated, the addition of failure rates of individual components in the OR gates can also be conservative. Cross correlation of unlike components is not modeled which could theoretically be unconservative. However, since only a few components appear as being significant contributors to CDF, and the screening level was set at a high acceleration, this simple generic correlation appears to be reasonable. The use of this simplified generic correlation is considered to meet the intent of the requirements of Capability Category I. With sensitivity studies as required in SA-E6, the requirements of Capability Category II could be considered to have been met.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

<table>
<tr><th>Index No. SA-E</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">SA-E5</td><td>USE the mean hazard, composite fragilities, and the systems analysis to generate point estimates for CDF and LERF. ESTIMATE the uncertainties in overall CDF and LERF.</td><td colspan="2">In the integration/quantification analysis, ACCOUNT for the uncertainties in CDF and LERF results that arise from each of the several inputs (the seismic hazard, the seismic fragilities, and the systems-analysis aspects.)</td></tr>
<tr><td colspan="3">The quantification of mean CDF in the SET was conducted using the mean hazard curve (average spectral acceleration from 1Hz to 10Hz) and the full uncertainty associated with the fragility curves. The mean CDF was reported as required in NUREG-1407 (USNRC, 1991b). Sensitivity studies were conducted to determine the sensitivity of excluding several nodes in the SET for ATWS and to determine the sensitivity of operator actions. In addition, CDF was calculated using the 84th percentile seismic hazard curve to test the sensitivity resulting from the seismic hazard. In the case of excluding nodes in the ATWS sequence, the addition of other possible failures in conjunction with ATWS were examined and it was concluded that the combined contribution of excluded nodes was less than 1E-7/y.

The sensitivity of unacceptable relay chatter associated with the CCW swing pump was evaluated. It was determined that chatter of relays that could make the swing pump unavailable resulted in minimal risk significance.

Six operator actions were analyzed and quantified in the SET. Sensitivity studies were performed by setting each operator action failure probability to 1.0. Only one operator action failure set to 100% failure probability resulted in an increase In CDF of any significance. That was failure of the operator to reset and start the diesel generators, given the loss of offsite power, which increased the CDF by an order of magnitude.

Another analysis was performed using the 85th percentile hazard curve. The dominant accident sequences did not change, however, the ranking of two sequences changed positions. The frequencies of four additional damage states were increased beyond the 1E-7 screening level and the overall CDF increased by about a factor of 2.

Although a complete quantitative uncertainty analysis was not performed, the sensitivity studies that were performed did not significantly change or alter the quantitative results or change the identification of dominant accident sequences, contributors or vulnerabilities.

The analyses performed met the requirements of Capability Category I. The sensitivity studies are considered to be a partial compliance with Capability Category II but not a rigorous compliance. The extension of the SPRA to meet all requirements of Capability Category II could be easily done by additional computations to propagate the hazard and fragility uncertainties, and uncertainties in the non-seismic failures throughout the risk quantification.</td></tr>
</table>

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Index No. SA-E	Capability Category I	Capability Category II	Capability Category III
SA-E6	PERFORM appropriate sensitivity studies to illuminate the sensitivity of the CDF and LERF results to the assumptions used about dependencies and correlations.		
	Sensitivity analyses of correlation were not conducted in the SONGS SPRA. Like components in redundant safety trains were assumed to be 100% correlated. Unlike components were assumed to be uncorrelated. This is typical modeling procedure. In this respect, hardly any SPRAs conducted over the past 20 years would satisfy this requirement. In the seismic Safety Margins Research Program (USNRC, 1981), response correlation was studied and software was developed to incorporate this correlation. Capacity correlation was assumed to be 100% for like components in separate trains and uncorrelated for unlike components. The requirement would be difficult to meet for two reasons. First, there is little background and experience on correlation of seismic failures. Assignment of partial correlation on response and capacity would be subjective. Second, the software to treat partial correlation of seismic failures is not readily available to the public. If there is a need to address partial correlation for future risk informed applications, the technology and software will evolve. At this point in time, meeting this requirement is difficult. This requirement was not met for any of the Capability Categories.		

Table 4-2
Comparison of Methodology used in the SONGS SPRA to the Supplemental Technical Requiremnts of the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement F: Documentation			
(HLR-SA-F): The seismic-PRA analysis SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.			
Index No. SA-F	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-F1	MEET the general documentation requirements in Section 7.		
	The Tier I documentation was in accordance with NUREG-1407which would meet the general requirements of the Standard for all Capability Categories.		
SA-F2	DESCRIBE the specific adaptations made in the internal-events PRA model to produce the seismic-PRA model, and their motivation.		
	A detailed description was provided of the construction of the SET in a hierarchy to determine the conditional Core Damage Frequency for seismic accident sequences and of the modification and use of internal event models to compute the contribution from non-seismic failures. The modified fault trees were not provided in the Tier 1 documentation but the nodal equations were provided for each node in the SET. A description was provided of the development of the SEL based on the internal event model and the SET. The SONGS SPRA met the requirements of the Standard for at least Capability Category II.		
SA-F3	*DESCRIBE the major contributors to the uncertainties in each of the important final results and insights of the systems analysis.*		
	A description was provided of sensitivity studies performed to determine the sensitivity of excluding nodes in the SET in certain accident sequences, the sensitivity of the Performance Shaping Factors applied to the operator action modeling, and the sensitivity to the uncertainty in the seismic hazard description. The reporting of the results and conclusions of these sensitivity studies is considered to meet the requirements of the Standard. However, considering that a full uncertainty analysis was not conducted, the documentation is only complete for Capability Category I.		

4.5.3 Fragility Analysis

The structures and equipment in SONGS 2 & 3 were conservatively designed for seismic loading. The results of the probabilistic response analysis of structures at SONGS demonstrated that for the large embedded structures, such as the auxiliary building, there was approximately a factor of two conservatism in the in-structure spectra originally developed for design. This was because of simplifications and regulatory restrictions in soil-structure-interaction analysis. Many of the inherently rugged components and commodities were pre-screened out based on the conservatism in design methodology, inherent ruggedness in construction and observations during the walkdown. The types of components and commodities that were pre-screened out were manual and check valves, cable raceways, breakers, circuit boards and piping. This pre-screening was subject to observations from the walkdown not identifying any conditions that would potentially result in the median capacity being below the screening level of 8.0g spectral acceleration. There were 600 components remaining on the SEL that required either further screening or a fragility calculation.

Because of the high seismicity at SONGS, the walkdown screening level could not be used as a basis for a generic fragility derivation. Plant specific qualification documentation or independent calculations were used as the basis of screening or for deriving plant specific fragilities.

The fragilities were defined as a conditional probability of failure relative to the spectral acceleration of the free field ground motion averaged over a frequency range of 1 Hz to 10 Hz.

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard

<table>
<tr><th colspan="4">Seismic Fragility Evaluation High Level Requirement A: Realism

(HLR-FR-A): The seismic fragility evaluation SHALL be performed to estimate plant-specific, realistic seismic fragilities of structures, systems and components whose failure may contribute to core damage and/or large early release.</th></tr>
<tr><th>Index No. FR-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">FR-A1</td><td colspan="3">DEVELOP seismic fragilities for all those structures, systems and components identified by the systems analysis (see REQ SA-D1).</td></tr>
<tr><td colspan="3">All components and commodities on the SEL and relays designated as chatter unacceptable were examined relative to their seismic qualification level to further screen them or to develop a plant specific fragility. The available qualification information was use to develop fragilities for those components, that could not be demonstrated to have a median spectral acceleration capacity of 8.0g, based on a simple review of their qualification information. The fragility evaluation scope is considered to meet the requirements of the Standard for all Capability Categories.</td></tr>
<tr><td rowspan="2">FR-A2</td><td>Generic data (e.g., fragility test data, generic seismic qualification test data and earthquake experience data) MAY be used to develop seismic fragilities. However, DEMONSTRATE that any use of such generic data is conservative.</td><td>BASE the seismic fragilities on plant-specific data and ENSURE that they are realistic (median with uncertainties). Generic data (e.g., fragility test data, generic seismic qualification test data and earthquake experience data) MAY be used for screening of certain SSCs and for calculating their seismic fragilities by applying the Requirements under HLR-FR-F which permits use of such generic data under specified conditions. However, DEMONSTRATE that any use of such generic data is conservative.</td><td>BASE the seismic fragilities on plant-specific data and ENSURE that they are realistic (median with uncertainties).</td></tr>
<tr><td colspan="3">Fragilities were developed from plant specific seismic qualification data or independent calculations. In some cases, relay fragilities were derived from Generic Equipment Ruggedness Spectra (EPRI, 1991b). The derivation of fragilities is considered to meet the requirements for Capability Category 2.</td></tr>
</table>

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Seismic Fragility Evaluation High Level Requirement B: Screening (HLR-FR-B): If screening of high seismic capacity components is performed, the basis for the screening SHALL be fully described.			
Index No. FR-B	**Capability Category I**	**Capability Category II**	**Capability Category III**
FR-B1	If screening of high-seismic-capacity components is performed, DESCRIBE fully the basis for screening and supporting documents. For example, guidance given in EPRI NP-6041 and NUREG/CR-4334 MAY be used to screen out components with high seismic capacity. However, CHOOSE the screening level high enough that the contribution to CDF and LERF from the screened-out components is not significant.		SCREEN high-seismic-capacity components ONLY if the components' failures can be considered as fully independent of the remaining components.
	Screening was conducted by a combination of the plant specific seismic qualification level, generic ruggedness and walkdown confirmation that potential vulnerabilities were not present. The screening tables in EPRI NP-6041 and NUREG/CR-4334 could not be used as the basis of the screening due to the high seismicity at SONGS. The screening level was chosen at 8.0g spectral acceleration at free field ground surface. This corresponded to a failure rate of 1E-7/y which was deemed to be low enough that screened out components would not have any significant contribution to seismic risk had they been included in the models and quantification of CDF. The screening methodology utilized is considered to meet the requirements of Capability Category II.		
FR-B2	ASSESS and DOCUMENT the applicability of the screening criteria given in EPRI NP-6041 (EPRI, 1991a) and NUREG/CR-4334 (Budnitz et al., 1985) for the specific plant and specific equipment.		
	EPRI NP-6041 and NUREG/CR-4334 were not used as a basis for screening, therefore, this requirement is not applicable.		

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

<table>
<tr><td colspan="4">Seismic Fragility Evaluation High Level Requirement C: Response

(HLR-FR-C): The seismic fragility evaluation SHALL be based on realistic seismic response that the SSCs experience at their failure levels. Depending on the site conditions and response analysis methods used in the plant design, realistic seismic response MAY be obtained by an appropriate combination of scaling, new analysis and new structural models.</td></tr>
<tr><td>Index No. FR-C</td><td>Capability Category I</td><td>Capability Category II</td><td>Capability Category III</td></tr>
<tr><td rowspan="2">FR-C1</td><td colspan="2">ESTIMATE the seismic responses that the components experience at their failure levels on a realistic basis using site-specific earthquake response spectra in three orthogonal directions, anchored to a ground motion parameter such as peak ground acceleration or average spectral acceleration, or ENSURE that the spectral shape used reflects or bounds the site-specific considerations.</td><td>ESTIMATE the seismic responses that the components experience at their failure levels on a realistic basis using site-specific earthquake response spectra in three orthogonal directions, anchored to a ground motion parameter such as peak ground acceleration or average spectral acceleration.</td></tr>
<tr><td colspan="3">Site specific ground motion spectra were used to develop probabilistic in-structure spectra to define the input motion to equipment. This was a state of the art definition of demand on equipment. Equipment response was estimated in the fragility calculations by comparing the probabilistic in-structure spectra to the design spectra or by conducting a new response analysis using the median in-structure spectrum at the equipment location of interest to define the demand on the equipment. The methods utilized to compute equipment response are considered to meet the requirements of the Standard for all Capability Categories.</td></tr>
</table>

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Index No. FR-C	Capability Category I	Capability Category II	Capability Category III
FR-C2	If probabilistic response analysis is performed to obtain realistic structural loads and floor response spectra, ENSURE that the number of simulations done (e.g., Monte Carlo simulation and Latin Hypercube Sampling) is large enough to obtain stable median and 85% non-exceedance responses. In the response analysis, appropriately ACCOUNT for the entire spectrum of input ground motion levels displayed in the seismic hazard curves.		PERFORM probabilistic seismic response analysis taking into account the uncertainties in the input ground motion and structural and soil properties and CALCULATE joint probability distributions of the responses of different components in the building.
	The probabilistic response was conducted using the Latin Hypercube stratified sampling technique that employed 26 simulations. The full range of uncertainties in the seismic motion input were captured in the 26 individual earthquake time histories used. The distribution of all important variables, such as soil stiffness, soil damping, structural stiffness and structural damping was included in the analysis. Studies conducted during the Seismic Safety Margin Research Program (SSMRP) by Lawrence Livermore National Laboratories (USNRC, 1981) concluded that approximately 30 simulations were adequate to define the distribution on response due to the variability in input motion and the soil and structural parameters that are important influences to response. In some of the Sandia Laboratory evaluations conducted in examining simplified SPRA methods, 10 simulations were used with minimal error relative to 30 simulations recommended in the SSMRP program. Thus, the 26 simulations are considered adequate to meet the requirements of the Standard for Capability Category II. Joint Probability distributions of the responses of different components in the building were not calculated as required for Capability Category III.		
FR-C3	If scaling of existing design response analysis is used, JUSTIFY it based on the adequacy of structural models, foundation characteristics, and similarity of input ground motion.		Addressed in FR-C2.
	Scaling was not conducted, thus this requirement is not applicable.		
FR-C4	For soil sites, or when the design response analysis models are judged not to be realistic and state-of-the-art, or when the design input ground motion is significantly different from the site-specific input motion, PERFORM new analysis to obtain realistic structural loads and floor response spectra.		Addressed in FR-C2.
	New probabilistic analysis was conducted that meets the requirements of the Standard for Capability Category II.		

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Index No. FR-C	Capability Category I	Capability Category II	Capability Category III
FR-C5	If median-centered response analysis is performed, ESTIMATE the median response (i.e., structural loads and floor response spectra) and variability in the response using established methods.		Addressed in FR-C2.
	This requirement is not applicable. New probabilistic response analysis was conducted that results in median and 85th percentile response spectra and loads.		
FR-C6	When soil structure interaction (SSI) analysis is conducted, ENSURE that it is median centered using median properties, at soil strain levels corresponding to the input ground motions that dominate the seismically induced core damage frequency. CONSIDER the uncertainties in the SSI analysis by varying the low strain soil shear modulus between the median value times $(1+C_v)$ and the median value divided by $(1+C_v)$, where C_v is a factor that accounts for uncertainties in the SSI analysis and soil properties. If adequate soil investigation data are available, ESTABLISH the mean and standard deviation of the low strain shear modulus for every soil layer. Then ESTABLISH the value of C_v so that it will cover the mean plus or minus one standard deviation for every layer. The minimum value of C_v SHALL be 0.5. When insufficient data are available to address uncertainties in soil properties, ENSURE that C_v is taken as no less than 1.0.		Addressed in FR-C2.
	New probabilistic response analysis was conducted. The shear strain modulus coefficient of variation (COV) was 0.5 which results in 5% and 95% confidence values of shear modulus that envelop the requirements in the Standard. The probabilistic analysis is considered to meet the requirements of the Standard for Capability Category II.		

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

<table>
<tr><td colspan="4">Seismic Fragility Evaluation High Level Requirement D: Failure Modes

(HLR-FR-D): The seismic fragility evaluation SHALL be performed for critical failure modes of structures, systems and components such as structural failure modes and functional failure modes identified through the review of plant design documents, supplemented as needed by earthquake experience data, fragility test data, generic qualification test data, and a walkdown.</td></tr>
<tr><td>Index No. FR-D</td><td>Capability Category I</td><td>Capability Category II</td><td>Capability Category III</td></tr>
<tr><td rowspan="2">FR-D1</td><td colspan="3">IDENTIFY realistic failure modes of structures and equipment that interfere with the operability of equipment during or after the earthquake through a review of the plant design documents and the walkdown.</td></tr>
<tr><td colspan="3">Failure modes were determined primarily by review of plant seismic qualification information supplemented by walkdowns to identify any potential spatial systems interactions, fire and flood sources, or undesirable conditions in the essential components themselves. Failure modes for structures were determined from plant seismic qualification documentation and reviews of drawings. This requirement is considered to have been met for all Capability Categories.</td></tr>
<tr><td rowspan="2">FR-D2</td><td colspan="3">CONSIDER all relevant failure modes of structures (e.g., sliding, overturning, yielding, and excessive drift), equipment (e.g., anchorage failure, impact with adjacent equipment or structures, bracing failure, and functional failure) and soil (i.e., liquefaction, slope instability, excessive differential settlement), and EVALUATE fragilities for critical failure modes.</td></tr>
<tr><td colspan="3">Structural failure modes were determined from reviews of design documents, drawing review and comparison of new probabilistic loads to design loads. Inelastic energy absorption (ductility) was considered in defining structural fragility. The degree of inelastic energy absorption associated with the median capacity was based on the level of story drift at the onset of significant structural damage. The potential for liquefaction, slope instability and foundation bearing failure were considered in the structural fragility calculations. Equipment failure modes were based on the evaluation of seismic qualification reports and independent calculations of anchorage. Both functional failures and structural failures were addressed. The methodology and procedures used are considered to meet the requirements of the Standard for all Capability Categories.</td></tr>
</table>

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Seismic Fragility Evaluation High Level Requirement E: Walkdown (HLR-FR-E): The seismic fragility evaluation SHALL incorporate the findings of a detailed walkdown of the plant focusing on the anchorage, lateral seismic support, and potential systems interactions.			
Index No. FR-E	**Capability Category I**	**Capability Category II**	**Capability Category III**
FR-E1	CONDUCT a detailed walkdown of the plant, focusing on equipment anchorage, lateral seismic support and potential systems interactions.		
	A detailed walkdown was performed using the guidance of EPRI NP-6041 to identify potential vulnerabilities. The IPEEE tier 1 submittal refers to filling out SEWS sheets. A summary of findings is presented in the Tier 1 IPEEE submittal but there are no specific references cited for documentation of the walkdown. The relay walkdown was conducted in conjunction with the equipment walkdowns. A sampling process was conducted for relays. A specific walkdown was conducted for fire/flood interaction. The equipment walkdown included the identification of potential spatial systems interactions. The walkdowns conducted are considered to meet the requirements of the Standard for all Capability Categories.		
FR-E2	DOCUMENT the walkdown procedures, walkdown team composition, walkdown observations and conclusions.		
	The Tier 1 report does not reference any specific procedures document. The walkdown was guided by the procedures described in EPRI NP-6041. SEWS in conformance to EPRI NP-6041 were filled out. The walkdown teams were identified and were a combination of utility personnel and consultants. Findings are summarized in the Tier 1 IPEEE submittal but there is no reference in the Tier 1 report as to a detailed report on the walkdown. The IPEEE Tier 1 report documentation is considered to be an adequate description of the walkdown team, the procedures and the findings, but the detailed walkdown documentation is not referenced. *The NRC requested additional information regarding the walkdown screening and the walkdown documentation. SCE clarified that there was no initial screening of components based on the walkdown. The walkdown was performed to verify that the caveats and anchorage criteria specified in EPRI NP-6041 were met. The walkdown observations, along with the review of equipment qualification documentation, were used to determine the most vulnerable elements. Seismic fragilities were calculated for these elements. Components were not screened out until knowledge was gained from calculating a number of seismic fragilities and determining a screening capacity.* *The screening level was determined to be 8.0g spectral acceleration averaged over the frequency range of 1 Hz to 10 Hz. This corresponded to a seismic induced failure rate of about 1E-7/y. The USNRC requested examples of walkdown notes, photographs and fragility calculations which SCE provided. This demonstrated that the walkdown and screening were well documented. It just was not evident from the Tier 1 submittal. The walkdown is considered to have met the requirements of the Standard for all Capability Categories.*		

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Index No. FR-E	Capability Category I	Capability Category II	Capability Category III
FR-E3	If components are screened out during or following the walkdown, DOCUMENT anchorage calculations or some other basis justifying such a screening.		
	The IPEEE Tier 1 report alludes to the fact that components were screened out based on the walkdown plus the team's knowledge of the seismic qualification. The USNRC requested additional information on the screening. Refer to the description of the requested information and the SCE response in the discussion of FR-E2 above. The requirements of the Standard are considered to have been met for all Capability Categories.		
FR-E4	During the walkdown, FOCUS on the potential for seismic induced fire and flooding.		
	A separate walkdown was conducted for seismic induced fire and flooding. The fire and flood sources examined are listed in the Tier 1 IPEEE submittal. This requirement of the Standard is considered to have been met for all Capability Categories.		
	NOTE FR-E4: Seismically induced fires and floods are to be addressed as described in NUREG-1407 (NRC, 1991b). The effects of seismically induced fires and impact of inadvertent actuation of fire protection systems on safety systems should be assessed. The effects of seismically induced external flooding and internal flooding on plant safety should be included. The scope of the evaluation of seismically induced flood, in addition to that of the external sources of water (e.g., tanks, upstream dams), should include the evaluation of some internal flooding consistent with the discussion in Appendix I of EPRI NP-6041 (EPRI, 1991a).		
FR-E5	During the walkdown, EXAMINE potential sources of interaction (e.g., II/I issues, impact between cabinets, flooding and spray) and consequences of such interactions on equipment contained in the systems model.		
	The Tier 1 IPEEE submittal describes the walkdown for II/I, commodity clearance, inadvertent actuation of fire protection systems and summarizes the findings. This requirement of the Standard is considered to have been met for all Capability Categories.		

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

<table>
<tr><td colspan="4">Seismic Fragility Evaluation High Level Requirement F: Data Sources

(HLR-FR-F): The calculation of seismic fragility parameters such as median capacity and variabilities SHALL be based on plant specific data supplemented as needed by earthquake experience data, fragility test data and generic qualification test data. Use of such generic data SHALL be justified.</td></tr>
<tr><td>Index No. FR-F</td><td>Capability Category I</td><td>Capability Category II</td><td>Capability Category III</td></tr>
<tr><td rowspan="2">FR-F1</td><td colspan="2">BASE component seismic fragility parameters such as median capacity, and variabilities (logarithmic standard deviations reflecting randomness and uncertainty) on plant specific data supplemented as appropriate by earthquake experience data, fragility test data and generic qualification test data.</td><td>DEVELOP component fragility as a function of the local response parameter. DERIVE the joint probability distribution of the seismic capacities of different components.</td></tr>
<tr><td colspan="3">Fragility analysis was based on plant specific information. The only generic data used for development of fragilities was the EPRI GERS (EPRI, 1991b) for relays which are applicable to specific manufacturers, models and state. Fragilities were developed as a function of average spectral acceleration defined at the ground surface. The joint probability distribution of the seismic capacities of different components was not derived. The requirements of the standard for Capability Category II are considered to have been met.</td></tr>
<tr><td rowspan="2">FR-F2</td><td colspan="2">For all SSCs that appear in the dominant accident cutsets, ENSURE that they have site-specific fragility parameters which are derived based on plant-specific information, such as anchoring and installation of the component or structure and plant-specific material test data. Exception: JUSTIFY the use of generic fragility for any SSC as being appropriate for the plant.</td><td>For all SSCs that appear in the dominant accident cutsets, ENSURE that they have site-specific fragility parameters which are derived based on plant-specific information, such as anchoring and installation of the component or structure and plant-specific material test data.</td></tr>
<tr><td colspan="3">Fragilities that appear in dominant plant accident cutsets are developed from plant specific data. Capability Category III implies a requirement for plant specific material test data. This is not considered a practical requirement, but if such data are available, some uncertainty could be eliminated in the fragility analysis. This requirement is considered to have been met for Capability Category II.</td></tr>
</table>

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Index No. FR-F	Capability Category I	Capability Category II	Capability Category III
FR-F3	PERFORM screening to identify low ruggedness relays. DEVELOP seismic fragilities of essential low ruggedness relays.	DEVELOP seismic fragilities for relays identified to be essential and which are included in the systems analysis model.	
	The treatment of relays was very thorough in the SONGS SPRA. The circuits were examined and some 1300 essential relays were identified. Those that were determined to be chatter unacceptable (CU) or requiring operator action (OA) for recovery, were modeled in the nodal equations leading to nodes in the SET. Fragilities were developed for the CU relays. Human reliability analysis was performed for the operator actions utilizing performance shaping factors to increase the operator failure rate. The requirements of the Standard for Capability Category II are considered to have been met. Capability Category III would require that STRs FR-C6 and FR-F1 also be met.		
FR-F4	DEVELOP seismic fragilities for SSCs that are identified in the systems model as playing a role in the LERF part of the SPRA. (See REQ. SA-A1 and REQ. SA-A3.)		
	The SEL contained components associated with LERF and fragilities were developed for those components that were not screened out on the basis of their seismic ruggedness. This requirement is considered to have been met for all Capability Categories.		

Table 4-3
Comparison of the SONGS Procedures used in Development of Fragilities with the Technical Requirements of the Standard (Continued)

Seismic Fragility Evaluation High Level Requirement G: Documentation			
(HLR-FR-G): The seismic fragility evaluation SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.			
Index No. FR-G	**Capability Category I**	**Capability Category II**	**Capability Category III**
FR-G1	MEET the general documentation requirements in Section 7.		
	The Tier 1 report for IPEEE meets the requirements of NUREG-1407 and the general requirements of Section 7 of the Standard. This requirement is met for all Capability Categories.		
FR-G2	DESCRIBE the methodologies used to quantify the seismic fragilities of SSCs, together with key assumptions.		
	The specific methods used to develop fragilities are not discussed in detail in the Tier 1 submittal for IPEEE. Reference is made to EPRI TR-103959 for fragility methodology. In a USNRC Request for Additional Information, fragility calculations were requested and supplied by SCE. All fragility calculations have calculation numbers assigned and were performed under a QA program, thus the calculations themselves, the methodology and results are well documented and retrievable in the SCE engineering files. This requirement is considered to have been met for all Capability Categories.		
FR-G3	PROVIDE a detailed list of SSC fragility values that includes the method of seismic qualification, the dominant failure mode(s), source of information, and the location of the component. PROVIDE the fragility parameter values (i.e., median acceleration capacity, β_R and β_U) and the technical bases for them for each analyzed SSC.		
	The Tier 1 IPEEE submittal lists all 600 components on the SEL and either states that they were screened on the basis of meeting the 8.0g Sa median capacity value for screening or else lists fragilities. The median value and the β_R *and* β_U *value are provided. It would be necessary to go to the calculations or other documents to determine the location of the component, the failure mode, method of seismic qualification and the source of fragility information. This documentation exists but is not specifically referenced in the Tier 1 submittal report. The intent of this requirement is considered to be met for Capability Category III even though there is not a clear roadmap to the source of all of the information that the Standard specifies to be included in the documentation.*		
FR-G4	DOCUMENT the different aspects of seismic fragility analysis, such as the seismic response analysis, the screening steps, the walkdown, the review of design documents, the identification of critical failure modes for each SSC, and the calculation of fragility parameter values for each SSC modeled.		
	The documentation is in full compliance with the requirements of NUREG-1407, thus is considered to meet the intent of this requirement in the Standard.		

4.6 Summary of SONGS SPRA Compliance with the Standard

The SONGS SPRA was one of the most thorough evaluations conducted for IPEEE. The high seismic hazard at the site required a state of the art seismic hazard study and emphasis on plant specific seismic qualification data rather than the typical seismic experience based screening and use of generic data in the development of fragilities. The study is considered to meet the requirements of Capability Category I and almost all of the requirements of Capability Category II. Many of the technical requirements are the same for all Capability Categories and in these cases, the requirements are almost universally met. The hazard analysis is considered to meet the requirements of Capability Category II.

The systems analysis requirements of SA-B3, SA-E4, SA-E6 that dependencies and correlations be evaluated in the screening process and the risk quantification and be included in the sensitivity analyses were not specifically addressed. It has been standard practice in SPRAS to assume that all like components in redundant safety trains are dependent, thus if one fails the other fails. This is conservative since the assumption completely negates any benefit of redundancy of parallel safety systems. For components that are not alike, it is assumed that they are totally independent. Since it is the same earthquake defining the demand on the components, there is some degree of correlation and this assumption could potentially be unconservative. If components that dominant seismic risk are totally different in design, are located in different structures, and have different dynamic response characteristics, the assumption of independence appears reasonable. On the other hand, if for instance, switchgear, motor control centers and control cabinets, all located in an auxiliary building, have equal contribution to CDF, and they have similar dynamic characteristics, there is a significant degree of correlation in their response to an earthquake and the assumption of independence may not be justified. Sensitivity studies could put bounds on the sensitivity to correlation.

The standard states that generic correlations and dependencies may be used for Capability Category I and II if justified. The correlations assumptions incorporated in the study can be considered to be generic. In this respect, the SONGS SPRA did not specifically examine the sensitivity of the correlation assumptions in the screening or in the final CDF and LERF results and therefore does not specifically meet these technical requirement of the Standard for any of the Capability Categories.

It would seem logical that there should be some gradation in the level of assessing correlation between Capability Categories. Category I should logically be what is commonly done regarding correlation, as was the case for SONGS and all other IPEEE SPRA submittals. Capability Category II should then require that the sensitivity studies be preformed and capability Category III should require a rigorous modeling of correlation. With these suggestions, SONGS would comply with Capability Category I and could be upgraded to Capability Category II with some sensitivity studies that quantify the effects of correlation assumptions on the computed CDF and LERF. A rigorous treatment of correlations is not currently a practical requirement for two reasons. First, there is little background and experience on correlation of seismic failures. Assignment of partial correlation on response and capacity would be subjective. Second, the software to treat partial correlation of seismic failures is not publicly available. If there is a need to address partial correlation for future risk informed applications, the technology and software will evolve. Currently, meeting this requirement in a rigorous sense is difficult. As the standard now reads, requirements SA-B3, SA-E4 and SA-E6 were not met for any of the Capability Categories.

Technical requirement SA-E5 requires that a full uncertainty analysis of CDF and LERF be conducted for Capability Categories II and III. The uncertainty analysis would incorporate the combined uncertainty in the seismic hazard, the fragilities and the system modeling. The SONGS SPRA was focused on meeting the requirements of NUREG-1407 that only required a point estimate of CDF. NUREG-1407 requirements would comply with Capability Category I. Sensitivity studies were conducted for the seismic hazard and for the Performance Shaping Factors used in the HRA of operator action, but a full uncertainty analysis was not conducted that integrated all uncertainties together. Thus, Capability Category I was achieved in the systems analysis and many, but not all, requirements of Capability Category II were met.

SA-F2 requires that the specific adaptation made in the internal-events PRA model to produce the SPRA model be described. The Tier 1 IPEEE report summarizes this but is not specific, thus, the extent of meeting this requirement is marginal. No reference is made of supporting Tier 2 reports that would describe this adaptation in more detail.

The fragility analysis of unscreened components was based on plant specific information and Generic Equipment Ruggedness Spectra in the case of some relays. The overall development of fragilities appears to be well done. However, STRs FR-G2 through FR-G4 require a lot of detailed documentation of the development of fragilities, failure modes, data sources, etc. that is not provided in the Tier 1 IPEEE submittal nor are the supporting calculations listed or referenced. The USNRC requested additional information in this respect and it was supplied by SCE and accepted by USNRC. Thus, the documentation requested by the Standard is available in the SCE files but it was not clearly referenced in the Tier 1 submittal report.

The peer-review requirements in the Standard are more stringent than the requirements in NUREG-1407 which set forth the requirements for IPEEE. The SONGS seismic hazard development was peer-reviewed by three experts who were independent of the hazard analysis process and the peer-review requirements of the Standard are considered to have been met for the hazard portion of SPRA. The systems analysis, including the human reliability analysis, was peer reviewed by in house operations personnel and PRA experts who were independent of the SPRA modeling and quantification. From the description of the peer review of systems analysis in the Tier 1 report, it is concluded that the documentation of the peer-review is weak relative to the requirements in the Standard. The fragility analysis and walkdowns were preformed jointly by in house SCE staff and EQE International, a contractor. It is stated in the Tier 1 report that the two organizations reviewed each other's work but is does not appear that the reviews were conducted by experts independent of the teams conducting the walkdowns and developing fragilities. An independent consultant performed a peer-review of the development of probabilistic response spectra and a focused review of a sample of the fragility calculations. The makeup of the review teams and the peer-review conclusions are contained in the Tier 1 IPEEE report. In general, the intent of the Standard appears to have been met but the documentation of the peer-review was sparse, thus the actual depth of the independent review of systems analysis and fragility analysis is not clear.

Overall, it is concluded the SONGS SPRA meets the requirements of Capability Category I and in most cases Capability Category II. In order to comply with all technical requirements of Capability Category II, a full uncertainty analysis would be required that includes the uncertainties in the seismic hazard, the uncertainty in the fragilities and uncertainty in the HRA. In addition, a complete sensitivity study would be required to address the affect of correlation assumptions on the computed CDF and LERF. The level of documentation would also have to be enhanced to summarize the information requested in the Standard, or to clearly list or reference all supporting Tier 2 documentation and to expand on the peer-review conducted.

5
SURRY SPRA

5.1 Overview of Surry SPRA

Surry Units 1 and 2 are 855 MWe maximum electrical output, Westinghouse 3 loop PWRs. The containment is a dry type steel lined reinforced concrete structure that operates at sub-atmospheric conditions. The plant is located in Gravel Neck, VA on the James River, about 17 miles NW of Newport News, VA. The two units began operation in 1972 and 1973 respectively.

The plant was originally designed for a Housner spectral shape anchored to 0.15g PGA for the DBE. NUREG-1407 binned the plant into the 0.3g focused scope category. Virginia Electric and Power Company (VEPCO) elected to conduct a SPRA for satisfaction of the seismic requirements of the IPEEE. Surry was also an A-46 plant and the IPEEE and A-46 programs were combined to optimize the walkdown screening and calculations.

The Surry SPRA included fire-seismic interaction, seismic induced flooding and seismic induced inadvertent actuation of fire protection systems. Relay performance was not modeled in the SPRA. Surry was a focused scope plant and NUREG-1407 only required a search for low capacity relays. In the A-46 program, only one type of low capacity relay was found. It was in the diesel generator field flash circuit. This type of relay was scheduled for replacement. The plant confirmed that this type of relay was not in any other circuits, so no further investigation of relay performance was conducted for IPEEE.

The system response to seismic events was modeled by a seismic event tree (SET) as shown in Figure 5-1. The SET was used to define accident sequences that led directly to core damage or to degraded plant states. The IPE internal events model was used to develop nodal equations for nodes in the event trees that included non-seismic failures arising from random failure and human error. The seismic modeling and risk computation was conducted by in-house personnel aided by consultants. Because the plant was designated a focused scope plant, relay performance was not modeled in the SPRA. Many components were screened out on the basis of seismic ruggedness. The screening level HCLPF was 0.3g PGA that corresponded to a seismic failure rate of 1.15 E-6/y. The overall mean core damage frequency was calculated to be 8.2E-6/y and was governed by failure of the turbine building and loss of offsite power combined with non-seismic failure of the emergency diesel.

Containment performance was evaluated to the extent that all components that could lead to containment failure or bypass were found to be seismically rugged. The SET shows one accident sequence resulting from failure of the turbine building that leads directly to loss of the heat sink thus, core damage and containment failure.

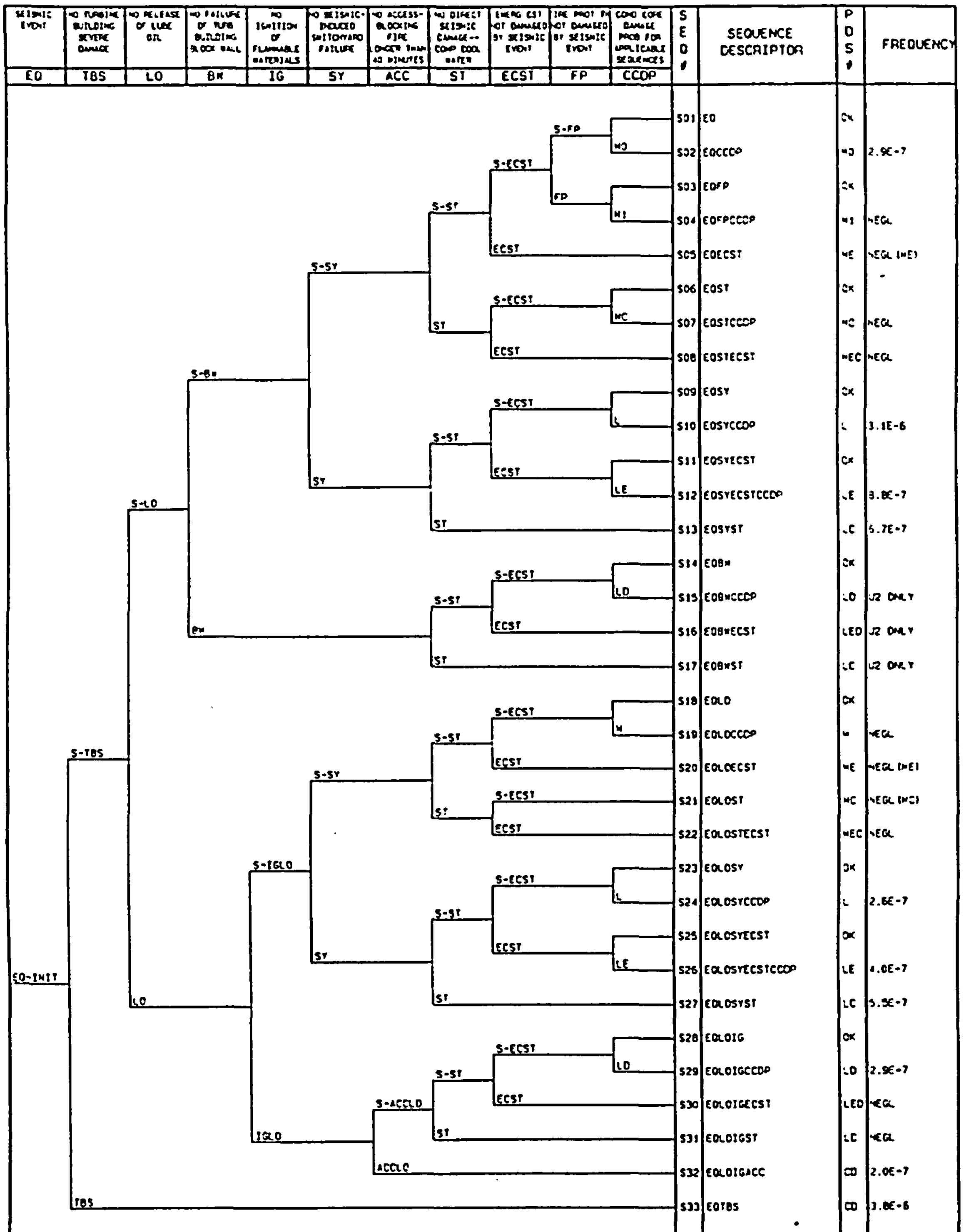


Figure 5-1
Surry Seismic Event Tree

5.2 Seismic Hazard

The Surry site was included in the LLNL (USNRC, 1994) and EPRI (EPRI, 1989a) hazard studies conducted for NPPs in the Central and Eastern U.S., thus a plant specific seismic hazard study was not necessary for the IPEEE. NUREG-1407 required that the LLNL seismic hazard be used for SPRA, however, VEPCO, as well as many other plants elected to utilize the EPRI hazard as the base case and conduct sensitivity studies regarding the effect of the LLNL hazard. IPEEE required, as a minimum, that the mean core damage frequency be calculated utilizing the mean hazard curve and 2 parameter (median and composite logarithmic standard deviation) fragility curves. The EPRI and LLNL hazard are defined in terms of peak ground acceleration vs. frequency of occurrence. Surry is a deep soil site and the hazard control point is specified in the free field. The SSE for Surry is 0.15g PGA. The frequency of occurrence of 0.15g from the EPRI mean hazard is about 1.2E-4/y.

In addition to the PGA hazard, uniform hazard spectra were provided for 1E-3, 2E-4, 1E-4 and 1E-5 annual probabilities of occurrence. The UHS are similar in shape and typically the 1E-4/y median UHS is selected as the ground motion spectral shape for evaluating the response of structures. Typical Eastern U.S. UHS have high amplification at high frequency. Because Surry is a deep soil site, some of the high frequency is filtered and the peak of the UHS is at 10 Hz. This is not typical of design spectra, such as contained in RG 1.60, that contain significant low frequency amplification. The higher frequency content in the UHS is less damaging than a lower frequency spectral shape anchored to the same PGA, therefore, it would be expected that structures and components designed for 0.15g PGA for a lower frequency ground motion spectral shape would have significant margin relative to the UHS.

5.3 Structural Response

Surry is a soil site. The original design basis ground motion spectra were different in shape than the UHS and the original SSI analysis was conducted using simple soil springs and dampers. It was not reasonable to attempt to scale the design response to reflect the structural response for the IPEEE hazard. Therefore, a probabilistic analysis of the structural response was conducted for the safety related structures housing equipment of interest. The turbine building was not originally designed for seismic loading and a more simplified response to earthquakes was conducted by comparing the seismic demand to an existing analysis for wind loading.

In the probabilistic analysis of structural response, a Latin Hypercube stratified sampling technique was used. Thirty natural and artificial time histories were scaled such that their median and 85th percentile response spectra closely matched the median and 85th percentile UHS for the site. Other important variables in the calculation of response to a time history input are the structural stiffness and damping and soil stiffness and damping. The distribution on these variables was divided into 30 equal increments. In the Latin Hypercube stratified sampling procedure, the combination of the earthquake time history and the structural and soil variables are selected randomly. Once a variable is used, it is eliminated, thus the 30 time history analyses are combined with all of the available structural and soil stiffness and damping variables. Statistics are then performed on the results to develop median and 85th percentile in-structure response spectra and loads.

This process was repeated for a UHS anchored to the 0.15g PGA level of SSE, two times the SSE and three times the SSE. As the seismic level increases, the soil properties change, thus in this manner, the probabilistic response most appropriate for the capacity of the element being evaluated can be selected.

5.4 Modeling of System Response and Quantification

The approach taken for the SPRA was to develop a seismic event tree (SET) in a hierarchy of failures such that the weakest events that could directly lead to core damage appear first in the event tree after the occurrence of an earthquake. The internal events IPE model was initially utilized to develop a seismic equipment list (SEL). In addition to the IPE list of basic events, structures and components that are passive, that were not modeled in the IPE due to their low random failure rates, were added to the SEL. Also, supporting system components (electrical cabinets, racks etc.) and certain components based on the USI A-46 equipment list were added. Many basic events in the IPE model were also deleted due to the fact that they rely on offsite power to function. Since offsite power is one of the lowest seismic capacity elements, it would govern the unavailability of these deleted components. The SEL was then walked down and most components were screened out based on their generic ruggedness or based on subsequent calculations. The final construction of the SET was then based on the seismic capacity of the components that were not screened out. The internal event models were pruned to eliminate initiating events that are not applicable to the seismic event tree logic. For cases where an operator action was necessary for success in a branch of the SET, the human reliability factors from the IPE model were modified to reflect stress on operator actions due to earthquakes.

For each node in the SET, nodal equations (Boolean expressions) were developed that represent the seismic failures and the non-seismic failures, including human error, obtained from the modified internal events model. These equations were used to develop the seismic sequence equations and quantify the SET. Each seismic sequence equation represents the Boolean logic associated with its corresponding seismic damage state (SDS). The Booleans for each SDS were then input into a computer program that integrates the seismic hazard curve and seismic fragilities to compute the unconditional core damage frequency for each sequence.

The 0.3g PGA screening level for screened out structures and components resulted in an unconditional seismic induced failure rate of a single screened-out element of 1.15 E-6/y. The total CDF was calculated to be 8.2E-6/y, not including the contribution of the screened-out elements. The dominant contributor to seismic risk was failure of the turbine building with the assumption that the isolation valves from the intake canal do not automatically close due to failure of control cabling in the turbine building and the assumption that building damage would preclude an operator from manually closing the valves in the critical time period. Failure to close the valves causes the intake canal to drain and starve the plant from cooling water. This accident sequence accounted for 36% of the calculated CDF. The next most dominant scenario involves loss of offsite power followed by random and human failure associated with the diesel generator or RHR valve alignment in containment. This scenario, which consists of two accident sequences, contributed 32 % of the CDF. Note that at Surry each unit has one dedicated emergency diesel generator and a swing diesel that can be aligned to either unit. In addition, there is a Station blackout diesel that is not seismically qualified. In the loss of offsite power sequence for Unit 1, the Station blackout diesel was conservatively assumed to be not available.

The CDF for Unit 2 with the swing diesel aligned was not quantified, but would be smaller than Unit 1 because the third diesel is preferentially assumed to connected to Unit 2 rather than Unit 1.

5.5 Comparison of SPRA Requirements in the Standard to the Surry IPEEE SPRA Submittal

5.5.1 Development of Seismic Hazard

The seismic hazard utilized for the Surry SPRA was defined by the EPRI study (EPRI, 1989a). The methodology used by EPRI contractors in development of the ground motion for 57 Central and Eastern U.S. NPPs generally follows the requirements of the Standard for Capability Category II. Surry is a deep soil site. In the EPRI seismic hazard study, the attenuation equations used were applicable to the rock beneath the soil column. Site amplification factors to transform the ground motion predicted at rock to the surface of the soil column were developed using an equivalent linear dynamic analysis and the final definition of the hazard was applicable to the free field. In the EPRI hazard study, the site amplification factors were all computed assuming a sand-like soil profile. For sand-like soil profiles, the shear wave velocity was assumed to vary with depth and the soil modulus was considered to be strain dependent. Thus, the hazard study for the Surry site contained a generalized site amplification and was not site specific. Note that for the development of the San Onofre hazard, as discussed in Section 4.5.1, attenuation equations were selected that were applicable for deep soil sites, and the hazard was computed directly for the free field. Though the Surry study is not site specific, the hazard defined for the site is believed to be a reasonable representation developed using state of the art methodology and accounting for uncertainties. It is noted though that the EPRI hazard, as well as the LLNL hazard, is defined for the horizontal ground motion only. No specific vertical ground motion uniform hazard spectra or correlation of horizontal and vertical PGA are provided. The standard does not specifically address vertical vs. horizontal ground motion, and it is assumed that the requirements apply to both directions. In this respect, the EPRI hazard study does not meet the Standard for any of the Capability Categories. This is discussed further in Section 5.6 and in the Section 6.0 Conclusions. Table 5-1 compares the supplemental technical requirements of the Standard to the applicability of the use of the EPRI derived hazard and notes the Capability Category to which the hazard study is considered to conform.

5.5.2 Systems Analysis

Table 5-2 compares the systems modeling and quantification conducted for the Surry SPRA to the Systems Analysis technical requirements in the Standard. A determination is made as to which Capability Category is met for each of the technical requirements.

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis

<table>
<tr><td colspan="4">Seismic Hazard Analysis High-Level Requirement A: Scope

(HLR-HA-A): The frequency of earthquakes at the site SHALL be based on a site-specific probabilistic seismic hazard analysis (PSHA) (existing or new) that reflects the composite distribution of the informed technical community. The level of analysis SHALL be determined based on the intended application and on site-specific complexity.

Note: The need for determining the composite distribution is discussed in (Budnitz et al., 1997.) Existing LLNL (USNRC, 1993) and EPRI (EPRI, 1989a) hazard studies and many hazard studies conducted for plant-specific PRAs also meet this overall requirement, subject to updating as necessary. (See Requirement HLR-HA-H below.)</td></tr>
<tr><th>Index No. HA-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>HA-A1</td><td>In performing the PSHA, BASE it on, and MAKE IT CONSIST of, the collection and evaluation of available information and data; consideration of the uncertainties in each element of the PSHA; and a defined process and documentation to make the PSHA traceable.</td><td colspan="2">In performing the PSHA, BASE it on, and MAKE IT CONSIST of, the collection and evaluation of available information and data; evaluation of the uncertainties in each element of the PSHA; and a defined process and documentation to make the PSHA traceable.</td></tr>
<tr><td></td><td colspan="3">The EPRI Study was based on the available data on geology, tectonics and response records. Since there is much less recorded history in the Eastern U.S. than for California and other more active regions, the data and methodology utilized are considered to be the best available for the study. The EPRI effort was comprised of 6 teams of experts in geology, seismology and geophysics and represents the state of the art in data gathering and interpretation and methodology used to process the data to predict the seismic hazard at the site. This effort is considered to meet the requirements of the Standard for Capability Category III.</td></tr>
</table>

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Index No. HA-A	Capability Category I	Capability Category II	Capability Category III
HA-A2	As the parameter to characterize both hazard and fragilities, USE the spectral accelerations, or the average spectral acceleration over a selected band of frequencies, or peak ground acceleration. In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are of interest and are dominant contributors to the PRA results and insights.	As the parameter to characterize both hazard and fragilities, USE the spectral accelerations, or the average spectral acceleration over a selected band of frequencies. In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are of interest and are dominant contributors to the PRA results and insights.	
	The hazard was defined in the form of mean and fractile peak ground acceleration vs. frequency of occurrence out to 0.8g for the mean and to about 0.6g for the median. Uniform hazard spectra were also developed from 1E-3/y to 1E-5/y. The fragilities would have to be developed relative to peak ground acceleration for the hazard description provided. The definition of the hazard complies with Capability Category II.		
HA-A3	In developing the PSHA results, whether they are characterized by spectral accelerations, peak ground accelerations or both, EXTEND them to large enough values (consistent with the physical data and interpretations) so that the final numerical results, such as core damage frequency, reflect accurate estimates of risk, and the delineation and ranking of seismic-initiated sequences are not affected.		
	In the IPEEE SPRA, only a point estimate of CDF was required and the mean PGA hazard was used. The hazard was extrapolated to 1.0g for the study. This corresponds to about 1.5E-7 frequency/y of occurrence and is well beyond the assumed median capacity of the screened out components. NUREG-1407 states that the hazard must be extended to 1.5g unless it is justified that a lower cutoff value will not significantly alter the results. The extension to 1.0g at a frequency of 1.5E-7/y was considered to be sufficient so as to not affect the calculated results. This treatment of the hazard is considered to meet the Standard requirements for all Capability Categories.		
HA-A4	**SPECIFY a lower bound magnitude for use in the hazard analysis, such that earthquakes of magnitude less than this value are not expected to cause significant damage to the engineered structures or equipment.**		
	The EPRI hazard study incorporated a lower bound magnitude of 5, which was justified in a comprehensive study in support of the EPRI hazard program and accepted by the USNRC. The requirements of the Standard for all Capability Categories is considered to have been met.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement B: Data Collection

(HLR-HA-B): To provide inputs to the PSHA, a comprehensive up-to-date data base including geological, seismological, and geophysical data; local site topography; and surficial geologic and geotechnical site properties SHALL be compiled. A catalog of historical, instrumental, and paleoseismicity information SHALL also be compiled.

Index No. HA-B	Capability Category I	Capability Category II	Capability Category III
HA-B1	In performing the PSHA, BASE it on available or developed geological, seismological, and geophysical data bases that reflect the current state-of-the-knowledge, and that are used by experts/analysts to develop interpretations and inputs to the PSHA.	*In performing the PSHA, BASE it on available and developed comprehensive geological, seismological, and geophysical databases that reflect the current state-of-the-knowledge, and that are used by experts/analysts to develop interpretations and inputs to the PSHA.*	
	For most sites, including Surry, available data was used in the prediction of seismic hazard. Since the EPRI study for Surry was not site specific, "developed comprehensive" data was not used for all parameters of the study. Primarily, the site amplification factors were generic rather than base on the actual soil profile. In this case, the EPRI hazard study clearly meets the requirements for Capability Category I and could be considered to meet the intent of Capability Category II but not Capability Category III.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Index No. HA-B	Capability Category I	Capability Category II	Capability Category III
HA-B2	ENSURE that the data base and information used are adequate to characterize all credible seismic sources that may contribute to the frequency of occurrence of vibratory ground motion at the site, considering regional attenuation of ground motions and local site effects. If the existing PSHA studies are to be used in the SPRA, ENSURE that any new data or interpretations that could affect the PSHA are adequately incorporated in the existing databases and analysis.	ENSURE that the size of the region to be investigated and the scope of investigations is adequate to characterize all credible seismic sources that may contribute to the frequency of occurrence of vibratory ground motion at a site, considering regional attenuation of ground motions and local site effects. If the existing PSHA studies are to be used in the SPRA, ENSURE that the investigations are of sufficient scope to determine whether there are new data or interpretations that are not adequately incorporated in the existing databases and analysis.	
	The size of the region was taken as a 200 km radius as requested by the USNRC. In addition, certain large faults within 500 km radius were included. An existing hazard study (EPRI 1989a) was utilized for the SPRA. There were no new investigation of data or interpretations by the utility before using the existing hazard in the SPRA. While, the prediction of seismic hazard is a continuously evolving technology, no significant new data or interpretations had been documented at the time of the SPRA, therefore, it is concluded that this technical requirement has been fulfilled for Capability Category III.		
HA-B3	As a part of the database used, INCLUDE a catalog of historically reported, geologically identified, and instrumentally recorded earthquakes. USE (USNRC, 1997b) requirements or equivalent.	As a part of data collection, COMPILE a catalog of historically reported, geologically identified, and instrumentally recorded earthquakes. USE (USNRC, 1997b) requirements or equivalent.	
	The six teams of experts that performed the EPRI hazard study used available catalogues of data. Some more recent earthquakes that occurred in the northeastern U.S. were integrated into the study. It is considered that the study at the time met the intent of capability Category III.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement C: Seismic Sources and Source Characterization			
To account for the frequency of occurrence of earthquakes in the site region, the seismic sources with the PSHA's hazard model SHALL consider all credible sources of potentially damaging earthquakes. For the purpose of characterizing the occurrence rates for those seismic sources, all earthquakes greater than magnitude 3 SHALL be considered. Both the aleatory and epistemic uncertainties SHALL be considered in characterizing the seismic sources.			
Index No. HA-C	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-C1	In the PSHA, CONSIDER all potential sources of earthquakes that affect the probabilistic hazard at the site. BASE the identification and characterization of seismic sources on regional and site geological and geophysical data, historical and instrumental seismicity data, the regional stress field, and geological evidence of prehistoric earthquakes.		
	The EPRI hazard study considered all potential sources within 200 km of the site. Specific sources with high-energy release potential were included if they were within 500 km of the site. This requirement for Capability Category III is considered to have been met.		
HA-C2	ENSURE that any expert elicitation process used to characterize the seismic sources is compatible with the level of analysis discussed in Req. HA-A, and FOLLOW a structured approach.		
	Six teams of experts were utilized in the hazard study and each team was weighted equally. This requirement is considered to have been met for all Capability Categories.		
HA-C3	The seismic sources are characterized by source location and geometry, maximum earthquake magnitude, and earthquake recurrence. ENSURE that the total uncertainties in these characterizations are accounted for.	The seismic sources are characterized by source location and geometry, maximum earthquake magnitude, and earthquake recurrence. INCLUDE the aleatory and epistemic uncertainties explicitly in these characterizations.	
	The aleatory and epistemic uncertainties were included in the seismic sources. This requirement is met for all Capability Categories.		
HA-C4	If an existing PSHA study is used, SHOW that any seismic sources that were previously unknown or uncharacterized are not significant, or INCLUDE them in the update of the hazard estimates.		
	At the time of the EPRI hazard study, all known seismic sources and postulated area sources were included. The Utility did not conduct further investigation prior to using the hazard in the SPRA. However, there was no known evidence of any new sources. This requirement is considered to have been met for at least Capability Category II.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement D: Ground Motion Characterization

(HLR-HA-D): The PSHA SHALL account for all credible mechanisms influencing estimates of vibratory ground motion that can occur at a site given the occurrence of an earthquake of a certain magnitude at certain location. Both the aleatory and epistemic uncertainties SHALL be considered in characterizing the ground motion propagation.

Index No. HA-D	Capability Category I	Capability Category II	Capability Category III
HA-D1	ACCOUNT in the PSHA for (a) all credible mechanisms governing estimates of vibratory ground motion that can occur at a site, and for (b) regional and site-specific geological, geophysical, and geotechnical data and historical and instrumental seismicity data (including strong motion data).		
	Three attenuation equations were used in the study that were determined to be the most representative for the propagation of the sources to the site. The equations fell into the categories of "Calibrated Theoretical Models" and "Semi Theoretical Models, also called Semi Empirical Methods." The selection of attenuation equations was made by comparing the accuracy of many candidate equations with observed attenuation of earthquakes in similar geological structures. One of the equations was weighted 50% and the other two were weighted 25% each. Weighting was done based on applicability and accuracy of the equations. The selection of the three representative attenuation equations is considered to meet all Capability Category requirements to define horizontal motions. However, the vertical motion was not developed, consequently, considering the concept of a graded approach, the hazard prediction at the site is judged to meet Capability Category I.		
HA-D2	ENSURE that any expert elicitation process used characterize the ground motion is compatible with the level of analysis discussed in Req. HA-A, and FOLLOW a structured approach.		
	The attenuation equations were selected by the teams of experts as the best calibration to available data. This approach is considered to meet Capability Category III for horizontal hazard but, the vertical motion was not addressed, thus it is judged that only Capability Category I was met.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Index No. HA-D	Capability Category I	Capability Category II	Capability Category III
HA-D3	*ENSURE that all of the uncertainties in the ground motion characterization are accounted for.*	*ADDRESS both the aleatory and epistemic uncertainties in the ground motion characterization in accordance with the level of analysis identified for REQ. HA-A.*	
	The ground motion attenuation equations were assigned a standard deviation representing aleatory uncertainty. The use of three attenuation equations represents the epistemic uncertainty. This modeling process is considered to meet the requirements for Capability Category III for horizontal motions. However, vertical motion was not developed. Consequently, considering the concept of a graded approach, the hazard prediction at the site is judged to meet Capability Category I.		
HA-D4	If an existing PSHA study is used, SHOW that any ground motion models or new information that were previously unused or unknown are not significant, or INCLUDE them in the update of the hazard estimates.		
	No additional evaluation of ground motion models was conducted in the IPEEE SPRA. At the time of the EPRI study, the six teams of experts examined all available attenuation equations and the three selected were the ones given the most weight for application to the Central and Eastern U.S. sites. There was no indication in the industry that these attenuation equations were not still applicable at the time of the SPRA. This requirement is considered to have been met for at least Capability Category II for horizontal motion. However, since vertical motion was not addressed, and considering the concept of a graded approach, the hazard prediction at the site is judged to meet Capability Category I.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement E: Local Site Effects (HLR-HA-E): The PSHA SHALL account for the effects of local site response.			
Index No. HA-E	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-E1	DEMONSTRATE that the PSHA accounts for the effects of site topography, surficial geologic deposits, and site geotechnical properties on ground motions at the site.	ACCOUNT in the PSHA for the effects of site topography, surficial geologic deposits, and site geotechnical properties on ground motions at the site.	
	The attenuation equations used were appropriate for propagation through rock. Local site response was conducted by conducting equivalent linear dynamic analysis of the response of the soil column. The Surry site was classified as a deep soil site (Soil Condition V). The site amplification factors were based on a sand-like soil. For the sand-like soil the shear wave velocity was specified as a function of depth. The strain dependency of the shear wave modulus and soil damping was also taken into account. In the LLNL studies, both sandy-like soils and till-like soils were considered. EPRI compared their site amplification factors to those of LLNL and concluded that for the deep soil sites (soil type V) that their amplification factors were conservative relative to the LLNL factors. EPRI varied the soil shear modulus and determined that the coefficient of variation in site amplification was about 0.3. This COV is considered to envelop the difference in site amplification that may occur for the Surry specific soil conditions vs. the generic sand-like properties used in the EPRI site amplification factors. It is considered that the site amplification analysis meets the intent of at least capability Category II for horizontal motions. However since vertical motion was not addressed, it is judged that only Capability Category I was met.		
HA-E2	**ENSURE that all of the uncertainties in the local site response analysis are accounted for.**	**ADDRESS both the aleatory and epistemic uncertainties in the local site response analysis.**	
	The site amplification factors for horizontal motion were developed for three cases of shear wave velocity. It was determined that the COV due to uncertainty in soil shear modulus and other parameters, thus shear wave velocity, was about 0.3. This COV lumps the aleatory and epistemic uncertainties. This portion of the hazard study is considered to meet Capability Category I, and could be considered to meet the intent of Capability Category II for horizontal motions. Since vertical motion was not addressed, the overall hazard study is considered to meet Capability Category I.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

<table>
<tr><th colspan="4">Seismic Hazard Analysis High-Level Requirement F: Aggregation and Quantification

(HLR-HA-F): Uncertainties in each step of the hazard analysis SHALL be propagated and displayed in the final quantification of hazard estimates for the site. The results SHALL include fractile hazard curves, median and mean hazard curves, and uniform hazard response spectra (UHS). For certain applications, the PSHA SHALL include seismic source deaggregation and magnitude-distance deaggregation.</th></tr>
<tr><th>Index No. HA-F</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">HA-F1</td><td>In the final quantification of the seismic hazard, INCLUDE mean estimates. ADDRESS how this accounts for uncertainties.</td><td colspan="2">In the final quantification of the seismic hazard, INCLUDE and DISPLAY the propagation of both aleatory and epistemic uncertainties.</td></tr>
<tr><td colspan="3">The final analysis and definition of the hazard included the aleatory and epistemic uncertainties in the seismic sources and attenuation equations for horizontal motion. The site amplification factors apparently incorporated the combined aleatory and epistemic uncertainty. Mean and fractile hazard was defined as PGA vs. frequency and UHS for frequencies from 1E-3/y to 1E-5/y. Capability Category I has been met and the intent of Capability Category II is considered to have been met for horizontal motion. If site-specific amplification factors were developed, considering the both the aleatory and epistemic uncertainty in the soil column response, then the requirements of Capability Category II would clearly be met for the horizontal motion. However, vertical motion was not addressed so it is judged that only Capability Category I was met.</td></tr>
<tr><td rowspan="2">HA-F2</td><td colspan="3">In the PSHA, INCLUDE appropriate sensitivity studies and intermediate results to identify factors that are important to the site hazard and that make the analysis traceable.</td></tr>
<tr><td colspan="3">Throughout the EPRI hazard study, sensitivity studies were conducted for the variables contributing to the site hazard. This was a major research program that was state of the art and employed six teams of experts, who explored the effects of uncertainties in the important variables. Several interim reports and a final report were developed that document the progress and sensitivity studies conducted.
This requirement is considered to have been met for all Capability Categories for horizontal motions. Vertical motion was not addressed, thus only Capability Category I is considered to have been met.</td></tr>
</table>

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Index No. HA-F	Capability Category I	Capability Category II	Capability Category III
HA-F3	DEVELOP the following results as a part of the quantification process, compatible with needs for the level of analysis determined in HLR-HA-A: • Mean hazard curves for peak ground acceleration and spectral accelerations; • Mean UHS.	DEVELOP the following results as a part of the quantification process, compatible with needs for the level of analysis determined in HLR-HA-A: • Fractile and mean hazard curves for each ground motion parameter considered in the PSHA; • Fractile and mean UHS.	DEVELOP the following results as a part of the quantification process, compatible with needs for the level of analysis determined in HLR-HA-A: • Fractile and mean hazard curves for each ground motion parameter considered in the PSHA; • Fractile and mean UHS; • Magnitude-distance deaggregation for the median and mean hazard; • Seismic source deaggregation; • Mean magnitude and distance.
	Fractile and mean PGA and UHS were developed. This complies with Capability Category II.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement G: Spectral Shape			
(HLR-HA-G): For further use in the SPRA, the spectral shape SHALL be based on a site-specific evaluation taking into account the contributions of deaggregated magnitude-distance results of the PSHA. Broadband, smooth spectral shapes, such as those presented in NUREG/CR-0098 (Newmark and Hall, 1978) (for lower-seismicity sites such as most of those east of the U.S. Rocky Mountains) MAY also be used taking into account the site conditions. The use of existing UHS is acceptable unless evidence comes to light that would challenge these UHS spectral shapes.			
Index No. HA-G	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-G1	ENSURE that the spectral shape used in the SPRA reflects or bounds the site-specific considerations.	BASE the response spectral shape used in the SPRA on site-specific evaluations performed for the PSHA. REFLECT or BOUND the site-specific considerations.	BASE the response spectral shape used in the SPRA on site-specific evaluations performed for the PSHA, and REFLECT or BOUND the characteristics of spectral shapes associated with the mean magnitude and distance pairs determined in the PSHA for the important ground motion levels.
	The spectral shape used in the Surry SPRA was the UHS defined in the EPRI hazard study. Even though the site amplification factors were deterministic, the median spectral shape should not significantly change if a full probabilistic site amplification analysis was conducted. This spectral shape is considered to meet the requirements for Capability Category II for horizontal motions. Vertical motion was not developed, thus only Capability Category I is considered to have been met.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement H: Use of Existing Studies (HLR-HA-H): When use is made of an existing study for PSHA purposes, it SHALL be confirmed that the basic data and interpretations are still valid in light of established current information, the study meets the requirements outlined in A through G above, and the study is suitable for the intended application.			
Index No. HA-H	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-H	[There are no Supporting Requirements here.]		
	The EPRI hazard Study was about 8 years old when the SPRA was conducted and was still considered to be applicable. There was no known new information that would significantly alter the results, thus this requirement is considered to have been met for Capability Category II for horizontal motions. Vertical motion was not addressed, therefore only Capability Category I is considered to have been met. Current USGS PGA hazard predictions for a 10,000-year return period are approximately equivalent to the EPRI mean PGA but the USGS spectral amplification is greater. The USG hazard is also higher for some other sites. If a new SPRA were being conducted, the difference between USGS and the EPRI and LLNL hazard should be addressed.		
Seismic Hazard Analysis High-Level Requirement I: other Seismic Hazards **(HLR-HA-I): A screening analysis SHALL be performed to assess whether, in addition to the vibratory ground motion, other seismic hazards, such as fault displacement, landslide, soil liquefaction, or soil settlement need to be included in the SPRA for the specific application. If so, the SPRA SHALL address the effect of these hazards through assessment of the frequency of hazard occurrence and/or the magnitude of hazard consequences.**			
Index No. HA-I	**Capability Category I**	**Capability Category II**	**Capability Category III**
	A screening for liquefaction was conducted for the Surry site and it was concluded that the soil was not subject to any types of failures for ground motion beyond the screening level capacity for components. The component screening level corresponded to an unconditional failure rate of about 1.15E-6/yr. We would conclude then that the CDF due to ground failure was less than 1E-6/yr. The failure threshold was not computed. This requirement is considered to be met for at least Capability Category II.		

Table 5-1
Comparison of the Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Hazard Analysis (Continued)

Seismic Hazard Analysis High-Level Requirement J: Documentation (HLR-HA-J): The PSHA SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.			
Index No. HA-J	**Capability Category I**	**Capability Category II**	**Capability Category III**
HA-J1	MEET the general documentation requirements in Section 7.		
HA-J2	MEET the documentation guidelines of (NRC, 1997a) for PSHA, including a description of the specific methods used for source characterization and ground-motion characterization, and of the scientific interpretations that are the basis for the inputs and results. If an existing PSHA is used, CHECK its documentation to ensure that it is adequate to meet the spirit of the requirement here.		
	The documentation of the EPRI hazard study was comprehensive and exceeds all requirements of the Standard.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis

Systems-Analysis High-Level Requirement A: Completeness (HLR-SA-A): The seismic-PRA systems models SHALL include all important seismic-caused initiating events that can lead to core damage or large early release, and SHALL include all other important failures that can contribute significantly to CDF or LERF, including seismic-induced SSC failures, non-seismic-induced unavailabilities, and human errors.			
Index No. SA-A	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-A1	ENSURE that all significant earthquake-caused initiating events are included in the seismic-PRA systems model.		
	The approach taken for the Surry SPRA was to develop a seismic Event Tree that is structured in a hierarchy of seismic fragility for essential structures and components. Most components were screened out, thus initiating events such as Large LOCA, Medium LOCA, seismic induced ATWS, etc are not included. Failures not common to SPRAs were however included such as a seismic induced turbine building fire that causes failure of the power to isolation valves from the intake canal to the condensers, thus draining the canal, which results in loss of heat sink to the essential systems. On the basis that the screening level was high enough to eliminate many seismic initiating events without compromising the results, it is concluded that this requirement is met. Further comments are made regarding the screening level.		
SA-A2	In the initiating-event selection process, DEVELOP a hierarchy to ensure that every earthquake greater than a certain defined size produces a plant shutdown within the systems model.		
	The hierarchy in the SET is structured such that equipment required after a plant shutdown is included. No specific mention is made in the IPEEE Tier 1 submittal about automatic or manual scram, but in all cases, auxiliary feed water appears in sequences that don't lead directly to core damage, therefore shutdown cooling is included. The long term RHR system is not modeled on the basis that components in the system are screened out. On the basis that the screening level is justified, the SET hierarchy meets the requirements of the standard.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-A	Capability Category I	Capability Category II	Capability Category III
SA-A3	ENSURE that the PRA systems models reflect all significant earthquake-caused failures and all significant non-seismic-induced unavailabilities and human errors. The analysis MAY group earthquake-caused failures if the leading failure in the group is modeled.		
	Most seismic induced failures were screened out and relays were not modeled. For those lower capacity components that were modeled, any operator action that was required to prevent core damage was modeled and the human error probabilities in the internal events model were increased to reflect increased stress on the operators arising from the earthquake. In the event of a seismic induced turbine building fire, operator access to manually close the valves between the intake canal and condenser is assumed to be prevented. For the sequences modeled, the random unavailabilities and human errors from the internal events model, appropriately modified for the occurrence of an earthquake, are included. On the condition that the screening level was set high enough, this requirement of the Standard is met.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement B: Adaptations Based on The Internal-Events Pra Systems Model **(HLR-SA-B): The seismic-PRA systems model SHALL be adapted to incorporate seismic-analysis aspects that are different from corresponding aspects found in the full-power, internal-events PRA systems model.** *Note*: While the most common procedure for developing the seismic-PRA systems model is to start with the internal-events systems model and adapt it by adding and trimming, in some circumstances it is acceptable instead to develop an ad-hoc seismic-PRA systems model tailored especially to the situation being modeled. If this approach is used, it is especially important that the resulting model be consistent with the internal-events systems model regarding plant response and the cause-effect relationships of the failures. Further, it is then especially important that a peer review be undertaken that concentrates on these aspects. See Section 3.7.2.1 and also the NOTE at REQ. SA-A3 for further commentary.			
Index No. SA-B	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-B1	In each of the following aspects of the seismic-PRA systems-analysis work, SATISFY the corresponding requirements in the ASME internal-events, full-power PRA standard (ASME, 2002), except where they are not applicable, or where this Standard includes additional requirements. DEVELOP a defined basis to support the claimed non-applicability of any exceptions. The aspects governed by this requirement are: 1. Initiating-event analysis 2. Accident-sequence analysis 3. Success-criteria analysis 4. Systems analysis 5. Data analysis 6. Human-reliability analysis 7. Use of expert judgment When the ASME requirements are used, FOLLOW the Capability-Category designations in that Standard, and for consistency USE the same Capability Category in this analysis.		
	In general, the above functions are employed in the SPRA although no specific comparison is made to each requirement of the ASME standard. This requirement is considered to have been met.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-B	Capability Category I	Capability Category II	Capability Category III
SA-B2	In the HRA (human reliability analysis) aspect, CONSIDER that additional post-earthquake stresses can increase the likelihood of human errors or inattention, compared to the likelihood assigned in the internal-events HRA when the same activities are undertaken in non-earthquake accident sequences. Whether or not increases in error probabilities are used, JUSTIFY the basis for this decision about what error rates to use.		
	Human error probabilities in the internal events models were increased to reflect seismic stress except in two cases. The first case was for small earthquakes where there is no seismic damage and offsite power remained available. The second case was for relatively routine actions that are not required to take place for 8 hours and can be re-performed if an error is made. *A factor of 3 on Human Error Probability (HEP) from the internal events model was applied for HEP between 0.1 and 1.0. The limit of course is 1.0. If the HEP was between 0.01 and 0.1 the increase factor was 5 with a limit of 0.3. If the internal event HEP was less than 0.01 the increase factor was 10 with a limit on HEP of 0.05. These factors for increasing HEP are subjective and vary from one study to another but are considered to be in a reasonable range. The factors were not a function of earthquake level as has been done in some other SPRAs. This requirement of the Standard is considered to have been met.*		
SA-B3	PERFORM an analysis of seismic-caused dependencies and correlations, in a way so that any screening of SSCs appropriately ACCOUNTS FOR those dependencies and correlations. The analysis MAY use generic dependency and correlation values if justified.		PERFORM an analysis of seismic-caused dependencies and correlations, in a way so that any screening of SSCs appropriately ACCOUNTS FOR those dependencies and correlations. USE plant-specific dependency and correlation values throughout.
	Dependencies and correlations do not appear to have been considered in the screening. The screening level was determined to result in a seismic induced failure rate of 1.16 E-6/y and this was judged to be low enough that the screening would have no significant impact on computed CDF. The screening of components based upon seismic ruggedness, without consideration of dependencies or correlations is commonly done in lower seismicity plants such as Surry. If the screening level is set high enough such that the resulting seismic induced failure rate is very low, ignoring the dependencies and correlations can be justified. In the case of Surry, the failure rate of components at the screening level is about 15% of the overall CDF, thus it is concluded that this requirement has not been completely met. The intent of Capability Category I would be met with a higher screening level or if sensitivity studies were conducted to demonstrate that the screening level and the possible correlations and dependencies have minimal effect on the results.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-B	Capability Category I	Capability Category II	Capability Category III
SA-B4	*ENSURE that any screening of human-error basic events and non-seismic-failure basic events does not significantly affect the PRA's results.*		
	The non-seismic failures and human error basic events that apply to seismic damage states were included in the SPRA. Human error and non-seismic failure for seismic initiating events not modeled were not included. In addition to the human error and non seismic failures from the internal events models, additional human error probabilities were assigned for nodal points in the SET associated with turbine building failure or turbine building fire. The most dominant contributor to CDF from non-seismic failure is the random failure of the Unit 1 diesel after loss of off-site power. This sequence contributes 32 percent of the CDF, thus any random failures or human errors left out should have very minimal contribution to overall CDF. Note that Surry has one diesel for each unit and a third swing diesel. The model for Unit 1 was based on the swing diesel being aligned to Unit 2, thus the random failure of a single diesel is the second most major contributor to CDF. The swing diesel and ancillaries are not qualified for the DBE and the cables run through a non-seismic building, thus, the swing diesel was assumed to be unavailable after an earthquake (a very conservative assumption) and its availability to Unit 2 was not modeled. The Tier 1 IPEEE submittal states that other non-seismic failures were not significant as there are a number of alternate systems to remove decay heat. Under the assumption that the seismic screening level was high enough, the treatment of random failures and human error are considered to have met the requirements of the Standard.		
SA-B5	CONSIDER the effects of the chatter of so-called low-ruggedness relays.	CONSIDER the effects of the chatter of relays and similar devices.	
	The effect of relay chatter was not modeled. In the A-46 program, one low ruggedness relay was discovered in the diesel generator field flash circuit. It was to be replaced by a qualified relay. It was determined by the plant that this type of relay was not installed in any other location in the plant. Surry was placed in the focused scope bin and the IPEEE requirements for focused scope plants was to search for low ruggedness relays. Beyond the A-46 search for low ruggedness relays, no other searches were conducted in circuits associated with IPEEE components in the safe shutdown paths or containment performance modeling. It is therefore concluded that most of this requirement for Capability Category I was met but the search for low ruggedness relays was short for the SPRA.		
SA-B6	In the systems analysis models, for each basic event that represents a seismically-caused failure, INCLUDE the complementary "success" state where applicable to a particular SSC.		
	The SET and Boolean nodal equations included success states as well as failures. This requirement of the Standard is met.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-B	Capability Category I	Capability Category II	Capability Category III
SA-B7	CONSIDER the possibility that a large earthquake can cause damage that blocks personnel access to safety equipment or controls, thereby inhibiting operator actions that might otherwise be credited.		
	This was specifically considered in the SET. The dominant contributor to CDF was failure of the turbine building and failure of the operator to be able to access and close the isolation valves between the intake canal and the condenser, thus draining the intake canal and destroying the heat sink for the plant. Access to this valve during a seismic induced turbine building fire was also specifically assessed. Most other human actions take place in the control room. This requirement is considered to have been met.		
SA-B8	CONSIDER the likelihood that system recoveries modeled in the internal-events PRA may be more complex or even not possible after a large earthquake, and ADJUST the recovery models accordingly. Conservative recovery values MAY be used.	CONSIDER the likelihood that system recoveries modeled in the internal-events PRA may be more complex or even not possible after a large earthquake, and ADJUST the recovery models accordingly.	
	Human error probability was increased for recovery actions as well actions required for alignment of equipment during the shutdown procedure. This requirement is considered to have been met for all Capability Categories.		
SA-B9	CONSIDER including an earthquake-caused "small-small LOCA" as an additional fault within each sequence in the seismic-PRA model.		
	Small LOCA was not modeled based on the fragility in the NUREG/CR-4550 study of Surry. Small LOCA was considered in sensitivity studies. When small LOCA was combines with non-seismic and human error failures, the CDF for the sequence with small LOCA was 7.2E-8/y, thus it was justified to not include it in the base case SET. Small-small LOCA would involve the same equipment plus likely the charging system. The components of the charging system were screened out on the basis of seismic ruggedness so an accident sequence involving small-small LOCA would likely have the same results and be considered to be insignificant. This requirement is considered to have been met based on the sensitivity study for small LOCA.		
SA-B10	In the SPRA walkdown, INCLUDE the potential for seismic-induced fires and flooding following the guidance given in NUREG-1407.		
	Seismic induced fire and flooding were specifically included in the walkdown. Turbine building fires were included in the SET. Fires in cable raceways caused by failure of poorly anchored electrical cabinets in the turbine building were also considered. This requirement is considered to have been met.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement C: Plant Fidelity (HLR-SA-C): The seismic-PRA systems models SHALL reflect the as-built and as-operated plant being analyzed.			
Index No. SA-C	Capability Category I	Capability Category II	Capability Category III
SA-C1	To ensure that the systems-analysis models reflect the as-built, as-operated plant, JUSTIFY any important conservatisms or other distortions introduced by demonstrating that they do not significantly alter the seismic-PRA's validity for applications.		
	The SPRA was conducted in conjunction with the resolution of USI A-46. The SPRA seismic equipment list (SEL) contained components in addition to the A-46 list to address containment performance, small LOCA, etc. Some 1850 components were incorporated into the SEL. The walkdown identified several components that did not meet the screening criteria and the plant committed to fix these issues. Some 60 modifications were to be conducted. Inherent in the SPRA model was the assumption that these 60 upgrades had been completed. The model therefore represents the as-built condition after the upgrades. This requirement is considered to have been satisfied.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement D: Seismic Equipment List			
(HLR-SA-D): The list of SSCs selected for seismic-fragility analysis SHALL include all SSCs that participate in accident sequences included in the seismic-PRA systems model.			
Index No. SA-D	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-D1	USE the PRA systems model as the basis for developing the SEL ("Seismic Equipment List"), which is the list of all SSCs to be considered by the subsequent seismic-fragility evaluation task.		
	The SEL was developed utilizing the IPE internal events PRA model as the source of the initial list of equipment. This list was enhanced following the guidelines of NUREG-1407 by: • *Determining the potential initiating events that could occur with a seismic event, either due to an earthquake or as a random or consequential event.* • *Removing systems and equipment from the IPE list that are either not required or not available.* • *Removing non-equipment from the list (e.g., human errors and pure probability events).* • *Adding components for pressure boundary integrity.* • *Adding electrical panels, cabinets and instrument racks (e.g., the internal events model contains the devices in the cabinets but does not model the cabinets).* • *Add unique equipment or features.* • *Cross check with A-46 equipment list.* • *Add structures housing the SEL equipment and any structures or equipment whose failure could affect equipment on the SEL (spatial systems interactions, seismic/ fire and seismic induced flood interactions).* *The resulting list contained about 1850 components which is much more comprehensive than most SELs developed for IPEEE. Of course, most of the components on the SEL are rugged and were subsequently screened out. The development of the SEL is considered to meet all requirements of the Standard.*		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement E: Integration and Quantification (HLR-SA-E): The analysis to quantify core-damage frequency (CDF) and large-early-release frequency (LERF) SHALL appropriately integrate the seismic hazard, the seismic fragilities, and the systems-analysis aspects.			
Index No. SA-E	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-E1	In the quantification of CDF and LERF, PERFORM the integration using the seismic hazard, fragility and systems analyses.		
	The integration was conducted at the SET level. For each node in the SET, failures and successes from seismic events and non-seismic failures were represented by Boolean equations. The successes and failures at each node were computed and propagated through the SET to arrive at failure rates in each accident sequence and the total CDF. A similar approach was taken in the evaluation of LERF. This process meets the requirements of the Standard.		
SA-E2	In quantifying CDF and LERF frequencies, PERFORM the quantification on a cut-set-by-cut-set or accident-sequence-by-accident-sequence basis (or for defined groups of these), as well as on a comprehensive/integrated basis. Broad groupings MAY be used.	In quantifying CDF and LERF frequencies, PERFORM the quantification on a cut-set-by-cut-set or accident-sequence-by-accident-sequence basis (or for defined groups of these), as well as on a comprehensive/integrated basis.	
	The SET was quantified on an accident sequence basis and on a comprehensive integrated basis. The SEISMIC software code does this quantification using a Monte Carlo process. The quantification meets the requirements of the Standard for all Capability Categories.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-E	Capability Category I	Capability Category II	Capability Category III
SA-E3	In the analysis, USE the quantification process to ensure that any screening of SSCs does not affect the results, taking into account the various uncertainties.		
	A quantification of the mean seismic failure rate of screened out components was conducted for comparison to the total CDF. The frequency of failure of a screened out component was 15% of the total CDF. The Tier 1 IPEEE submittal stated that this was judged to contribute insignificantly to seismic risk. Almost all components were screened out. If all were modeled, they would appear in numerous OR gates and could end up dominating CDF. In EPRI (1994) it is recommended that surrogate elements representing the screened out components be added to fault trees who's top event leads to a node on the event tree. This is an attempt to include the contribution of screened out components. Only one surrogate element is added to each fault tree on the basis that most of the screened out components have capacities beyond the screening level and that only one weak link in a chain exists. This can be conceptually unconservative if several components that are screened out have capacities equal to the screening level. In many IPEEE submittals, only one surrogate element was used in the model to represent all screened out components. This practice does not comply with the recommendations in EPRI (1994). The Standard does not suggest the use of surrogate elements. It requires that the screening out of components from the risk model be done at a high enough level so that there is little effect on the overall CDF or LERF. The standard also requires that sufficient analysis be conducted to assure that the screened out components do not have any significant effect on the final results. In the case of the Surry SPRA, an analysis was conducted to determine the frequency of failure of screened out components but further sensitivity analysis was not conducted to demonstrate that if screened out components had been included in the model, there would not have been a significant effect on the computed CDF or LERF. In this case, the Surry SPRA does not comply with the standard for any of the Capability Categories.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-E	Capability Category I	Capability Category II	Capability Category III
SA-E4	In the integration/quantification analysis, ACCOUNT for all significant dependencies and correlations that affect the results. The analysis MAY use generic dependency and correlation values if justified.		In the integration/quantification analysis, ACCOUNT for all significant dependencies and correlations that affect the results. USE plant-specific dependency and correlation values throughout.
	There is no mention in the Tier 1 IPEEE report of correlation. Standard practice has been to assume that like components that appear in redundant trains are correlated, thus negating any benefit of redundancy for seismic failures. This would tend to be conservative but is a practical way to address common cause failure of like components subjected to essentially the same earthquake motion. Components that are not alike are assumed to be uncorrelated regardless of their location. Two components that are not alike but located adjacent to each other have correlation in the input motion but not in strength and possibly not in dynamic response characteristics. Any attempt to consider partial correlation has been limited to research programs such as SSMRP (USNRC, 1981). The methodology for treating partial correlation and the software to do so are just not readily available, thus, this requirement of the Standard, as it is written, was not technically met for any of the Capability Categories. The standard does suggest that generic dependency and correlation may be used for Capability Categories I and II if justified. It is the author's opinion in this case that the procedure used in Surry and other IPEEE SPRAs to address correlation should meet Capability Category I. For Capability Category II, some sensitivity studies should be required to demonstrate the sensitivity to the correlation assumptions. Thus, it is considered that the correlation treatment in the Surry SPRA meets the intent of Capability Category I.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Index No. SA-E	Capability Category I	Capability Category II	Capability Category III
SA-E5	USE the mean hazard, composite fragilities, and the systems analysis to generate point estimates for CDF and LERF. ESTIMATE the uncertainties in overall CDF and LERF.	In the integration/quantification analysis, ACCOUNT for the uncertainties in CDF and LERF results that arise from each of the several inputs (the seismic hazard, the seismic fragilities, and the systems-analysis aspects).	
	The quantification was conducted in accordance with the requirements of NUREG-1407, which focused on a point estimate of CDF and LERF using the mean hazard and composite fragilities. Sensitivity studies were conducted taking into account the uncertainty in the fragility curves and the random failures but the uncertainty in the seismic hazard was not included. A separate analysis was conducted using the mean LLNL (USNRC, 1993) PGA hazard curve. Results were not reported in the Tier 1 IPEEE submittal. In an internal quantification report (VEPCO, 1997) the mean CDF using the LLNL hazard was about 55% higher than the mean CDF using the EPRI hazard. The calculation of a point estimate and the sensitivity and uncertainty analyses conducted, meet the requirements of the Standard for Capability Category I.		
SA-E6	PERFORM appropriate sensitivity studies to illuminate the sensitivity of the CDF and LERF results to the assumptions used about dependencies and correlations.		
	The sensitivity analyses conducted did not address the subject of correlation. In this respect, the Surry SPRA does not meet the requirements for any Capability Category. As stated previously, it is the authors opinion that the treatment of correlation in like and unlike components that was done for the Surry SPRA and for most IPEEE SPRAs, should be considered to meet the intent of Capability Category I. The standard should be revised accordingly.		

Table 5-2
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Systems Analysis (Continued)

Systems-Analysis High-Level Requirement F: Documentation			
(HLR-SA-F): The seismic-PRA analysis SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.			
Index No. SA-F	**Capability Category I**	**Capability Category II**	**Capability Category III**
SA-F1	MEET the general documentation requirements in Section 7.		
	The Tier 1 Documentation meets the requirements of NUREG-1407 for IPEEE submittals. The Tier 2 quantification report is referenced and contains the Boolean expressions and the computer results. The information presented enables a peer review. This meets the general requirements of the Standard.		
SA-F2	DESCRIBE the specific adaptations made in the internal-events PRA model to produce the seismic-PRA model, and their motivation.		
	The Tier 1 and Tier 2 reports provide a general description of the modifications made to the internal event models and the development of a SET. The modified internal event trees and fault trees are not provided. Boolean equations used in the final quantification are provided in the Tier 2 report. The Tier 1 and Tier 2 reports are considered to meet the requirements of the Standard for at least Capability Category II.		
SA-F3	DESCRIBE the major contributors to the uncertainties in each of the important final results and insights of the systems analysis.		
	Some uncertainty analysis was conducted but there was not any specific documentation of the sensitivity of the dominant accident sequences. The major accident sequence involved failure of the turbine building and 100% failure of the operator to access and close the valves from the intake canal to the condenser. This results in rapid draining of the canal and loss of heat sink, thus leading directly to core damage and containment failure. In this case, the uncertainty analysis conducted incorporated the uncertainty in the fragility curves. Interim uncertainty analysis of this accident sequence was not reported, only the change in CDF associated with the uncertainty in all of the fragility curves and the random failures were reported. The second most dominant sequence was seismic induced LOOP plus random failure of the single diesel generator. The uncertainty analysis conducted included the uncertainty in the fragility curves for LOOP and the uncertainty in the random failure but the interim results for this sequence were not provided for Unit 2. The swing diesel was assumed to be unavailable for Unit 1. As it stands, the analysis was conservative in this respect. This documentation requirement is considered to have been met for the studies that were conducted. Other uncertainty analysis would be required for meeting the Standard requirements for Capability Categories greater than I, thus the documentation can only comply with Capability Category I.		

5.5.3 Fragility Analysis

Most of the 1850 components on the SEL were screened out on the basis of the walkdown, existing seismic qualification documentation or screening and anchorage calculations conducted for A-46. Fragilities were reported in the Tier 1 IPEEE submittal for 21 components. The HCLPFs ranged from 0.21g to 1.9g. Only three of these components had HCLPFs below the 0.3g screening level. One was a control cabinet associated with automatic containment isolation and cooling. There were no fragilities calculated for relays. Surry was a focused scope plant and was only required to search for low ruggedness relays. Only one type of low ruggedness relay was found in the A-46 evaluation. It was in the diesel generator field flash circuitry. These relays were to be replaced. All others were implicitly assumed to meet the screening level of 0.3g HCLPF. Fragility calculations were performed for nine structures. The structural HCLPFs ranged from 0.19g for the turbine building to 4.5g for the containment external structure. The lowest HCLPF for structures other than the turbine building was 0.65g for the Safeguards building, thus all structures except the turbine building were screened out.

The walkdown identified some potential seismic fire issues and spatial interactions. In most cases, either a fix or a housekeeping procedure was assumed to be carried out. One fragility for a lube oil tank in the turbine building was calculated. This was a potential fire source. Masonry walls that could fail and damage safety related equipment were evaluated. The masonry walls could affect Unit 2 only and a bounding fragility was used in the Unit 2 CDF computation.

In the final calculation of CDF, only nine fragilities were used. In the base case for Unit 1, only six fragilities were used, two of which were generic. One generic fragility was for a non-seismic fire water storage tank, which was modeled as a backup to the Emergency Condensate Storage Tank for the source of auxiliary feedwater. The other generic fragility was for loss of off-site power. Specific fragilities included in the model were for the emergency condensate storage tank, component cooling water surge tank, lube oil storage tank (fire source) and the turbine building. A block wall fragility was added for the Unit 2 analysis and found to increase the CDF by only 8%. A seismic induced small LOCA fragility was included in a sensitivity study and found to be an insignificant contribution to CDF. A turbine building electrical cabinet failure was used in a sensitivity study (fire source for nearby cables). It was screened out from the base case as a result of the sensitivity study.

Of the fragilities calculated, only a few were contributors to CDF. The turbine building failure was a 36% contributor to CDF and lead to late term containment failure die to loss of plant heat sink. The loss of off site power and random failure of the single diesel was almost an equal contributor at 32%. A sequence with the loss of off-site power and failure of the Emergency Condensate Storage Tank contributed 13% and a loss of off-site power and failure of the CCW surge tank contributed 11% to CDF. The failure of the lube oil tank and subsequent fire contributed 5% to CDF. All other sequences contributed a total of 3%.

However, if the screened out components were assumed to lead directly to core damage, the total CDF would increase by 14% with the contribution of one surrogate element being equal to about 12%. There are two issues to be considered for the screening level. The first issue is that the actual capacity of screened components is not known. If several of them appeared in OR gates and had capacity equal to the screening level, the CDF could rise significantly and the screened out components could become more significant to the overall CDF. The second issue is the assignment of a HCLPF equal to 0.3g. The initial screening was conducted using the EPRI NP-6041 screening tables or alternatively the SQUG GIP screening criteria. However, for all the components that were initially screened-in and walked down, explicit calculations were performed to either determine the fragility or to show that they can be screened out if $HCLPF_{84}$ >0.3g. The EPRI screening tables are assumed to be equivalent to a HCLPF. However, this is based on the assumption that the seismic demand is specified as an 84^{th} percentile demand. In SPRA, the fragilities are developed relative to a median (50^{th} percentile) ground motion so an adjustment should be made to the screening level to define the $HCLPF_{50}$. In EPRI (1991a) the screening is relative to a spectral acceleration at ground. The spectral acceleration screening level corresponding to 0.3g PGA in the original edition of EPRI NP-6041 is 0.8g Sa. It is assumed in EPRI (1994) that the median capacity is conservatively twice this screening level. However, for Eastern U.S. sites, the ratio of $HCLPF_{84}$ to $HCLPF_{50}$ is about 1.3 so the $HCLPF_{50}$ would be 0.8/1.3 = 0.615g Sa and the median capacity would be 1.23g Sa. If we compare the ratio of the 10,000 year median UHS peak to the zpa it is about 1.73, thus the screening PGA HCLPF could be determined to be about 0.615/1.73 = 0.355g and the median capacity would be twice this value or about 0.71g. This would result in a lower failure rate than computed for the assumed fragility of 0.30g PGA HCLPF and 0.74g PGA median capacity for the screened out components.

The issued of the low screening level still remains though. In many SPRAS, such as the SONGS SPRA reviewed in this report, the screening level has been set so the failure rate was about two orders of magnitude lower than the final CDF. In other cases, hundreds of higher capacity components are modeled and hundreds of accident sequences are evaluated. In these cases, the small contributions can add up to a significant portion of total CDF. Thus, for risk informed applications, a more complex model and a higher screening level, accompanied by more plant specific fragilities, may be necessary.

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis

<table>
<tr><th colspan="4">Seismic Fragility Evaluation High Level Requirement A: Realism

(HLR-FR-A): The seismic fragility evaluation SHALL be performed to estimate plant-specific, realistic seismic fragilities of structures, systems and components whose failure may contribute to core damage and/or large early release.</th></tr>
<tr><th>Index No. FR-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">FR-A1</td><td colspan="3">DEVELOP seismic fragilities for all those structures, systems and components identified by the systems analysis (see REQ SA-D1).</td></tr>
<tr><td colspan="3">Fragilities for safety related structures and components not screened out were developed for use in the SPRA. Most of the fragilities that were developed were higher capacity than the screening level. The requirements of the Standard were met.</td></tr>
<tr><td rowspan="2">FR-A2</td><td>Generic data (e.g., fragility test data, generic seismic qualification test data and earthquake experience data) MAY be used to develop seismic fragilities. However, DEMONSTRATE that any use of such generic data is conservative.</td><td>BASE the seismic fragilities on plant-specific data and ENSURE that they are realistic (median with uncertainties). Generic data (e.g., fragility test data, generic seismic qualification test data and earthquake experience data) MAY be used for screening of certain SSCs and for calculating their seismic fragilities by applying the Requirements under HLR-FR-F, which permits use of such generic data under specified conditions. However, DEMONSTRATE that any use of such generic data is conservative.</td><td>BASE the seismic fragilities on plant-specific data and ENSURE that they are realistic (median with uncertainties).</td></tr>
<tr><td colspan="3">Fragilities that were developed were based on plant specific data. The generic fragility for LOOP is based on seismic experience and has been commonly used in several SPRAs. The generic fragility for the fire water storage tank is considered to be conservative. The requirements of the Standard for Capability Category II are considered to have been met for fragilities developed for components that were walked down.</td></tr>
</table>

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

<table>
<tr><th colspan="4">Seismic Fragility Evaluation High Level Requirement B: Screening
(HLR-FR-B): If screening of high seismic capacity components is performed, the basis for the screening SHALL be fully described.</th></tr>
<tr><th>Index No. FR-B</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">FR-B1</td><td colspan="2">If screening of high-seismic-capacity components is performed, DESCRIBE fully the basis for screening and supporting documents. For example, guidance given in EPRI NP-6041 and NUREG/CR-4334 MAY be used to screen out components with high seismic capacity. However, CHOOSE the screening level high enough that the contribution to CDF and LERF from the screened-out components is not significant.</td><td>SCREEN high-seismic-capacity components ONLY if the components' failures can be considered as fully independent of the remaining components.</td></tr>
<tr><td colspan="3">Screening was primarily conducted on the basis of EPRI NP-6041 or the SQUG Generic Implementation Procedure (SQUG, 1991). The examination of equipment during the walkdown and examination of documents in support of screening appears to have been very thorough. However, the argument presented that screened out components have only a 1.15E-6/y frequency of failure does not appear sufficient to ignore the screened out components in the risk model or at least include surrogate elements in the risk model representing the screened out components. In this case, it is judged that sufficient justification for the screening level was not provided and that it is debatable if the screening met Capability Category I.</td></tr>
<tr><td rowspan="2">FR-B2</td><td colspan="3">ASSESS and DOCUMENT the applicability of the screening criteria given in EPRI NP-6041 (EPRI, 1991a) and NUREG/CR-4334 (Budnitz et al., 1985) for the specific plant and specific equipment.</td></tr>
<tr><td colspan="3">There is no discussion in the Tier 1 submittal regarding the applicability of the screening Tables to Surry equipment. Surry is an A-46 plant and the applicability of the GIP to Surry equipment was established. The walkdown documentation also notes the applicability of the screening criteria to equipment at Surry. This requirement is considered to have been met by the appropriate entries on the walkdown SEWS.</td></tr>
</table>

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

<table>
<tr><th colspan="4">Seismic Fragility Evaluation High Level Requirement C: Response

(HLR-FR-C): The seismic fragility evaluation SHALL be based on realistic seismic response that the SSCs experience at their failure levels. Depending on the site conditions and response analysis methods used in the plant design, realistic seismic response MAY be obtained by an appropriate combination of scaling, new analysis and new structural models.</th></tr>
<tr><th>Index No. FR-C</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">FR-C1</td><td colspan="2">ESTIMATE the seismic responses that the components experience at their failure levels on a realistic basis using site-specific earthquake response spectra in three orthogonal directions, anchored to a ground motion parameter such as peak ground acceleration or average spectral acceleration, or ENSURE that the spectral shape used reflects or bounds the site-specific considerations.</td><td>ESTIMATE the seismic responses that the components experience at their failure levels on a realistic basis using site-specific earthquake response spectra in three orthogonal directions, anchored to a ground motion parameter such as peak ground acceleration or average spectral acceleration.</td></tr>
<tr><td colspan="3">Probabilistic response analysis was conducted for three earthquake levels (SSE, 2XSSE and 3XSSE). The EPRI median uniform hazard spectral shape for a 10,000 year return period was used. The development of probabilistic response spectra is considered to meet the requirements of all Capability Categories.</td></tr>
<tr><td rowspan="2">FR-C2</td><td colspan="2">If probabilistic response analysis is performed to obtain realistic structural loads and floor response spectra, ENSURE that the number of simulations done (e.g., Monte Carlo simulation and Latin Hypercube Sampling) is large enough to obtain stable median and 85% non-exceedance responses. In the response analysis, appropriately ACCOUNT for the entire spectrum of input ground motion levels displayed in the seismic hazard curves.</td><td>PERFORM probabilistic seismic response analysis taking into account the uncertainties in the input ground motion and structural and soil properties and CALCULATE joint probability distributions of the responses of different components in the building.</td></tr>
<tr><td colspan="3">The Latin Hypercube stratified sampling technique using 30 simulations was employed for development of probabilistic response spectra. Numerous studies in the SSMRP program (USNRC, 1981) have confirmed that 30 simulations are adequate to accurately predict the median and 84th percentile response. This process met the requirements of Capability Category II.</td></tr>
</table>

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

Index No. FR-C	Capability Category I	Capability Category II	Capability Category III
FR-C3	If scaling of existing design response analysis is used, JUSTIFY it based on the adequacy of structural models, foundation characteristics, and similarity of input ground motion.		Addressed in FR-C2.
	Scaling was not conducted.		
FR-C4	For soil sites, or when the design response analysis models are judged not to be realistic and state-of-the-art, or when the design input ground motion is significantly different from the site-specific input motion, PERFORM new analysis to obtain realistic structural loads and floor response spectra.		Addressed in FR-C2.
	New probabilistic analysis was conducted. The analysis met this requirement for Capability Category II.		
FR-C5	If median-centered response analysis is performed, ESTIMATE the median response (i.e., structural loads and floor response spectra) and variability in the response using established methods.		Addressed in FR-C2.
	Median response was calculated by probabilistic methods. This requirement applies to deterministic methods and is not applicable.		

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

Index No. FR-C	Capability Category I	Capability Category II	Capability Category III
FR-C6	When soil structure interaction (SSI) analysis is conducted, ENSURE that it is median centered using median properties, at soil strain levels corresponding to the input ground motions that dominate the seismically induced core damage frequency. CONSIDER the uncertainties in the SSI analysis by varying the low strain soil shear modulus between the median value times $(1+C_v)$ and the median value divided by $(1+C_v)$, where C_v is a factor that accounts for uncertainties in the SSI analysis and soil properties. If adequate soil investigation data are available, ESTABLISH the mean and standard deviation of the low strain shear modulus for every soil layer. Then ESTABLISH the value of C_v so that it will cover the mean plus or minus one standard deviation for every layer. The minimum value of C_v SHALL be 0.5. When insufficient data are available to address uncertainties in soil properties, ENSURE that C_v is taken as no less than 1.0.		Addressed in FR-C2.
	The probabilistic response was conducted for three earthquake levels (SSE, 2XSSE and 3XSSE) in order to provide realistic response based on increasing strain levels and decreasing shear modulus as the level of seismic input motion increases. In each probabilistic analysis the Coefficient of Variation on shear modulus was taken as 0.5. Thus, the 95% confidence bounds on shear modulus for each seismic input level analysis enveloped the above recommendations. The analysis conducted met the requirements of Capability Category II.		

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

Seismic Fragility Evaluation High Level Requirement D: Failure Modes			
(HLR-FR-D): The seismic fragility evaluation SHALL be performed for critical failure modes of structures, systems and components such as structural failure modes and functional failure modes identified through the review of plant design documents, supplemented as needed by earthquake experience data, fragility test data, generic qualification test data, and a walkdown.			
Index No. FR-D	**Capability Category I**	**Capability Category II**	**Capability Category III**
FR-D1	IDENTIFY realistic failure modes of structures and equipment that interfere with the operability of equipment during or after the earthquake through a review of the plant design documents and the walkdown.		
	Structural failures are associated with the onset of severe structural damage. In all cases except the turbine building the structures had very high capacity and remained elastic out to very high levels of ground motion. Thus, there is no concern regarding the level of shaking that distresses the structures to a point that equipment function is lost. Most equipment was either screened out or was found to have very high capacity. Equipment that had capacity low enough to be included in the model failed in a passive mode and due consideration was taken for limited ductility. The requirements of all Capability Categories are considered to have been met.		
FR-D2	CONSIDER all relevant failure modes of structures (e.g., sliding, overturning, yielding, and excessive drift), equipment (e.g., anchorage failure, impact with adjacent equipment or structures, bracing failure, and functional failure) and soil (i.e., liquefaction, slope instability, excessive differential settlement), and EVALUATE fragilities for critical failure modes.		
	Relevant failure modes were considered. Since Surry was a focused scope plant, ground type failures associated with liquefaction were not examined. The structures have 2 inches of rattle space between them and impact was ruled out. Only the turbine building was found to have a capacity low enough for inclusion in the risk model. It was not originally designed for earthquakes and structural failure governed its fragility. Requirements for all Capability Categories are considered to have been met.		

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

Seismic Fragility Evaluation High Level Requirement E: Walkdown (HLR-FR-E): The seismic fragility evaluation SHALL incorporate the findings of a detailed walkdown of the plant focusing on the anchorage, lateral seismic support, and potential systems interactions.			
Index No. FR-E	Capability Category I	Capability Category II	Capability Category III
FR-E1	CONDUCT a detailed walkdown of the plant, focusing on equipment anchorage, lateral seismic support and potential systems interactions.		
	A very detailed walkdown was conducted for some 1800 components and the structures. The walkdown included a search for spatial interactions, seismic-fire interactions, inadvertent actuation of fire protection systems, seismic induced flooding and relay mounting. Requirements of the Standard for all Capabilities were met.		
FR-E2	DOCUMENT the walkdown procedures, walkdown team composition, walkdown observations and conclusions.		
	The walkdowns were documented on SQUG GIP SEWS for the A-46 components and on EPRI SEWS for IPEEE only components. The Tier 1 IPEEE report contains a description of the walkdown teams and includes their applicable experience and training and resumes. The walkdown identified several issues, primarily systems interactions that the plant proceeded to fix. A peer reviewer conducted a partial confirmatory walkdown and it was concluded that the walkdown was very thorough. The walkdown documentation is considered to have met all requirements of the Standard for all Capability Categories.		
FR-E3	If components are screened out during or following the walkdown, DOCUMENT anchorage calculations or some other basis justifying such a screening.		
	The screening of IPEEE components was in most cases based on the A-46 screening that requires documentation of anchorage calculations or justification for screening of anchorage. Anchorage verification is noted on walkdown SEWS or in supporting calculations. This requirement is considered to have been met for all Capability Categories.		

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

Index No. FR-E	Capability Category I	Capability Category II	Capability Category III
FR-E4	During the walkdown, FOCUS on the potential for seismic induced fire and flooding.		
	Specific walkdowns were performed and documented for seismic induced fire. Turbine building fires were modeled in the SPRA. Several tanks that were not on the SEL were identified as possible flood sources. Only one of these tanks was in a safety related building and it was determined that it had been abandoned in place. Consequently, there were no seismic induced internal flood issues to be modeled. The fire and flood walkdowns conducted met the requirements of the Standard for all capability Categories.		
FR-E5	During the walkdown, EXAMINE potential sources of interaction (e.g., II/I issues, impact between cabinets, flooding and spray) and consequences of such interactions on equipment contained in the systems model.		
	The walkdown searched for II/I issues, impact between cabinets, flooding and spray issues. Several cases of impact between cabinets were identified and scheduled for fixes. Some II/I issues, such as light diffusers in the control room, gas bottles secured by only one chain, etc were identified. Wet fire protection piping with threaded joints was determined to be in the turbine building only and spray from these wet systems would not affect any safety related equipment. All of these issues were thoroughly examined during the walkdowns and the requirements of the Standard for all Capability Categories are considered to have been met.		

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

<table>
<tr><th colspan="4">Seismic Fragility Evaluation High Level Requirement F: Data Sources

(HLR-FR-F): The calculation of seismic fragility parameters such as median capacity and variabilities SHALL be based on plant specific data supplemented as needed by earthquake experience data, fragility test data and generic qualification test data. Use of such generic data SHALL be justified.</th></tr>
<tr><th>Index No. FR-F</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">FR-F1</td><td colspan="2">BASE component seismic fragility parameters such as median capacity, and variabilities (logarithmic standard deviations reflecting randomness and uncertainty) on plant specific data supplemented as appropriate by earthquake experience data, fragility test data and generic qualification test data.</td><td>DEVELOP component fragility as a function of the local response parameter. DERIVE the joint probability distribution of the seismic capacities of different components.</td></tr>
<tr><td colspan="3">Fragilities that were developed for the SPRA were based on plant specific data. The fragility description was a standard double lognormal model. A generic fragility was developed for the screening level. Most screening was based on seismic experience. The development of plant specific seismic fragilities is considered to have met the requirements of the Standard for Capability Categories I and II.</td></tr>
<tr><td rowspan="2">FR-F2</td><td colspan="2">For all SSCs that appear in the dominant accident cutsets, ENSURE that they have site-specific fragility parameters which are derived based on plant-specific information, such as anchoring and installation of the component or structure and plant-specific material test data. Exception: JUSTIFY the use of generic fragility for any SSC as being appropriate for the plant.</td><td>For all SSCs that appear in the dominant accident cutsets, ENSURE that they have site-specific fragility parameters which are derived based on plant-specific information, such as anchoring and installation of the component or structure and plant-specific material test data.</td></tr>
<tr><td colspan="3">The dominant accident sequence involved failure of the turbine building. The turbine building fragility was plant specific. The second most dominant accident sequence was loss of offsite power and random failure of the diesel generators. The loss of offsite power is a generic fragility and the random failure of the diesels was based on specific and generic reliability data. Human reliability associated with the random failure of the diesels was judgmental. Other dominant accident sequences involved component failures with plant specific fragilities. In this case, it is not considered feasible to base loss of off site power on plant specific fragility evaluations since the entire grid would have to be assessed. The intent of the requirement to derive fragility parameters as realistic as possible is considered to have been met for Capability Categories I and II.</td></tr>
</table>

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

<table>
<tr><th>Index No. FR-F</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td rowspan="2">FR-F3</td><td>PERFORM screening to identify low ruggedness relays. DEVELOP seismic fragilities of essential low ruggedness relays.</td><td colspan="2">DEVELOP seismic fragilities for relays identified to be essential and which are included in the systems analysis model.</td></tr>
<tr><td colspan="3">Low ruggedness relay screening was conducted in the A-46 program. One type of low ruggedness relay was found in each of the three diesel generator field flash circuits. This type of relay was scheduled to be replaced with a seismically qualified relay. It was determined that this type of relay does not exist anywhere else in the plant. In addition, mercury relays were identified in the fire protection control system of the Emergency Diesel Generator rooms. It was determined that the Emergency Diesel Generators were able to withstand a spurious release of CO_2 in the diesel rooms. No other relay evaluations were conducted. Surry was a focused scope plant for IPEEE and according to the requirements set in NUREG-1407, only a search for low ruggedness relays was required. It appears that only the A-46 equipment list was evaluated for low ruggedness relays. Equipment unique to IPEEE only, was not specifically evaluated for low ruggedness. The licensee stated that the intent of NUREG-1407 had been fulfilled. In this respect, the SPRA did not completely comply with Capability Category I requirements of the Standard but for the most part met the intent. To completely comply with the Standard for Capability Category I, it would have to be demonstrated that relays had capacity equal to or exceeding the 0.3g HCIPF screening level or demonstrate that relay chatter was acceptable.</td></tr>
<tr><td rowspan="2">FR-F4</td><td colspan="3">DEVELOP seismic fragilities for SSCs that are identified in the systems model as playing a role in the LERF part of the SPRA. (See REQ. SA-A1 and REQ. SA-A3.)</td></tr>
<tr><td colspan="3">It is shown in the SET that long term containment overpressure will occur for several of the seismic accident sequences. There were no sequences modeled where large early release would occur. Containment integrity, containment isolation and containment bypass modes of failure were screened out on the basis of walkdowns and calculations. As stated above, containment isolation and bypass modes associated with spurious relay action were not addressed since Surry was a focused scope plant. The requirement in the Standard as it pertains to LERF is considered to have been met.</td></tr>
</table>

Table 5-3
Comparison of Methodology used in the Surry SPRA to the Supplemental Technical Requirements in the Standard for Fragility Analysis (Continued)

Seismic Fragility Evaluation High Level Requirement G: Documentation			
(HLR-FR-G): The seismic fragility evaluation SHALL be documented in a manner that facilitates applying the PRA and updating it, and that enables peer review.			
Index No. FR-G	**Capability Category I**	**Capability Category II**	**Capability Category III**
FR-G1	MEET the general documentation requirements in Section 7.		
	The Tier 1 IPEEE submittal and the supporting calculations reference in the Tier 1 submittal met the requirements of the Standard.		
FR-G2	DESCRIBE the methodologies used to quantify the seismic fragilities of SSCs, together with key assumptions.		
	The Tier 1 IPEEE submittal provides a brief description of the fragility model and states that the fragilities were developed in accordance with EPRI (1994). Supporting calculations are referenced. It is described briefly how the fragility for the screened out components was developed from the assumed HCLPF of 0.3g PGA. However the derivation of the HCLPF is not described. It is implied that it is the screening level but it does not completely comply with the methodology in EPRI, 1994. This requirement is considered to have been met except for the derivation of the fragility for screened out components.		
FR-G3	PROVIDE a detailed list of SSC fragility values that includes the method of seismic qualification, the dominant failure mode(s), source of information, and the location of the component. PROVIDE the fragility parameter values (i.e., median acceleration capacity, β_R and β_U) and the technical bases for them for each analyzed SSC.		
	A list of fragilities is provided in the Tier 1 IPEEE report. Locations are provided in the SEL in Appendix A to the Tier 1 report. Failure modes, method of seismic qualification and source of information are not provided in the Tier 1 IPEEE report. Supporting calculation files are referenced that would contain this information. This requirement is considered to have been met by the Tier 1 report and supporting calculations.		
FR-G4	DOCUMENT the different aspects of seismic fragility analysis, such as the seismic response analysis, the screening steps, the walkdown, the review of design documents, the identification of critical failure modes for each SSC, and the calculation of fragility parameter values for each SSC modeled.		
	The documentation follows the requirements of NUREG-1407. The Tier 1 submittal document summarizes the IPEEE study and references the Tier 2 supporting calculations. This requirement of the Standard is considered to have been met.		

5.6 Summary of Surry SPRA Compliance with the Standard

The Surry SPRA was conducted to satisfy the requirements for IPEEE, principally to identify the most likely severe accidents and severe accident vulnerabilities. The USNRC in their SER concluded that the intent of Supplement 4 of GL 88-20 has been met. In comparing the requirements of the Standard to the IPEEE submittal for Surry, it is concluded that the overall intent of Capability Category 1 has been met but not all requirements have clearly been met. There are some areas noted in the detailed comparisons that may make the usefulness of the current model marginal for future risk informed applications which are based on the ANS standard criteria.

5.6.1 Hazard

The study was conducted using the EPRI hazard (EPRI, 1989a). For most of the Central and Eastern U.S. sites, EPRI and LLNL conducted extensive studies of the regional seismicity and developed seismic hazards applicable to the general area of the sites. These hazard studies are generally considered to meet Capability Category II of the Standard unless there is new evidence regarding seismic sources, attenuation equations or local site conditions that would suggest an update to the studies. One area of the Standard where the current LLNL and EPRI hazard studies may not completely comply with Capability Category II is in requirements HA-E1, HA-E2 and HA-F1. In the case of many of the LLNL and EPRI hazard studies, as well as the Surry hazard study, site amplification factors were applied to the predicted rock ground motion to transfer this motion to the surface of the deep soil site. The site amplification factors were based on a generalized soil type. Surry is a deep soil site and soil type V was used in the EPRI hazard study for the site amplification analysis. Soil type V is a sand-like deep soil profile (greater than 400 feet depth). The resulting surface hazard would apply to the general area but is not truly site specific.

Supplemental Technical Requirement HA-E1of the Standard alludes to the fact that existing PSHA studies should be shown to account for the *local* site effects or should be modified. For purposes of IPEEE, almost all submittals of SPRA utilized the EPRI or LLNL hazard results as reported without any special effort to compare the actual site conditions to the conditions used in developing the site amplification factors. In this case, a rigid interpretation of the technical requirement for Capability Category II is not completely met.

Supplemental Technical Requirement HA-E2 requires that both aleatory and epistemic uncertainties be addressed in the local site response analysis in order to comply with Capability Category II. The site amplification factors were calculated for three cases of shear wave velocity. The Coefficient of Variation was stated to be about 0.3. For Capability Category I, it is required to assure that all of the uncertainties in the local site response analysis are accounted for. In this case, the analysis of three cases of shear wave velocity would meet the intent of this requirement. In order to meet a rigid interpretation of Capability Category II, it would be implied that the aleatory and epistemic uncertainties be separated. This was apparently not done and in this area the PSHA does not meet a rigid interpretation of the requirements for Capability Category II.

For Capability Category II and III, Supporting Technical Requirement HA-F1 requires that the aleatory and epistemic uncertainty in the final quantification of the hazard be included and displayed. The aleatory and epistemic uncertainty in the quantification of the sources and the propagation of the energy at the source to the site was included but as noted above, the uncertainty in the site amplification was lumped. Thus, this requirement was not met for a rigid interpretation of Capability Category II. However, for all practical purposes, the EPRI PSHA utilized in the Surry SPRA should be considered to meet the requirements of Capability Category II in defining the horizontal ground motion at the site.

The existing EPRI and LLNL hazard studies define only the horizontal ground motion. The vertical ground motion is not specifically addressed. The Standard provides general requirements for developing the seismic ground motion at the site without differentiation as to the applicability to horizontal or vertical ground motion. The requirements in the Standard are assumed to apply equally to defining vertical as well as horizontal motion. Applying the basic concept of the Standard for a graded approach and considering that almost all of the existing SPRAs were conducted using EPRI and LLNL definitions of *horizontal* Uniform Hazard Spectra (UHS) and horizontal PGA, it would be beneficial if the Standard would clarify what is acceptable for the three Capability Categories. It would seem logical to allow the development of only a horizontal PGA hazard and horizontal UHS for Capability Category I. However, the hazard analyst should provide some guidance to the fragility and systems analysts on how to correlate the vertical ground motion to the defined horizontal ground motion. In this case, the LLNL and EPRI hazard studies would still fall short of meeting Capability Category I without some further guidance on the relationship of vertical to horizontal motion. Note that for SONGS, the vertical ground motion was specifically defined although only a single attenuation equation was used for vertical motion. In that respect, the vertical ground motion did not contain the full uncertainty distribution that would be expected for capability Category II but would clearly meet the intended requirements for Capability Category I.

5.6.2 Fragility

In the fragility analysis, the methodology of EPRI TR-103959 (EPRI, 1994) was utilized for developing plant specific fragilities. Most of the components were screened out on the basis of A-46 evaluations, walkdown screening in accordance with EPRI NP-6041 or supplemental calculations. The fragility for the screening level adopted had a HCLPF of 0.3g PGA and a median capacity of 0.75g PGA. When the mean hazard curve was convolved with this fragility, the frequency of failure was 1.15E-6/y. The calculated mean CDF was 8.2E-6/y, thus the screening level was about 14% of the total computed CDF. The screening level fragility was stated in the IPEEE submittal to result in insignificant contribution to risk and the screened out components were not modeled.

Supporting Technical Requirement FR-B1 requires that the screening level be set high enough that the contribution to CDF and LERF from the screened out components is not significant. It is further required that the basis for screening be fully described. In several other IPEEE SPRAs the fragility for screened out components was included as surrogate elements and in some cases, the contribution to CDF by the surrogate elements was a significant portion of the total CDF. In the Surry SPRA very few fragilities that were developed had HCLPFs less than the 0.3g PGA screening level, consequently, the effect of the low capacity fragility for screened out components is not known but is suspected to be significant. The derivation of the generic fragility for screened out components is not documented. If the procedures in EPRI TR-103959 are followed for development of a fragility from the screening tables in EPRI NP-6041, and the EPRI UHS is compared to the screening level in EPRI NP-6041, then the screening level fragility could be increased to have a HCLPF value of 0.355g and a median value of at least 0.71g compared to a HCLPF of 0.3g and a median value of 0.75g. This would slightly reduce the sensitivity of the results from not modeling the contribution of screened out elements to CDF. This issue of screening level is discussed further in the summary of system modeling.

5.6.3 Systems Analysis

Surry was a focused scope plant and was required to only search for low ruggedness relays for IPEEE. Only one type of low ruggedness relay was identified in the A-46 evaluation. This type of relay existed in the field flash circuits for the three emergency diesel generators. This type of relay was confirmed by utility engineers not to exist in other areas of the plant. There appeared to be no further search for low ruggedness relays in circuits associated with IPEEE only equipment which would include emergency core cooling and containment isolation and cooling system circuits. Supporting Technical Requirement FR-F3 requires that seismic fragilities be developed for low ruggedness relays for Capability Category I. The low ruggedness relays in the field flash circuits were to be replaced and were not modeled. It is implied that fragilities for all other relays would exceed the screening level, thus relays were not modeled. However, it appears that the search for low ruggedness relays was not carried beyond the A-46 scope of work, thus the questions exists if there are any low ruggedness relays in additional circuits associated with IPEEE scope. The compliance with Capability Category I requirements doesn't appear to be completely met unless the relay screening for low ruggedness relays is expanded to include all IPEEE equipment.

The systems model for Surry ended up to be very simple. There are some unique issues at Surry that resulted in two thirds of the calculated risk being attributed to two accident sequences. Surry has an intake canal that is the source of circulating water and service water. In the event of an earthquake, with the loss of offsite power to the circulating water pumps, the isolation valves to the condenser water boxes must be closed in order to keep from draining the intake canal and loosing the heat sink. The turbine building was not seismically designed and has a low capacity (HCLPF = 0.19g PGA). Failure of the turbine building is assumed to fail the electrical and control cables to the isolation valves. It also is assumed to keep operators from accessing and manually closing the valves, thus core damage would result with loss of containment cooling. This is 36% of the total computed CDF.

Surry has only one dedicated emergency diesel generator for each unit and a third diesel generator that can be aligned to either unit. In the internal events model the third diesel is aligned to Unit 2, thus Unit 1 has only a single emergency diesel available. In the event of loss of offsite power, the random failure of the single diesel and human error to start or restart the diesel contributes to a station blackout and ultimate core damage and loss of containment cooling. This scenario appears in two accident sequences and contributes 29% of the CDF in one sequence and 3% in the other sequence.

Other contributors arise from loss of Auxiliary feedwater due to failure of the Emergency Condensate tank and loss of component cooling due to loss of the CC surge tank. The two tanks have HCLPFs less than the 0.3g screening level. These four failures contribute 92% of the total core damage frequency. Thus, it was logical for IPEEE to screen out all components with HCLPF greater than the 0.3g screening level HCLPF. However, Supplemental Technical Requirement SA-E3 of the Standard states to use the quantification process to ensure that any screening of SSCs does not affect the results, taking into account the various uncertainties. The calculated frequency of failure of screened out components was greater than 1E-6/y. Ignoring screened out components in the systems model does not comply with this requirement.

If the effects of the screened out components and other components with calculated HCLPFs in the 0.3g to 0.4g range were modeled, the total CDF would rise but it is unlikely that the governing accident sequences would change position for the EPRI hazard. A sensitivity study was conducted using the LLNL hazard (USNRC, 1994). The results were not reported in the Tier 1 IPEEE submittal. In a Tier 2 report, the LLNL hazard increased the CDF by 55%. It is interesting to note that the mean LLNL and mean EPRI hazard are equal at the calculated plant level HCLPF of 0.155g. But, the slopes are much different and at 0.3g, the screening level HCLPF for components not modeled, the LLNL mean frequency of occurrence is 2.5 times that of the EPRI hazard. At the median value of the fragility for screened out components (0.75g PGA). The LLNL hazard frequency is about 7.5 times that of the EPRI hazard. If the LLNL hazard was used in an expanded model that contained additional accident sequences involving screened out components and components with calculated HCLPFs greater that 0.3g, the contribution from these additional sequences would rise rapidly.

It appears that if the Surry SPRA were to be used for future risk informed applications (and comply with the intent of the ANS standard), the model would have to be expanded to include components with higher capacities and include the accident sequences in which they may participate.

Other areas of the Standard for which the Surry IPEEE submittal does not comply are related to correlation and dependencies as previously discussed for the SONGS SPRA. Supplemental technical requirements SA-B3, SA-E4 and SA-E6 address dependencies and correlations. In the Surry SPRA, as in virtually all SPRAs, it is assumed that like components in redundant trains are correlated and unlike components in the same train or in different systems are independent. No sensitivity analyses of correlation are addressed. As discussed for the SONGS SPRA, this is a generic issue with the Standard and the methodology applied in SPRAs. As was discussed in the summary of the SONGS SPRA, these supporting technical requirements for Capability Category I should probably accept what is commonly done in the industry whereas the requirements as written should apply to Capability Categories II and III.

Supplemental Technical Requirement SA-E5 requires a full uncertainty analysis for CDF and LERF for capability Category II and III. The Surry SPRA was conducted in accordance with the NUREG-1407 that only required a point estimate of CDF. This meets the requirements of Capability Category I.

Supporting Technical Requirement SA-B5 requires that the effects of relay chatter of so-called low ruggedness relays be considered for Capability Category I. As previously discussed, the search for low ruggedness relays was apparently not extended to include non-A-46 components, consequently, it is not assured that there are not any additional low ruggedness relays in the circuits that are unique to IPEEE scope of equipment.

5.6.4 Documentation

The Tier1 documentation is in accordance with NUREG-1407 but does not provide the detail required in the Standard in SA-F2 regarding the specific adaptations made in the internal-events PRA model to produce the SPRA model. Also, Supplemental Technical Requirements FR-G2 through FR-G4 require a lot of detail on the development of fragilities. The Surry Tier 1 submittal for IPEEE provides little detail on the development of fragilities and refers only to the EPRI methodology in EPRI TR-103959. The calculation files are identified in the reference list but are not identified in the text of the Tier 1 report. The information required by the Standard is identified and recoverable, thus meets the intent of the Standard. It is just not summarized in enough detail in the Tier 1 report to satisfy all of the requirements of the Standard.

5.6.5 Peer Review

Another requirement in the Standard that was not completely met in any of the studies reviewed is the requirement for peer-review. The Standard refers to the general requirements in the ASME Standard for PRA (ASME, 2002) and provides specific requirements for SPRA and SMA. IPEEE required peer-reviews but not in the depth required in the Standard.

In the case of Surry, the peer-review was conducted by a single consultant and focused primarily on the walkdown. Some sampling of fragility analyses were also conducted by the peer-reviewer. The peer-reviewer's report is included as an Appendix to the Tier 1 IPEEE report and the resolution of his findings are documented. There seems to be no peer review of the systems modeling including the human reliability analysis. The EPRI hazard was used for the SPRA. The EPRI hazard study was comprehensive, was previously peer reviewed and was taken as a given input so no additional reviews of the hazard study were conducted in IPEEE. In the systems and fragility areas, the peer review was insufficient to meet the intent of the Standard.

The conclusion is that the Surry IPEEE SPRA generally meets the intent of Capability Category I of the Standard but in several areas discussed above, a rigid interpretation of the Standard was not met. The screening level was set wherein a single screened out component that would lead to core damage would contribute an additional 14% to CDF. Including screened out components as surrogate elements in accordance with the recommendations in EPRI TR-103959 would significantly expand the model and potentially increase the calculated CDF. The Standard does not address the use of surrogate elements. It requires the screening level to be high enough that the effect on calculated CDF and LERF is not significant. In either case, the screening level was not justified in relation to the goal of the Standard to "set forth requirements for external–event probabilistic risk assessment (PRA) used to support risk-informed decisions for commercial nuclear power plants." Consequently, the simplified model would likely require enhancements by adding more components and accident sequences if it is to be used universally for risk informed applications.

6 CONCLUSIONS

The three studies that were compared to the Standard represent two extremes in the site seismic hazard for SPRA and a typical SMA. The two SPRAs were conducted to meet the requirements of IPEEE as defined in NUREG-1407. The minimum requirements in NUREG-1407 for a point estimate of CDF would fall within the requirements of the Standard for Capability Category I. Much of the activity that was conducted in the two SPRA studies would meet the requirements of Capability Category II or in many cases Capability Category III. The Catawba SMA was originally conducted as a trial plant review to test the initial EPRI SMA methodology (EPRI, 1988). That work was performed before the requirements for IPEEE were defined in NUREG-1407. Consequently, the scope of the Catawba SMA did not include containment performance, seismic/fire interaction or peer-review as required in IPEEE. Catawba submitted a SPRA for IPEEE and these additional requirements were included in their IPEEE submittal.

The Standard was written to envelop the state-of-the-art practice in external event PRA and SMA and included the NRC requirements for IPEEE. The requirements in the Standard for SMA closely follow the requirements of both EPRI NP-6041 and NUREG-1407. It would be expected then that IPEEE SPRA submittals would conform to at least Capability Category I requirements and that SMA submittals would be in agreement with the SMA requirements in the Standard. This was determined to be the general case. However, there are a few areas in the Standard where the requirements are not completely clear or not practically achievable and some areas in the cases studied where a rigorous interpretation of the Standard was not completely met, even for Capability Category I. The two SPRA submittals for IPEEE were accepted by the NRC as meeting the intent of the IPEEE program to identify the most limiting SSCs in a nuclear power plant. It is concluded in this report that the intent of the Standard was met for Capability Category I, though not every detail of the Standard was clearly met. The Catawba SMA was performed in accordance with the requirements of EPRI NP-6041. The EPRI requirements focus on safe shutdown paths but do not address containment performance or the Sandia Seismic/Fire Interaction issues (USNRC, 1989). Otherwise the Catawba SMA followed the requirements of the Standard.

Tables 6-1 through 6-3 summarize the Capability Categories that were met or not met for each of the Supplemental Technical Requirements for hazard analysis, systems analysis and fragility analysis.

Table 6-1
Supplemental Technical Requirements, Hazard Analysis

Supplemental Technical Requirements	Plant	Capability Category I	Capability Category II	Capability Category III	Notes
HA-A1	SONGS			X	
	SURRY			X	
HA-A2	SONGS		X		4
	SURRY		X		4
HA-A3	SONGS			X	
	SURRY			X	
HA-A4	SONGS			X	
	SURRY			X	
HA-B1	SONGS			X	
	SURRY		X		5
HA-B2	SONGS			X	
	SURRY			X	
HA-B3	SONGS			X	
	SURRY			X	
HA-C1	SONGS			X	
	SURRY			X	
HA-C2	SONGS			X	
	SURRY			X	
HA-C3	SONGS			X	
	SURRY			X	
HA-C4	SONGS				Not Applicable (1)
	SURRY		X		6
HA-D1	SONGS			X	
	SURRY	X			7
HA-D2	SONGS			X	
	SURRY	X			7
HA-D3	SONGS			X	
	SURRY	X			7
HA-D4	SONGS				Not Applicable (1)
	SURRY	X			7, 8
HA-E1	SONGS		X		2
	SURRY	X			7
HA-E2	SONGS		X		2
	SURRY	X			7

Table 6-1
Supplemental Technical Requirements, Systems Analysis (Continued)

Supplemental Technical Requirements	Plant	Capability Category I	Capability Category II	Capability Category III	Notes
HA-F1	SONGS			X	
	SURRY	X			7
HA-F2	SONGS			X	
	SURRY	X			7
HA-F3	SONGS		X		3
	SURRY	X			3, 7
HA-G1	SONGS		X		3
	SURRY	X			3, 7
HA-H	SONGS				Not Applicable (1)
	SURRY		X		9
HA-I	SONGS			X	
	SURRY		X		10
HA-J1	SONGS			X	
	SURRY			X	
HA-J2	SONGS			X	
	SRRY			X	

Notes

1. A new hazard analysis was conducted, therefore this requirement relating to use of an existing hazard study is not applicable.
2. A single attenuation equation was used for predicting vertical response, thus it is judged that the site amplification of vertical motion did not include sufficient parameter variations to comply with the intent of Capability Category III.
3. Seismic Source and magnitude and distance deaggregation required for Capability Category III were not conducted.
4. The requirements for Capability Category III would imply that the hazard be defined at specific frequencies or narrow frequency ranges – corresponding to the fundamental frequency of each of the essential structures. This was not done in either case for SONGS or SURRY.
5. Although the stated requirements are the same for all Capability Categories, the representation of the soil properties for determining site amplifications was generic, thus the EPRI hazard study cannot be considered to meet Capability Category III.
6. The utility did not conduct further investigation into the seismic sources (known and postulated area sources), thus meeting the requirements of Capability Category III was not demonstrated.
7. Vertical motion was not predicted in the EPRI studies, thus, considering the concept of a graded evaluation, it is judged that the attenuation portion of the hazard analysis only met the requirements of Capability Category I.
8. The utility did not conduct further investigations into the ground motion attenuation models, thus Capability Category III would not have been met for horizontal motion. Refer to Note 7 for vertical motion.
9. At the time of the Surry SPRA, the EPRI hazard study was about 8 years old and still considered to be valid although the validity was not addressed in the SPRA. Currently, the hazard study is 14 years old and may be outdated. Capability Category II is considered to have been met at the time of the SPRA.
10. The screening level was sufficiently high that the unconditional failure of soil, assumed to lead to core damage, was less than 1E-6/yr. The actual threshold of failure was not predicted. Considering the graded approach concept, it is judged that Capability Category II was met but Capability Category III would require a higher screening level on the development of a fragility description for soil failures.

Table 6-2
Supplemental Technical Requirements, Systems Analysis

Supplemental Technical Requirements	Plant	Capability Category I	Capability Category II	Capability Category III	Notes
SA-A1	SONGS			X	
	SURRY			X	
SA-A2	SONGS			X	
	SURRY			X	
SA-A3	SONGS			X	
	SURRY			X	
SA-B1	SONGS			X	
	SURRY			X	
SA-B2	SONGS			X	
	SURRY			X	
SA-B3	SONGS	X			1
	SURRY				7
SA-B4	SONGS			X	
	SURRY			X	
SA-B5	SONGS			X	
	SURRY				8
SA-B6	SONGS			X	
	SURRY			X	
SA-B7	SONGS	X			2
	SURRY			X	
SA-B8	SONGS	X			2
	SURRY			X	
SA-B9	SONGS			X	
	SURRY			X	
SA-B10	SONGS			X	
	SURRY			X	
SA-C1	SONGS			X	
	SURRY			X	
SA-D1	SONGS			X	
	SURRY			X	
SA-E1	SONGS			X	
	SURRY			X	
SA-E2	SONGS			X	
	SURRY			X	
SA-E3	SONGS			X	
	SURRY				9
SA-E4	SONGS	X			3
	SURRY	X			3

Table 6-2
Supplemental Technical Requirements, Systems Analysis (Continued)

Supplemental Technical Requirements	Plant	Capability Category I	Capability Category II	Capability Category III	Notes
SA-E5	SONGS	X			4
	SURRY	X			4
SA-E6	SONGS				5
	SURRY				5
SA-F1	SONGS			X	
	SURRY			X	
SA-F2	SONGS		X		6
	SURRY		X		6
SA-F3	SONGS	X			10
	SURRY	X			10

Notes

1. Correlations and dependencies were not specifically addressed in determining the screening level. However, the screening level was set so that the unconditional failure rate of screened out components was less than 1E-7/year. This is more than 2 orders of magnitude less than the computed CDF, therefore, a specific consideration of correlations and dependencies is considered to be unnecessary in this case to comply with Capability Category I.
2. Blockage of operator access to perform actions outside of the control room were not specifically addressed. However, with the consideration of seismic/fire interaction, seismic induced internal flooding spatial systems interactions and performance shaping factors (multipliers for operator error) for operator actions outside the control room, the intent was met for at least Capability Category I.
3. Correlations and dependencies were addressed in the simplest manner assuming like components in redundant trains to be correlated and all other components to be uncorrelated. This is the common assumption in SPRAs. A rigorous interpretation of the Standard would conclude that this requirement was not met for any of the Capability Categories. However, it is suggested that the simplified correlation criteria applied in SONGS, Surry and other IPEEE SPRAs should be considered to meet Capability Category I.
4. The calculation of CDF was limited to a point estimate. A full uncertainty analysis would be required for Capability Category II or III.
5. Sensitivity analysis for assumptions made in correlations and dependencies was not conducted. Thus, the SPRA did not meet any of the Capability Categories for this STR.
6. The Tier 1 documentation was in accordance with the requirements of NUREG-1407 and in general met the requirements of the Standard. The Tier 2 documentation was not reviewed. The Tier 1 documentation does not provide a complete road map to all supporting Tier 2 documents. Considering that there is a gradation in completeness and quality through the three Capability Categories, it is considered that Capability Category II was met for the work conducted.
7. Correlations and dependencies were not addressed in the screening of components. The screening level was set at 0.3g PGA which resulted in an unconditional failure rate of 1.15E-6/yr for screened out components. The combination of not considering correlations and dependencies in setting the screening level, a relatively high failure rate for screened out components and not modeling the contribution of screened out components is considered to not meet the intent of the Standard for any of the Capability Categories.
8. Surry was a focused scope plant and the treatment of relays was limited to a search for low ruggedness relays. The search for low ruggedness relays was not extended beyond the USI A-46 program, thus the requirements of the Standard for Capability Category I was not completely met.
9. The screening level for the Surry SPRA results in an unconditional failure rate of 1.15E-6/yr. The contribution of screened out components to CDF and LERF were not modeled nor was the screening level justified. Therefore this requirement was not met for any of the Capability Categories.
10. Uncertainty analyses of a few variables were conducted, however, a full uncertainty analysis including the uncertainty in the seismic hazard, was not conducted, thus, only a Capability Category I analysis was documented.

Table 6-3
Supplemental Technical Requirements, Fragility Analysis

Supplemental Technical Requirements	Plant	Capability Category I	Capability Category II	Capability Category III	Notes
FR-A1	SONGS			X	
	SURRY			X	
FR-A2	SONGS		X		1
	SURRY	X			7
FR-B1	SONGS		X		2
	SURRY				8
FR-B2	SONGS				Not Applicable
	SURRY			X	
FR-C1	SONGS			X	
	SURRY			X	
FR-C2	SONGS		X		3
	SURRY		X		3
FR-C3	SONGS				Not Applicable
	SURRY				Not Applicable
FR-C4	SONGS		X		3
	SURRY		X		3
FR-C5	SONGS				Not Applicable
	SURRY				Not Applicable
FR-C6	SONGS		X		3
	SURRY		X		3
FR-D1	SONGS			X	
	SURRY			X	
FR-D2	SONGS			X	
	SURRY			X	
FR-E1	SONGS			X	
	SURRY			X	
FR-E2	SONGS			X	
	SURRY			X	
FR-E3	SONGS			X	
	SURRY			X	
FR-E4	SONGS			X	
	SURRY			X	
FR-E5	SONGS			X	
	SURRY			X	
FR-F1	SONGS		X		4
	SURRY		X		4
FR-F2	SONGS		X		5
	SURRY		X		5
FR-F3	SONGS		X		6
	SURRY				9

Table 6-3
Supplemental Technical Requirements, Fragility Analysis (Continued)

Supplemental Technical Requirements	Plant	Capability Category I	Capability Category II	Capability Category III	Notes
FR-F4	SONGS			X	
	SURRY			X	
FR-G1	SONGS			X	
	SURRY			X	
FR-G2	SONGS			X	
	SURRY				10
FR-G3	SONGS			X	
	SURRY			X	
FR-G4	SONGS			X	
	SURRY			X	

Notes

1. Fragilities in some cases were based on GERS. Thus not all were plant specific.
2. Screening was not demonstrated to be independent, thus, the Capability Category III requirement is not met.
3. Probabilistic response analysis was conducted, however, joint probability distributions of the responses of different components in the building were not calculated, thus Capability Category III requirements were not met.
4. Fragilities were derived as a function of average spectral acceleration for SONGS and PGA for Surry. The joint probability distributions of the capacity of different components was not derived. Thus Capability Category III requirements were not met.
5. Capability Category III requires that plant specific material test data be incorporated into the fragility derivation. This is not a practical requirement for all components thus Capability Category III cannot be achieved.
6. Capability Category III would also require that FR-C6 and FR-F1 be met.
7. Most components were screened out on the basis of earthquake experience data, thus only Capability Category I is met.
8. The screening of component was based primarily on the SQUG-GIP screening and EPRI NP-6041 screening. The unconditional failure rate for screened out components was 1.15E-6/yr. The contribution to CDF of screened out components was not included in the quantification, thus it is judged that the screening level was too low to not be a significant contributor to CDF. In this respect, the Standard was not met for any of the Capability Categories.
9. Surry was a focused scope plant and only a search for low ruggedness relays was conducted and this appeared to be limited to A-46 equipment only. Consequently, the requirements of Capability Category I were not completely met.
10. *Requirement is met for fragilities that were plant specific but the derivation of the generic fragility for screened out* components is not documented. Thus, in this respect, the Standard was not met.

Areas where there may be confusion regarding the requirements of the Standard or where there was not a clear case made that the Standard was met relate to (1) correlation and dependencies, (2) Screening level and treatment of screened out components in the risk modeling, (3) Use of existing PSHA, (4) peer-review and (5) documentation. The requirements as they relate to Capability Category I and II are addressed. It is unlikely that any user will attempt Capability Category III outside of a research program, thus, there is no critique offered on the requirements or whether the case studies met or could meet parts of Capability Category III requirements.

1. Correlation and Dependencies: There are three supporting technical requirements in the standard that deal with correlation and dependencies. In STR SA-B3, the requirements for Capability Category I and II are the same, and are stated to "PERFORM an analysis of seismic –caused dependencies and correlations in a way so that any screening of SSCs appropriately ACCOUNTS FOR those dependencies and correlations. The analysis MAY use generic dependency and correlation values if justified." It appears for the case studies reviewed in this document and in the review of all IPEEE submittals (EPRI, 2000a) that the screening level has been selected without any analysis of correlation and dependency. Consequently no one has fully complied with this requirement. Typically, the screening level has been set at the seismic experience based screening levels in EPRI NP-6041 (EPRI, 1988 and EPRI, 1991a). This has often proven to be too low of a screening level if the risk models are to be used in risk informed regulation. In other cases, the screening levels were set at a higher value and it is likely that the correlation issue is not of concern. In this case, the SONGS screening level was considered high enough that the degree of correlation of screened out components should not make a significant difference. The screening level for Surry, while adequate for the objective of IPEEE, was likely too low for future risk informed applications and the SA-B3 requirement in the standard was not considered in establishing a screening level. Surry will likely have to increase the screening level and include more components in the risk model for some future risk informed applications.

   SA-E4 and SA-E6 deal with the modeling of correlation and dependency in the risk quantification. SA-E4 has the same requirements for Capability Category I and II; "In the integration/quantification analysis, ACCOUNT for all significant dependencies and correlations that affect the results. The analysis MAY use generic dependency and correlation values if justified." SA-E6 requires that sensitivity studies be performed to "illuminate the sensitivity of the CDF and LERF results to the assumptions used about dependencies and correlations." SA-E6 applies to all Capability Categories.

   Common seismic risk modeling practice is to assume that the seismic failures of like components in redundant trains are correlated. They are the same component in essentially the same location and would have the same strength and respond the same to the earthquake, thus if one fails, the other fails. This may have a small amount of conservatism if there are some small differences in the actual strength, the input motion or actual response. On the other hand, components that are not alike are considered to be uncorrelated regardless of their location. This could be conservative or unconservative depending on their function in the risk model. The OECD/NEA Workshop (OECD/NEA, 1999) had some technical papers on this subject although the examples are simplified and no clear guidance for treating correlations and dependencies in full scale SPRAs exists in the public domain.

   In this area, the Standard could be more specific in the notes to possibly state that the above current modeling practice is one generic method to treat correlation and should be acceptable for Capability Category I providing that the screening level produces failure rates something like two orders of magnitude below the calculated mean CDF. One order of magnitude is likely not enough when considering the contribution of uncorrelated multiple screened out components that appear in OR gates in the Boolean expressions of many accident sequences that lead to core damage. For Capability Category II, the quantification must contain an uncertainty analysis and should include, as a minimum, the sensitivity of the correlation assumptions on the final distribution of CDF and LERF. With the above suggestions, the

SONGS SPRA would meet Capability Category I but the Surry SPRA would still fall short of meeting the requirements mainly because of the low screening level. With the wording as it is now, some would conclude that the SONGS SPRA, as well as other IPEEE SPRAs, do not comply with Capability Category I.

2. Screening Level and Treatment of Screened out Components in the Risk Model: STR FR-B1 requires the screening level to be high enough that the contribution to CDF and LERF from the screened out components is not significant. In conjunction with this STR, SA-B3 requires that an analysis be conducted addressing the dependencies and correlations of screened-out components in such a way so that any screening of SSCs appropriately accounts for those dependencies and correlations. This has been discussed to some extent in item 1 above and some clarification and additional guidance in the Standard was recommended to separate the requirements for Capability Category I to those of Capability Category II. The SONGS screening level was high enough that STR FR-B1 was considered to be met but the Surry screening level was much lower and it is concluded that STR FR-B1 was not completely met.

3. Use of existing PSHA: The Surry SPRA and almost all IPEEE SPRAs used either the EPRI (1989a) or USNRC (1994) hazard studies to define the earthquake frequency and spectral shape. At the time of IPEEE for Surry and most other plant IPEEE SPRAs, the existing hazard studies were the most current available and were used without any questions regarding their applicability. STR HA-D4 and HA-H allude to assuring that an existing PSHA is still applicable for the site. The USGS has released probabilistic hazard studies in recent years that suggest in some cases that the hazard is more severe than the EPRI and LLNL hazard studies. If existing IPEEE SPRAs are to be used in future risk informed applications, the user may need to address the differences in the current USGS hazard and the EPRI and LLNL hazard. Also, the issue of vertical hazard vs. horizontal hazard may need to be addressed.

   The existing EPRI and LLNL hazard studies define only the horizontal ground motion. The vertical ground motion is not specifically addressed. The Standard provides general requirements for developing the seismic ground motion at the site without differentiation as to the applicability to horizontal or vertical ground motion. The requirements in the Standard are assumed to apply equally to defining vertical as well as horizontal motion. In the case of the SONGS SPRA, the seismic ground motion was defined in both the vertical and horizontal directions.

   The Standard refers to NUREG/CR-6372 (Budnitz, 1997) for further guidance on developing the seismic hazard. In that document it is stated that "Less emphasis is usually placed on the vertical component of motion. The vertical component is often estimated from the horizontal component using a rule-of-thumb, for example where the vertical is about 2/3 of the horizontal. Such rules should be used with caution. The actual ratio may depend on the frequency of motion, the local site conditions, the focal mechanisms and the distance from the event. If important, we recommend that vertical motions be obtained from independent analyses, in the same manner as for the horizontal motions."
   In most cases the fragilities are not significantly influenced by the vertical motion and uncertainties regarding the vertical vs. horizontal acceleration are included in the derivation of fragilities. However, if the vertical ground motion UHS are much different in shape than the horizontal UHS, this uncertainty is not captured. The typical UHS for Central and Eastern

U.S. sites has high frequency amplification of the peak ground acceleration. The structures are stiffer in the vertical direction, thus the floor spectra applied as demand to equipment may have very high spectral acceleration in the vertical direction and a more accurate definition of vertical ground motion input may be desirable.

The basic concept of the Standard is to have a graded approach. Considering that almost all of the existing SPRAs were conducted using EPRI and LLNL definitions of *horizontal* Uniform Hazard Spectra (UHS) and horizontal PGA, it would be beneficial if the Standard would clarify what is expected for the three Capability Categories.

It would seem logical to allow the development of only a horizontal PGA hazard and horizontal UHS for Capability Category I. However, the hazard analyst should provide some guidance to the fragility and systems analysts on how to correlate the vertical ground motion to the defined horizontal ground motion. In this case, the LLNL and EPRI hazard studies would still fall short of meeting Capability Category I without some further guidance on the relationship of vertical to horizontal motion. For SONGs, the vertical ground motion was specifically defined although only a single attenuation equation was used for vertical motion. In that respect, the vertical ground motion did not contain the full uncertainty distribution that would be expected for capability Category II.

It is suggested that the Standard clarify the requirements for vertical hazard as well as horizontal hazard. Existing PSHA (EPRI and LLNL) should be acceptable for Capability Category I provided that the user can justify that the studies are still realistic for the site. The Standard might go further to state that existing studies such as those by EPRI and LLNL may also be acceptable for Capability Category II provided that sensitivity studies show that the resulting CDF is not appreciably influenced by "rule-of-thumb" assumptions regarding the correlation between vertical and horizontal hazard.

4. Another requirement in the Standard that was not completely met in any of the studies reviewed is the requirement for Peer Review. The Standard refers to the general requirements in the ASME Standard for PRA (ASME, 2002) and provides specific requirements for SPRA and SMA. IPEEE required peer reviews but not in the depth required in the Standard. In the case of SONGS, the seismic hazard was peer reviewed by three independent experts. The systems analysis, including HRA, was reviewed by knowledgeable in house staff that did not directly participate in the SPRA. Fragility analyses and walkdowns were performed jointly by the utility and EQE, a consulting company. The two teams reviewed each other although the reviewers were not independent of those doing the work. An independent consultant performed a focused review of the response analysis and some fragility analyses. The review teams and their conclusions are contained in the Tier 1 IPEEE report.

   In the case of Surry, the peer review was conducted by a single consultant and focused primarily on the walkdown. Some sampling of fragility analyses was also conducted by the peer reviewer. The peer reviewer's report is included as an Appendix to the Tier 1 IPEEE report and the resolution of his findings are documented. There seems to be no peer review of the systems modeling including HRA. The EPRI hazard was used for the SPRA. The EPRI hazard study was comprehensive and was previously peer reviewed and was taken as a given input so no additional reviews of the hazard study were conducted in IPEEE. The overall level of peer review was insufficient to meet the intent of the Standard.

The Catawba SMA was conducted before the issuance of NUREG-1407 that required peer review. The objective of the Catawba SMA was a Trial Plant Review of EPRI NP-6041. The EPRI document did not require a peer review, therefore none was conducted. If existing SPRAs are to be used for risk informed applications the peer-review requirements of the Standard should be met. If changes are made to the SPRA each change should be subject to peer review in accordance with the requirements of the Standard.

5. Documentation: The documentation of existing SPRAs and SMAs was conducted in a format required by NUREG-1407 for Tier 1 reports. Tier 2 detailed reports and supporting calculations are generally available in the utility files but in some cases the reference to them was missing. The requirements of the Standard would suggest that the reporting be more complete and informative than the Tier 1 reports in order for independent reviewers to perform an effective peer-review. In most cases, the USNRC requested additional information due to the fact the IPEEE Tier 1 reports were not sufficient to completely understand the methodologies and assumptions incorporated into the computation of CDF. It may not be necessary to reformat the existing IPEEE documentation for future risk informed applications, but in order to provide for more thorough peer-review of risk informed applications, some additional referencing and road maps to the backup documentation may be necessary. The objective would to be have a base analysis and documentation that clearly has been subjected to proper peer review. For each risk informed application, the changes, assumptions and results could be appended and subject to the peer-review required by the Standard.

From the reviews conducted in this study and those of EPRI (2000a) it appear that the IPEEE SPRAs meet almost all of the requirements of the Standard for Capability Category I and could be considered to meet the intent of Capability Category I. Some, as in the case of SONGS, conducted their screening at a high enough level that there should be very little additional work that needs to be done to make convincing seismic risk based arguments in accordance with Regulatory Guide 1.174 (USNRC, 1998) to address changes in the licensing basis, plant operation, inspection or testing procedures. Ultimately, a full uncertainty analysis accounting for the uncertainty in the hazard and the fragilities and the affects of the correlation assumptions would have to be conducted to support some of the risk informed applications. In the case of Surry and several other plants that screened out components at a low level and did not address the correlation of screened out components, it would appear that the models would have to be expanded to incorporate the fragilities of screened out components and address their correlation. A higher screening level may also be necessary.

The application of SMA to risk informed regulation will require a SPRA model to be developed to a degree necessary to address the issue at hand. The existing screening levels and HCLPF calculations can be transformed into fragilities for use in the risk quantification. However, it may be necessary to increase the screening level, thus the fragility of screened out components, in order to derive a useful model for many risk informed applications.

7
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51. USNRC (1997b), "Standard Review Plan," NUREG-0800, Section 2.5.2, 1997.

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53. USNRC (2000), "Risk-Informed Regulation Implementation Plan," October 2000.

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55. VEPCO (1997b), "Surry Power Station Units 1 and 2, Report on Individual Plant Examination of External Events (IPEEE) – Seismic," Prepared in Response to USNRC Generic Letter 88-20 Supplements 4 and 5, November 1997.

Program:
Nuclear Power

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Comments on American Nuclear Society
American National Standard on
External-Events PRA Methodology

The following presents a select set of overview comments on the subject standard for use in external events. The comments are not intended to be exhaustive or have a significant level of depth. Rather, these selected comments are designed to illustrate that a more critical review of the standard, performed as part of a pilot application of the standard, is needed to ensure that the standard meets the needs of the user community.

System Analysis High Level Requirement A: Completeness (SA-A1). This requirement seems to indicate (via note SA-A1) that effort should be expended in the evaluation of seismic initiating events. While this is true for several of the examples provided, seismic initiating events associated with the loss of offsite power and loss of supporting systems need not be investigated and this investigation should not be a requirement of any capability category. This observation is based on the fact that for seismic accelerations that result in a high likelihood of system failure should result in a trip of the main turbine as a result of actuation of vibration sensors installed in the turbine systems for the purpose of turbine protection. These sensors and logic result in a trip of the turbine at very low vibrations and their success will result in a turbine trip. Subsequent failure of offsite power or other support systems need not be addressed as initiating event unless a case can be made for the uniqueness of the resulting plant response. This is due to the fact that these events will most likely lag the turbine trip on a successful actuation of sensors and logic performing as designed as opposed to a failure of systems, structure or components (SSCs). Consideration of support system failure as an initiating event in seismic analysis can affect PRA logic model success criteria as well as the progression of the accident sequence and frequency of seismic CDF.

System Analysis High Level Requirement B: Adaptations Based on the Internal-Events PRA Systems Model (SA-B9). This requirement seems to indicate that a small-small LOCA should be added to each individual accident sequence. While a statement is made that this requirement is just to consider the addition of this term to each accident sequence, justification for omission is also required. However, in the text above it is stated "Further-more, breaks from one to a few square centimeters cannot otherwise be precluded ...". These statements appear to contradict each other. In any event, the arbitrary addition of a small loss of coolant to every accident sequence is very conservative requiring additional mitigative systems that would otherwise not be required for the mitigation of many accident sequences.

Seismic Fragility Evaluation High Level Requirement A: Realism. A strict interpretation of the note FR-A1 indicates that a seismic fragility is required for every SSCs modeled in the event tree and fault trees. This is actually not current state-of-the-art practice where the "weak-link" approach is used. In the weak link approach, the weakest link of a system or system function, in terms of an SSC, is identified and a fragility is performed to represent this SSC. It is assumed that the note does not actually imply a unique fragility needs to be developed for each SSC included in the model however, the wording of the requirement is unclear.

Comments to DG-1138:
NRC Staff Regulatory Position on ANS External Hazards PRA standard

Specific comments are included within the text in color.

DRAFT APPENDIX C

NRC REGULATORY POSITION ON ANS EXTERNAL HAZARDS PRA STANDARD

Introduction

The American Nuclear Society has published ANSI/ANS-58.21-2003, "External Events PRA Methodology Standard". The standard states that it "sets forth requirements for external-event probabilistic risk assessments (PRAs) used to support risk informed decisions for commercial nuclear power plants, and prescribes a method for applying these requirements for specific applications." The NRC staff has reviewed ANSI/ANS 58.21-2003 against the characteristics and attributes for a technically acceptable PRA as discussed in Chapter 3 of this regulatory guide. The staff's position on each requirement (referred to in the standard as a requirement, a high-level requirement, or a supporting requirement) in ANSI/ANS 58.21-2003 is categorized as "no objection," "no objection with clarification," or "no objection subject to the following qualification," and defined as follows:

- No objection: the staff has no objection to the requirement.
- No objection with clarification: the staff has no objection to the requirement. However, certain requirements, as written, are either unclear or ambiguous and therefore, the staff has provided its understanding of these requirements.
- No objection subject to the following qualification: the staff has a technical concern with the requirement and has provided a qualification to resolve the concern.

Table C-1 provides the staff position on each requirement in ANSI/ANS 58.21-2003. A discussion of the staff concern (issue) and the staff proposed resolution is provided. In the proposed staff resolution, the staff clarification or qualification to the requirement is indicated either in bolded text (i.e., **bold**) or strikeout text (i.e., ~~strikeout~~); that is, the necessary additions or deletions to the requirement (as written in ANSI/ANS 58.21-2003) for the staff to have no objection are provided.

DRAFT Table C-1 Staff Position on ANSI/ANS 58.21-2003

Index No	Issue	Position	Resolution
SECTION 1			
1.1	The standard is only for current generation LWRs, the requirements may not be sufficient or adequate for other types of reactors	Clarification	The objectives of this standard are to set forth requirements for external-event probabilistic risk assessments (PRAs) used to support risk-informed decisions for **current** commercial **light water reactor** nuclear power plants, and to prescribe a method for applying these requirements for specific applications **(additional or revised requirements may be needed for other reactor designs).**
1.2	----------------	No objection	----------------

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Index No	Issue	Position	Resolution
1.3 Scope	Second Paragraph can potentially lead to confusion and misinterpretation, concerning when the term "PRA " is inclusive of "SMA" and when it is not. Further, the distinction between the seismic PRA and SMA methodologies needs to be clearly stated.	Qualification	Delete the 2nd para. Add a para: **Although both seismic PRA and SMA are intended to support risk-informed applications, the distinction between them regarding their applicability to develop risk insights needs to be clearly understood. The SMA is a *deterministic* risk methodology, and in this context, a well executed SMA analysis can provide qualitative, and limited quantitative risk insights that could be used to support an intended application. However, for situations where detailed quantitative risk insights are necessitated, a seismic PRA is needed to obtain the required insights.** The intent of the Standard in this paragraph was to inform the reader that the standard typically uses the term SPRA to refer to both SPRA and SMA studies. The proposed change by the NRC deletes this message entirely and would not be appropriate. The standard states "In some places in the standard, the phrase "seismic PRA" is used in a generic sense. Often, for example, in most of the language in this Introductory Section 1, the intent is to include SMA methods as well as seismic PRA methods within the scope of the acronym PRA."
1.3.2	The term *full-scope PRA* is misleading in the context of RG 1.200.	Clarification	...that use *aspects of PRA methodology but are* not ~~full-scope~~ **complete** PRAs themselves (see 3.4, for example). The substitution of the word "complete" for "full-scope" offers no further clarification.
1.3.2	The "demonstrably conservative" and "bounding" analyses are performed using different approaches, and should not be used interchangeably.	Clarification	...~~(Herein, the phrases "bounding analysis" and "demonstrably conservative analysis" are used interchangeably.)~~
1.3.3	-------------------	No objection	-------------------
1.3.4	The effects of the external event (e.g., earthquake) on the integrity of the containment boundary should be discussed. A potential LERF may be mitigated by containment for an internal event initiator. However, *effective containment* may be compromised by physical damage/weakening of	Clarification	The analysis of the LERF endpoint proceeds in the same way as the analysis of the CDF endpoint, with one major exception, as follows: There are some accident sequences, leading to core damage but not to large early releases in the internal-events PRA model, that need to be elevated to potential LERF sequences when the initiator is an *external event*. **One set of sequences are those where the effects of the external initiators might compromise**

DRAFT Table C-1 Staff Position on ANSI/ANS 58.21-2003

Index No	Issue	Position	Resolution
	the containment boundary due to the external event.		**containment integrity and thereby possibly contribute to LERF. The other set** ~~These~~ are sequences in which offsite protective action (specifically, the evacuation of nearby populations) is impeded due to the external event. The same sequence that might not be a LERF sequence due to any internal initiator may perhaps affect nearby populations who cannot evacuate as effectively.
1.3.5-1.3.6	-------------------	No objection	-------------------
1.4, 5th para.	The interpretation of supporting requirements (SR) that use the same word under more than one capability category is different from that currently adopted in RG 1.200.	Qualification	Furthermore ... , ~~it is understood that the interpretation is somewhat graded, with more detail, or more specificity, or more realism, or a combination thereof, required for the higher Capability Category than for the lower one.~~ **, it applies equally to each Capability Category without any need to identify a corresponding Capability Category. The differentiation between capability categories is made in other SRs.**
1.4, 2nd to the last para.	It is inappropriate to make statements regarding the quality and uniformity of past SMA analyses for IPEEE in the standard.	Qualification	Concerning the requirement ... from the EPRI guidance report. ~~Essentially every SMA that has been completed using the EPRI SMA method followed the EPRI guidance closely, with only minor deviations. Thus there exists little gradation among the SMAs accomplished to date, and it is anticipated that if another SMA were to be done it too would exhibit very little difference from those already completed.~~ Therefore, it has been judged ...
1.4, the last para.	The last para needs greater clarity of intent. A choice of words such as "As a matter of philosophy" could lead an analyst to do things outside the requirements of this standard.	Clarification	~~The SMA covered in Section 3.6 and the Seismic PRA covered in Section 3.7 may be used together. As a matter of philosophy, an analyst can augment an SMA with issue-focused specific PRA evaluations and seismic-PRA evaluations to support an application. The analyst would need justify the adequacy of the blended or enhanced treatment, and peer review is to be relied upon to verify the treatment.~~ **This standard permits the use of issue-focused specific PRA evaluations to augment an SMA. The analyst needs to document the technical basis for the adequacy of the methodology, and a peer review needs to verity it.**
1.4, Table 1	The table does match the Table of Addenda to ASME RA-Sa-2003	Qualification	Replace with the table 1.3-1 of Addenda to ASME RA-Sa-2003.
1.5	To be consistent with the ASME Standard, the word SHALL, should only appear in a high level requirement. The words, 'should' and 'may' are	Qualification	~~**Shall, Should, and May:** The high level requirements contained herein are phrased in the usual language of standards, namely the language of "shall," "should," or "may." These three terms are defined in Section 2. These~~

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Index No	Issue	Position	Resolution
	permissives and do not provide a minimum requirement. Action verbs should be used in all SRs.		~~definitions are repeated here:~~ ~~shall—used to state a mandatory requirement~~ ~~should—used to state a recommendation~~ ~~may—used to state an option to be implemented at the user's discretion.~~ **SHALL is used to state a high-level requirement.** ~~Action Verbs: Some of the~~ **Supporting** requirements are phrased in "action verb" form, *to conform to the format in the ASME standard* (ASME, 2002). Whenever an action verb is used, the requirement is to be understood as if the "shall" form were used. As an example, the requirement REQ. EXT-B4 reads in part, "REVIEW any significant changes since the NRC operating license was issued." This is to be understood as equivalent to "Any significant changes since the NRC operating license was issued SHALL BE REVIEWED."
1.5, 3rd para	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~The Word "Consider": ... pay particular attention to this topic.~~
1.6-1.10	-------------------	No objection	-------------------
SECTION 2			
2.1	Acronysms and Initialisms	Clarification	**HLR - High-Level Requirement** **SR - Supporting Requirements**
2.2			
	Definition of the bounding analysis should be provided	Clarification	**bounding analysis: Analysis that uses assumptions such that the assessed outcome will meet or exceed the maximum severity of all creditable outcomes.**
	Definition of the demonstrably conservative analysis should be provided	Clarification	**demonstrably conservative analysis: Analysis that uses assumptions such that the assessed outcome will be conservative relative to the expected outcome.**
Composite variability	The term 'uncertainty' should be used consistent with the aleatory and epistemic uncertainty definitions	Clarification	*Composite* variability, the composite variability variability includes the ~~randomness variability~~ **aleatory (randomness) uncertainty** randomness variability ($\tilde{N}_R$) and the **epistemic (modeling)** uncertainty ($U\tilde{N}_U$). The logarithmic

DRAFT Table C-1 Staff Position on ANSI/ANS 58.21-2003

Index No	Issue	Position	Resolution
			standard deviation of composite variability, $\tilde{N}_c$, is expressed as $(\tilde{N}_R^2 + \tilde{N}_U^2)^{1/2}$
Core Damage	See issue discussed in RG 1.200 Table A-1, Chapter 2, 2.2, Core Damage.	Clarification	*core damage:* ....enough of the core, **if released, to result in offsite public health effects** ~~to cause a significant release~~.
Dependency	The definition should be consistent with the ASME RA-Sa-2003.	Clarification	dependency: Requirement external to an item and upon which its function depends and **is associated with dependent events that are determined by, influence by, or correlated to other events or occurrences.**
Dominant contributor	*See Significant contributor* in Table A-1, Reg. Guide 1.200, Appendix A. The language used in the Resolution column is antiquated and unnecessarily restrictive. The use of the term "cutset" presupposes a specific approach. The criteria should be worded to be methodology neutral. For example, that currently available techniques, such as binary decision diagrams, do not involve cutset generation. While the use of cutsets is acceptable, the language is restrictive. Significance can be identified via importance measures. It should be noted that the criterion of 0.005 for the Fussell-Vesely measure to indicate importance implies that the PRA is well structured (core damage known to less than 0.5%). This is not the case if truncation impacts are greater than 0.5%.	*Clarification*	~~**dominant contributor:** A component, a system, and an accident class, or an accident sequence that has a major impact on the CDF or on the LERF.~~ **significant contributor***:* **(a) in the context of an accident sequence, a significant basic event or an initiating event that contributes to a significant sequence; (b) in the context of an accident progression sequence, a contributor which is an essential characteristic (e.g., containment failure mode, physical phenomena) of a significant accident progression sequence, and if not modeled would lead to the omission of the sequence.** **significant basic event: those basic events that have a Fussell-Vesely importance greater than 0.005 OR a risk-achievement worth greater than 2.** **significant cutset (relative to sequence): those cutsets, when rank ordered by decreasing frequency, comprise 95% of the sequence CDF OR that individually contribute more than 1% to the sequence CDF.** **significant cutset (relative to CDF): those cutsets, when rank ordered by decreasing frequency, comprise 95% of the CDF OR that individually contribute more than 1% to CDF.** **significant accident sequence: a significant sequence is one of the set of sequences, defined at the functional or systemic level that, when rank ordered by decreasing frequency, comprise 95% of the core damage frequency (CDF)), OR that individually contribute more than ~1% to the CDF.** **Significant accident progression sequence: one of a set of containment event tree sequences that, when rank ordered by decreasing frequency, comprise 95% of the**

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Index No	Issue	Position	Resolution
			large early release frequency (LERF), OR that individually contribute more than ~1% to the LERF.
Failure mode	This is an incorrect definition. Use ASME definition.	Clarification	**failure mode:** ~~A condition ... or a system.~~ **a specific functional manifestation of a failure (i.e., the means by which an observer can determine that a failure has occurred) by precluding the successful operation of a piece of equipment, a component, or a system (e.g., fails to start, fails to run, leak).**
Fractile hazard curves	Definition of terms lacks clarity.	Clarification	**fractile hazard curves** - A set of hazard curves used to reflect the uncertainties associated with estimating seismic hazard. A common family of hazard curves used in describing the results of a PSHA~~-is~~ **consists of** curves of fractiles of the probability distributions of estimated seismic hazard as a function of the level of ground motion parameter.
Fragility	The use of uncertainty should be consistent with the aleatory and epistemic uncertainty definitions	Clarification	...Fragility of an SSC is the conditional probability of its failure at a given hazard input level. The input could be earthquake motion, wind speed, or flood level. The fragility model used in seismic PRA is known as a double lognormal model with three parameters, A_m, $\tilde{N}_R$ and $\tilde{N}_U$ which are respectively, the median acceleration capacity, logarithmic standard deviation of **aleatory** (randomness) **uncertainty** in capacity and logarithmic standard deviation of ~~the~~ **epistemic (modeling)** uncertainty in the median capacity.
Large early release	Inconsistent with ASME definition	Clarification	...protective actions **such that there is a potential for early health effects.**
Screening analysis	Inconsistent with ASME definition	Clarification	... An analysis that eliminates items from further consideration based on their negligible contribution to the probability of ~~a significant~~ **an** accident or its consequences.
Success path	Success path is usually defined at the system level rather than components. I don't have a major problem with the suggested change here but I disagree with this statement. The success path term used in SMA methodology is meant to define the specific set of components required to bring the plant to the appropriate condition. A description of the systems alone would not be of sufficient detail.	Clarification	...A set of **systems and associated** components that can be used to bring the plant to a stable hot or cold condition and maintain this condition for at least 72 hours.

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Index No	Issue	Position	Resolution
SECTION 3			
3.1-3.2	----------------	No objection	----------------
3.3			
1st para.	----------------	No objection	----------------
2nd para.	To ensure the quality of the outcome of the application of this standard, the minimum qualifications of the analyst need to be clearly stated.	Clarification	The high-level requirements ... and the peer review team (see Section 5). **Further, the analysis team needs to be experienced in performing activities associated with all elements of the PRA. As a minimum, the analysis team must show capability by direct experience from previous PRA studies of the methodology, and by training in the use of computer codes used in the analyses.**
3rd para.	The Supporting Requirements depend on the Capability Category selected for the PRA. The category may be different for different systems or elements included in the PRA. The analyst should specify which SR's are being used and justify their use for the intended application.	Qualification	The High Level Requirements and the Supporting Requirements, taken together, are formulated in a way that is intended to support the applications being considered. Specifically, a PRA can meet the High Level Requirements and Supporting Requirements at various levels-of-detail and various scopes, that need not extend beyond what is adequate to support the intended application. **The analysis team needs to identify the SR's used in the PRA and justify the selection of Capability Category from which they have been selected.**
3.4			
Title	The title lacks clarity.	Clarification	~~Probabilistic Risk Assessment for Other External Events:~~ Requirements for Identification and Screening ~~and Conservative Analysis~~
3.4.1	----------------	No objection	----------------
3.4.2, 1st para., item (3)	The "demonstrably conservative" and "bounding" analyses are performed using different approaches, and should not be used interchangeably.	Clarification	...~~(Herein, the phrases "bounding analysis" and "demonstrably conservative analysis" are used interchangeably.)~~
3.4.2, last para., 3.4.3, 2nd para.	Since this section pertains to external events screening other than seismic event, references to 3.6 and 3.7 requirements should be removed.,	Clarification	...subjected to the requirements in 3.5, ~~3.6, 3.7,~~ 3.8, or ...

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Index No	Issue	Position	Resolution
3.4.3 HLR-EXT-A	The section is entitled Requirements for Screening and Conservative Analysis. However, the HLR has a requirement to perform a screening, bounding, or detailed analysis. The latter is inconsistent with the intent. Furthermore, the supporting requirements only address identification of external hazards. The screening is *performed in HLR-EXT-B and* HLR-EXT-C.	Qualification	HLR-EXT-A: ~~All~~ ~~p~~Potential external events (i.e., ~~all~~ natural...... SHALL be **identified** ~~considered and conservative analysis), or detailed analysis~~. ~~SHALL be subjected to either screening bounding analysis (demonstrably conservative analysis), or detailed analysis~~.
3.4.3 HLR-EXT-B	--------------	No objection	--------------
3.4.3 HLR-EXT-C	The "demonstrably conservative" and "bounding" analyses are performed using different approaches, and should not be used interchangeably.	Clarification	HLR-EXT-C: A bounding or (demonstrably conservative) analysis, if used ...
3.4.3 HLR-EXT-D to HLR-EXT-E	------------	*No objection*	------------
3.4.4 HLR-EXT-A	The section is entitled Requirements for Screening and Conservative Analysis. However, the HLR has a requirement to perform a screening, bounding, or detailed analysis. The latter is inconsistent with the intent. Furthermore, the supporting requirements only address identification of external hazards. The assessment is performed in HLR-EXT-B and HLR-EXT-C.	Qualification	HLR-EXT-A: ~~All~~ ~~p~~Potential external events (i.e., ~~all~~ natural...... SHALL be **identified** ~~considered and conservative analysis), or detailed analysis~~. ~~and SHALL be subjected to either screening bounding analysis (demonstrably conservative analysis), or detailed analysis~~.
3.4.4, REQ. EXT-A1	Permissive MAY is inappropriate for a SR requirement.	Qualification	"... and this list ~~MAY be used as~~ **PROVIDES** one acceptable way to meet this requirement."
3.4.4, REQ. EXT-A2 and Note EXT-A2	------------------	No objection	------------------
3.4.4, REQ. EXT-B1	Permissives should not be used in SRs.	Qualification	...the following screening criteria ~~MAYbe used as~~ **PROVIDE** an acceptable basis:
3.4.4,	Permissives should not be used		..., the following screening criterion ~~MAY be~~

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Index No	Issue	Position	Resolution
REQ. EXT-B2	in SRs.	Qualification	~~used as~~ **PROVIDES** an acceptable basis..."
3.4.4, REQ. EXT-B3	-------------------	No objection	-------------------
3.4.4, REQ. EXT-B4	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	REVIEW... *In particular,* ~~CONSIDER in the review~~ **REVIEW** all of the following:
3.4.4 HLR-EXT-C and NOTE HLR-EXT-C	The "demonstrably conservative" and "bounding" analyses are performed using different approaches, and should not be used interchangeably.	Clarification	HLR-EXT-C: A bounding or {demonstrably conservative} analysis, if used ... ~~NOTE HLR-EXT-C: Herein, the phrases "bounding analysis" and "demonstrably conservative analysis" are used interchangeably~~.
3.4.4, REQ. EXT-C1	Permissive MAY should not be used in SRs.	Qualification	For screening out an external event, ~~the analytst ... screening criteria is met:~~ **any one of the following three screening criteria PROVIDE an acceptable basis for bounding analysis or demonstrably conservative analysis:**
3.4.4, NOTE EXT-C1	The "demonstrably conservative" and "bounding" analyses are performed using different approaches, and should not be used interchangeably.	Clarification	NOTE EXT-C1: The bounding or {demonstrably conservative} analysis ...
3.4.4, REQ. EXT-C2	This SR addresses the hazard analysis. The SR contains two alternatives. The first is a state-of-the-art hazard analysis, the second is a bounding analysis. The SR should reflect the minimum requirement which is that for a bounding analysis. In the ASME Standard, the term "state-of-the-art" is used to correspond to a capability category III. To conform to that meaning, the term should not be used here. Furthermore, the last sentence is appropriate for a detailed analysis but not for a bounding analysis.	Qualification	~~BASE the estimation of the mean frequency and opther parameters of the design basis hazard on state of the art modeling and recent data (.......), or BOUND the estimation for the purposes of a demonstrably conservative analysis> CONSIDER the uncertainties in modeling and data in this hazard evaluation~~ **ESTIMATE the frequency and other *parameters of the hazard using a bounding* analysis or a demonstrably conservative analysis.**
3.4.4, NOTE EXT-C2	The "demonstrably conservative" and "bounding" analyses are performed using different approaches, and	Clarification	NOTE EXT-C2: The spirit of a bounding or {demonstrably conservative} analysis ...

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	should not be used interchangeably.		
3.4.4, REQ. EXT-C3	The requirement in the standard should represent the minimum, which is a demonstrably conservative analysis.	Qualification	~~In estimating the mean conditional core damage probability (CCDP), USE a systems model of the plant that meets the systems-modeling requirements in ASME-RA-S-2002 insofar as they apply [1]. For the purposes of this screening analysis, a demonstrably conservative approach to the analysis is acceptable.~~ **Calculate the CCDP using a *bounding analysis or a demonstrably* conservative analysis.**
3.4.4, REQ. EXT-C3a	There is no requirement that identifies the impact of the hazard on the plant SSCs.	Qualification	NEW SR: **Identify those SSCs required to maintain the plant in operation or that are required to respond to an initiating event to prevent core damage, that are vulnerable to the hazard, and determine their failure modes.**
3.4.4, REQ. EXT-C3b	There is no requirement that addresses the incorporation of the impact of the hazard into the estimation of the CCDP	Qualification	NEW SR: **ESTIMATE the CCDP taking into account the initiating events caused by the hazard, and the systems of functions rendered unavailable. Modifying the internal events PRA model as appropriate, using conservative assessments of the impact of the hazard *(fragility analysis)*, is an acceptable approach.**
3.4.4, REQ. EXT-C4	Permissives should not be used in SRs.	Qualification	BASE...This includes not only the hazard analysis but also any fragility analysis that ~~may be necessary~~ **is applicable.**
3.4.4, REQ. EXT-C5	Since section 3.4 provides requirements for external event hazards other than seismic, reference to sections dealing with SMA and seismic PRA should be removed.	Clarification	...(See 3.5, ~~3.6, 3.7~~, 3.8, and 3.9.)
3.4.4, REQ. EXT-D1, D2	----------------	No objection	----------------
3.4.4, NOTE EXT-D1	----------------	No objection	----------------
3.4.4, REQ. EXT-E1- E3	----------------	No objection	----------------
3.5			
3.5.1	As currently written, the scope of this section allows analyses of wind hazards and external flooding hazards to be performed using the	Qualification	Scope: ...The term "other external events" refers to external events other than **earthquakes, high winds, and external floods.**

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Index No	Issue	Position	Resolution
	requirements of this section. However, requirements for analyses of wind and external flooding hazards are explicitly provided in sections 3.8 and 3.9. Therefore, the scope of section 3.5 should be narrowed.		**Applicability**: ... external event. ~~Alternatively, the requirements in 3.8 ..then all of the requirements therein apply.~~
3.5.3, HLR-ANA-A	The last sentence in the statement of the high level requirement contains the phrase "SHOULD NOT be unduly influenced by ... ", but there is no supporting requirement that relates to this. It is not, in fact clear what this last sentence means. If there is a real trend in frequencies this should in fact be included in the assessment.	Clarification	The analysis ... a mixture of the two. ~~The models used for ..., short term trends in the frequencies.~~
3.5.3, HLR-ANA-B thru. HLR-ANA-D	----------------	No objection	----------------
3.5.4, HLR-ANA-A	The last sentence in the statement of the high level requirement contains the phrase "SHOULD NOT be unduly influenced by ... ", but there is no supporting requirement that relates to this. It is not, in fact clear what this last sentence means. If there is a real trend in frequencies this should in fact be included in the assessment.	Clarification	The analysis ... a mixture of the two. ~~The models used for ...... short term trends in the frequencies.~~
3.5.4, REQ.ANA-A1	----------------	No objection	----------------
3.5.4, REQ.ANA-A2	The word "properly" in the statement "ACCOUNT properly for and ..." is superfluous.	Clarification	... ACCOUNT ~~properly~~ for and ...
3.5.4, NOTE ANA-A2	The note contains a discussion on the parameterization of the hazard curve(s). This does not clarify the requirement, but suggests that another requirement be added.	Qualification	NEW SR: **To develop the PRA model, define the hazard curve in terms of the parameter that best represents a measure of the intensity of the hazard.**
3.5.4, REQ.ANA-A3 thru. B1	----------------	No objection	----------------
3.5.4, REQ.ANA-B2	The word "consider" is permissive and inappropriate for SRs. Action verbs should be	Qualification	... ~~CONSIDER~~ **INCORPORATE** the findings of a plant walkdown in this evaluation.

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	used.		
3.5.4, NOTE ANA-B3	The note contains discussions that should be requirements.	Qualification	NEW SR: **Define the fragility curve for each failure mode as a function of the same parameter used to represent the intensity of the hazard.**
3.5.4, REQ.ANA-C1	There is no requirement to identify the SSCs affected by the hazard, nor the initiating events caused by the hazard. The supporting requirements do not support the HLR as stated. There is no requirement that addresses the incorporation of the impact of the hazard into the estimation of the CCDP	Qualification	NEW SR: **Identify those SSCs required to maintain the plant in operation or that are required to respond to an initiating event to prevent core damage, that are vulnerable to the hazard, and determine their failure modes.** NEW SR: **ESTIMATE the CCDP taking into account the initiating events caused by the hazard, and the systems of functions rendered unavailable. Modifying the internal events PRA model as appropriate, using conservative assessments of the impact of the hazard (fragility analysis), is an acceptable approach.**
3.5.4, REQ.ANA-C1	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	ASSESS the accident sequences initiated by the external event to estimate CDF and LERF contribution. In the analysis, **USE as appropriate** the ~~appropriate~~ **applicable** hazard curves and the fragilities of structures and equipment.
3.5.4, REQ.ANA-D1 thru D7	----------------	No objection	----------------------
3.6			
7th para, 2nd and 3rd sentences	These sentences need greater clarity of intent. A choice of words such as "As a matter of philosophy" could lead an analyst to do things outside the requirements of this standard.	Clarification	As discussed in 1.4, ~~the SMA covered in Section 3.6 and the Seismic PRA covered in Section 3.7 may be used together. As a matter of philosophy, an analyst can augment an SMA with issue focused specific PRA evaluations and seismic PRA evaluations to support an application. The analyst would need justify the adequacy of the blended or enhanced treatment, and peer review is to be relied upon to verify the treatment.~~ **this standard permits the use of issue-focused specific PRA evaluations to augment an SMA. The analyst needs to document the technical basis for the adequacy of the methodology, and a peer review needs to verify it. ...**
3.6.1, HLR-SM-A	----------------	No objection	------------------
3.6.1, HLR-SM-B	The last phrase, "..."...following an earthquake larger than the	Clarification	"...following an earthquake **equal to or larger** than the RLE".

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	RLE", could be misinterpreted.		
3.6.1, HLR-SM-C	----------------	No objection	----------------
3.6.1, HLR-SM-D	----------------	No objection	----------------
3.6.1, HLR-SM-E	Plant walkdown is a major part of the margin assessment process (not a supplemental part) for identifications of SSC failure modes. I concur with this statement.	Clarification	..., through the review of design documents, including plant-specific analysis and test reports **, and the results of a plant walkdown** supplemented by earthquake experience data, fragility test data, and generic qualification test data. ~~, and by a walkdown~~ All of these listed items can be key sources of information in the derivation of seismic margins. I think the term supplemented should be removed and that all data/information sources should be listed equally
3.6.1, HLR-SM-F	----------------	No objection	----------------
3.6.1, HLR-SM-G	----------------	No objection	----------------
3.6.1, HLR-SM-H	The wording "..applying the *PRA and updating it,"* needs to changed. The term "PRA" should not be used in an HLR for an SMA.	Clarification	...~~applying the PRA and updating it~~ **its application and update ...**
3.6.2, REQ SM-A1 to REQ SM-C1	----------------	No objection	----------------
3.6.2, REQ SM-C2	Permissives should not be used in SRs.	Qualification	..., realistic seismic responses ~~MAY be~~ **are** obtained...
3.6.2, REQ SM-C3 to SM-D4	----------------	No objection	----------------
3.6.2, REQ SM-D5 and NOTE SM-D5	The word "FOCUS" does not provide a direction regarding what actions should be taken.	Clarification	~~FOCUS the walkdown on~~ **During the walkdown, IDENTIFY** the potential for ...
3.6.2, NOTE SM-D6	NOTE SM-D6, related to "II/I issue" is misleading in the context of SMA. Any object (whether seismically qualified to the plant design basis or not) that can fall on and damage any item on the SSEL is a "II/I issue" for SMA. The HCLPF capacity of the falling object may control the HCLPF capacity of the success path and potentially the plant HCLPF	Qualification	**NOTE SM-D6: For SMA, ~~A~~ a** "II/I issue" refers to ~~the condition ... safety equipment.~~ **any object (whether seismically qualified to the plant design basis or not) that can fall on and damage any item on the SSEL. The HCLPF capacity of the falling object may control the HCLPF capacity of the success path and potentially the plant HCLPF capacity if it is less than the HCLPF capacity of the weakest item on the SSEL.** Strictly speaking the II/I issue does indeed refer the effects of Category II components affecting

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	capacity if it is less than the HCLPF capacity of the weakest item on the SSEL .		(displacement, failing, etc.) the Category I components (not Category I and II components affecting the Category I components). Thus the language suggested in this section by the NRC is not correct. A note could be added to address the issue of Category I components effects to other Category I components if it is felt to be necessary.
3.6.2, REQ. SM-E1	------------------	No objection	--------------------
3.6.2, REQ. SM-E2	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~CONSIDER~~ **EXAMINE** all relevant failure modes...
3.6.2, REQ. SM-F1	REQ. SM-F1 duplicates HLR-SM-F, and is less prescriptive.	Clarification	~~**(REQ. SM-F1)** BASE ...test data~~
3.6.2, REQ. SM-F2 and NOTE SM-F2	------------------	No objection	--------------------
3.6.2, REQ. SM-F3 and NOTE SM-F3	------------------	No objection	--------------------
3.6.2, REQ. SM-G1 and NOTE SM-G1	------------------	No objection	--------------------
3.6.2, REQ. SM-G2 and NOTE SM-G2	"Seismic upgrade" is interpreted to mean a physical plant modification to increase the seismic capacity of a weak SSC. This is not part of the SMA methodology just as performing seismic upgrade as a result of a seismic PRA is not part of the PRA methodology.	Clarification	~~**(REQ. SM-G2)** REPORT ... have been done.~~ ~~**Note SM-G2:** If the plant ... would have been done.~~ My interpretation of the process of performing an SMA (or an SPRA for that matter) would be that it allows for the presentation of results either before or after the upgrading of components depending on the purpose of the study. Thus, the elimination of this requirement is not important.
3.6.2, REQ. SM-H1 thru H5 and NOTE SM-H5	------------------	No objection	--------------------
3.7			
3.7, 3.7.1.1	------------------	No objection	--------------------
3.7.1.2, HLR-HA-A to	------------------	No objection	--------------------

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HLR-HA-B			
3.7.1.2, HLR-HA-C	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... SHALL ~~consider all~~ **examine** ... SHALL be ~~considered~~ **addressed** in characterizing the ground motion propagation.
3.7.1.2, HLR-HA-D	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... SHALL ~~account for all~~ examine credible ... Both the aleatory ... be ~~considered~~ **addressed** ...
3.7.1.2, HLR-HA-E	------------------	No objection	------------------
3.7.1.2, HLR-HA-F	------------------	No objection	------------------
3.7.1.2, HLR-HA-G	The reference to NUREG/CR-0098 broad band spectrum shape should be made in a supporting requirement. Further, NURGE/CR-0098 spectral shapes are not always appropriate, particularly for CEUS sites.	Qualification	For further use in the SPRA, the spectral shape SHALL be based on a site-specific evaluation taking into account the contributions of deaggregated magnitude-distance results of the PSHA. ~~Broad band, smooth spectral shapes, such as those presented in NUREG/CR-0098 [6] (for lower seismicity sites such as most of those east of the U.S. Rocky Mountains) may also be used taking into account the site conditions.~~ The use of uniform hazard response spectra ~~may also be appropriate~~ **is acceptable** if it reflects the site-specific shape. **NEW SR HA-G1a: Broad-band, smooth spectral shapes, such as those presented in NUREG/CR-0098 [6] are acceptable if they are shown to be appropriate for the site.** **NEW NOTE HA-G1a: Recent developments [42] indicate that these spectral shapes are not appropriate for CEUS sites where high frequency content is dominant at hard rock sites.**
3.7.1.2, HLR-HA-H to HLR-HA-J	------------------	No objection	------------------
3.7.1.3, HLR-HA-A	------------------	No objection	------------------
3.7.1.3, HA-A1	------------------	No objection	------------------
3.7.1.3, HA-A2, Cat. I and II	This requirement contains two separate requirements. There is a requirement to capture the frequencies of SCCs that are dominant to the PRA results and insights. This can not be a priori.	Qualification	As the parameter to characterize both hazard and fragilities, USE the spectral accelerations, or the average spectral acceleration over a selected band of frequencies, or peak ground acceleration. ~~In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are of interest and are dominant contributors to the PRA~~

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			~~results and insights.~~ **NEW SR HA-A2a:** In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are ~~of interest and dominant contributors to~~ **significant in** the PRA **quantification** ~~results anc insights~~.
3.7.1.3, HA-A2, Cat. III	This requirement contains two separate requirements. There is a requirement to *capture the frequencies of* SCCs that are dominant to the PRA results and insights. This can not be a priori.	Qualification	As the parameter to characterize both hazard and fragilities, USE the spectral accelerations, or the average spectral acceleration over a selected band of frequencies. ~~In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are of interest and are dominant contributors to the PRA results and insights.~~ **NEW SR HA-A2b:** In the selection of frequencies to determine spectral accelerations or average spectral acceleration, CAPTURE the frequencies of those SSCs that are ~~of interest and dominant contributors to~~ **significant in** the PRA **quantification** ~~results anc insights~~.
3.7.1.3, HA-A3	As stated, the requirement is difficult to meet.	Clarification	In developing the PSHA results, whether they are characterized by spectral accelerations, peak ground accelerations or both, EXTEND them to large enough values (consistent with the physical data and interpretations) so that the truncation does not significantly impact the numerical results. ~~final numerical results, such as core damage frequency, reflect accurate estimates of risk, and the delineation and ranking of seismic initiated sequences are not affected.~~
3.7.1.3, HLR-HA-B	----------------	No objection	----------------
3.7.1.3, HA-B1	For Capability Category III applications, the available data base must be able characterize local effects on site response.	Clarification	In performing the PSHA, BASE it on available and developed comprehensive geological, seismological, ~~and~~ geophysical **and geotechnical** data bases that reflect the current state-of-the-knowledge, and that are used by experts/analysts to develop interpretations and inputs to the PSHA. **For Category III applications, INCLUDE site specific laboratory data for site soils including their potential uncertainty to characterize local site response effects .**
3.7.1.3, NOTE HA-B1	The use of term "the amount of resources and sophistication..." as the reason for the distinction between Capability Categories II and III is inconsistent with the	Qualification	... ~~The difference between Capability Category II and III is .... the databases.~~

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	bases for PRA capability categories.		
3.7.1.3, HA-B2 and HA-B3	------------	No objection	--------------------
3.7.1.3, NOTE HA-B2 and NOTE HA-B3	The use of term "the amount of resources and sophistication..." as the reason for the distinction between Capability Categories II and III is inconsistent with the bases for PRA capability categories.	Qualification	... ~~The difference between Capability Category II and III is ... the databases.~~
3.7.1.3, HLR-HA-C	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... SHALL ~~consider all~~ **examine** ... SHALL be ~~considered~~ **addressed** in characterizing the ground motion propagation.
3.7.1.3, HA-C1 - C4	------------	No objection	--------------------
3.7.1.3, HLR-HA-D	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... SHALL ~~account for all~~ examine credible ... Both the aleatory ... be ~~considered~~ **addressed** ...
3.7.1.3, HA-D1	Since attenuation relationships for characterizing the ground motion propagation are developed based on empirical data and subjective inputs, several attenuation models may exist.	Qualification	ACCOUNT in ... Seismicity data (including strong motion data), **and c) Current attenuation models in the ground motion estimates.**
3.7.1.3, HA-D2 -D4	------------	No objection	------------------
3.7.1.3, HLR-HA-E	------------------	No objection	------------------
3.7.1.3, HA-E1,	------------.	No objection	------------------
3.7.1.3, Note HA-E1	The site-specific transfer functions that are used to modify the rock ground motions should computed using probabilistic estimates of site properties.	*Clarification*	*The purpose of a local site response analysis...* for the site characteristic [41]. **Probabilistic estimates of site properties should be used in determining the site-specific functions.**
3.7.1.3, HA-E2 and Note HA-E2	------------	No objection	--------------------
3.7.1.3, HLR-HA-F	------------------	No objection	------------------
3.7.1.3, HA-F1 to HA-	------------	No objection	--------------------

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F3			
3.7.1.3, HLR-HA-G	The reference to NUREG/CR-0098 broad band spectrum shape should be made in a supporting requirement. Further, NURGE/CR-0098 spectral shapes are not always appropriate, particularly for CEUS sites. Also, the last sentence is inconsistent with that stated by 3.7.1.2 HLR-HA-G	Qualification	For further use in the SPRA, the spectral shape SHALL be based on a site-specific evaluation taking into account the contributions of deaggregated magnitude-distance results of the PSHA. ~~Broad band, smooth spectral shapes, such as those presented in NUREG/CR-0098 [6] (for lower seismicity sites such as most of those east of the U.S. Rocky Mountains) may also be used taking into account the site conditions.~~ The use of ~~existing~~ uniform hazard response spectra (UHSs) is acceptable ~~unless evidence comes to light that would challenge these UHS spectral shapes~~ **if it reflects the site-specific shape**. I strongly disagree with taking this statement "unless evidence comes to light that would challenge these UHS spectral shapes". This was a long, hard fought effort to agree on these words between the standard writers and EPRI/utility representatives. Our consensus thinking was these words allowed for those instances where new hazard data were known to be available to be required to assess their effects. But for sites where there was not evidence of this nature, they were not required to have to go through an expensive time consuming exercise to prove that the existing EPRI or LLNL hazard study was still valid. **NEW SR HA-G1a: Broad-band, smooth spectral shapes, such as those presented in NUREG/CR-0098 [6] are acceptable if they are shown to be appropriate for the site.** **NEW NOTE HA-G1a: Recent developments [42]** (this is McGuire 2001 Study) **indicate that these spectral shapes are not appropriate for CEUS sites where high frequency content is dominant at hard rock sites.** We should fight to have this removed. A broad based statement like this does not belong in a Standard. This would lead to rock sites having to make their UHS (Livermore or EPRI) more conservative/broadband.
3.7.1.3, HA-G1	--------------	No objection	--------------------
3.7.1.3, Note HA-G1	Spectral shapes used to evaluate in-structure SSC's must include the effects of amplification from both local site conditions and SSI. This is confusing. Soil	Clarification	**NOTE HA-G1**: The issue of which spectral shape should be used in the screening of structures, systems, and components (SSCs) and in quantification of SPRA results requires careful consideration. For screening purposes, the spectral shape used should have

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	structure interaction is a structural response effect based on the local site conditions. Rewording suggested here. Based on IPEEE reviews, certain UHS shapes used for CEUS were not appropriate for the screening purpose.		amplification factors, **including effects from both local site conditions as well as soil-structure interaction,** such that the demand resulting from the use of this shape is higher than that based on the design spectra. This will preclude premature screening of components and will avoid anomalies such as the screened components (e.g., surrogate elements) being the dominant risk contributing components. Additional discussion on this issue can be found in Ref. 22. In the quantification of fragilities and of final risk results, it is important to use as realistic a shape as possible. Semi-site specific shapes, such as those given in NUREG-0098, have been used in the past and ~~are considered~~ **may be** adequate for this purpose, **provided that they are shown to be reasonably appropriate for the site [42]**. This should be taken out. The UHS is acceptable for this purpose **if it can be shown that the UHS shape is appropriate for the site.** ~~unless evidence comes to light (e.g., within the technical literature) that these UHS do not reflect the spectral shape of the site-specific events.~~ This is another instance of eliminating carefully crafted wording between the ANS standard writing committee and the EPRI and utility participants and reviewers. The elimination of this phrase potentially places a large burden on the utility to prove the existing seismic hazard would not be changed appreciably if it was redone to the latest criteria and methods. This is unnecessary in our judgement for the vast majority of plants and will result in an expensive exercise.
3.7.1.3, HLR-HA-H	----------------	No objection	----------------
3.7.1.3, Note HA-H	----------------	No objection	----------------
3.7.2			
3.7.2.1	----------------	No objection	----------------
3.7.2.2, HLR-SA-A	Words: "important, significant" used to characterize the contribution to CDF should be clearly stated in quantitative manner.	Clarification	The seismic-PRA systems models SHALL include ~~all important~~ seismic-caused initiating events and ~~that can lead to core damage or large early release, and SHALL include all~~ other ~~important~~ failures ~~that can contribute significantly to CDF or LERF,~~ including seismic-induced SSC failures, non-seismic-induced unavailabilities, and human errors- **, that give rise to significant accident sequences and/or significant accident progression sequences.** The guidance that indicates "... that give rise to

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			significant accident sequences and/or significant accident progression sequences" does not provide meaningful clarification. What is desired is an integrated model that includes seismic initiators, seismic and nonseismic system successes and failures and operator actions.
3.7.2.2, HLR-SA-B to HLR-SA-F	--------------------	No objection	--------------------
3.7.2.3, HLR-SA-A	Words: "important, significant" used to characterize the contribution to CDF should be clearly stated in quantitative manner.	Clarification	The seismic-PRA systems models SHALL include ~~all important~~ seismic-caused initiating events and ~~that can lead to core damage or large early release, and SHALL include all~~ other ~~important~~ failures ~~that can contribute significantly to CDF or LERF~~, including seismic-induced SSC failures, non-seismic-induced unavailabilities, and human errors~~.~~ **, that give rise to significant accident sequences and/or significant accident progression sequences.**
3.7.2.3, SA-A 1	To more closely follow the ASME Standard, this SLR should conclude with the statement "using a systematic process", and there needs to be a definition of significant.	Clarification	ENSURE that ~~significant~~ earthquake-caused initiating events **that give rise to significant accident sequences and/or significant accident progression sequences are** included in the seismic-PRA system model **using a systematic process**
3.7.2.3, NOTE SA-A 1	The note does not identify systematic process.	Clarification	NOTE SA-A1: It is ...br thoroughly investigated. **One approach that has been used successfully is to perform an FMEA of the seismic failures identified by the fragility analysis...**
3.7.2.3, SA-A2	The requirement is unclear.	Clarification	To be resolved.
SA-A3	1st paragraph: The SR contains the word "all", which is inappropriate in a Standard. There needs to be a definition of significant. 2nd paragraph: Permissives should not be used in Srs. Move to new SA-A3b below. The note contains two issues that should be requirements. Last sentence of th 1st para refers to the use of "supercomponent". Although	Qualification	ENSURE that the PRA system model reflect ~~all significant~~ earthquake-caused failures and ~~all significant~~ nonseismically induced unavailabilities and human errors **that give rise to significant accident sequences and/or significant accident progression sequences** ~~The analysis MAY~~ **It is acceptable to group** earthquake-caused failures **in the analysis if** the leading failure in the group is modeled. NOTE SA-A3: **NEW SA-A3a: USE the event trees and fault trees from the internal-events full-power PRA model as the basis for the seismic event trees.** **NOTE SA-A3a:** ~~The event trees and fault trees from the internal events full power PRA model~~

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	"supercomponent" could greatly simplify system modeling, it could also lead to a situation where the "supercomponent" becomes a dominant contributor and the risk insights of SSCs within the "supercomponent" could be masked, if it is not applied properly.		~~are generally used as the basis for the seismic event trees.~~ This is done both to capture the thinking that has gone into their development, and to assist in allowing comparisons between the internal-events PRA and the seismic PRA to be made on a common basis ... The lumping of certain groups of individual components into so-called "supercomponents" in the systems model is also a valid approximation in many situations. **However, it is cautioned that supercomponents should be used in a manner that they will not become significant contributors to the seismic CDF.]** In special circumstances ... Further, it is then especially important that a peer review be undertaken that concentrates on these aspects. **NEW SA-A3b: INCLUDE in the PRA system models, the consequences of those earthquake caused failures of structures and components that are not included in the internal event models. ~~The analysis MAY~~ It is acceptable to group earthquake-caused failures in the analysis if the leading failure in the group is modeled.** Clarification is needed by what is meant by "leading failure." The analysis must identify the most limiting failure mode as well as take into account the contribution to failure frequency/likelihood from each element of the group. **Note for SA-A3b:** Earthquakes can cause failures that are not explicitly represented in the internal-events models, primarily (but not exclusively) due to damage to structures and other passive items ... This means that initiating events and SSC failures that could lead to LERF-type consequences need to be included in the systems model even if the CDF frequency is quite low. (See FR-F4 and NOTE FR-F4.)
3.7.2.3, HLR-SA-B	-------------------	No objection	-------------------
3.7.2.3, SA-B1	-------------------	No objection	-------------------
3.7.2.3, SA-B2	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	In the human reliability analysis (HRA) aspect, ~~CONSIDER~~ EXAMINE ~~that~~ whether...
3.7.2.3, SA-B3, 2nd para, cat. I and II	Permissives should not be used in SRs.	Qualification	~~The analysis MAY~~ **It is acceptable to use** generic dependency and correlation values **in the analysis and PROVIDE bases** ~~if justified~~.

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3.7.2.3, SA-B4	---------------	No objection	---------------
3.7.2.3, SA-B5	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~CONSIDER~~ **EXAMINE** the effects ..,
3.7.2.3, SA-B7	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~CONSIDER~~ **EXAMINE** the possibility ...
6.7.2.3, SA-B8	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~CONSIDER~~ **EXAMINE** the likelihood ...
3.7.2.3, SA-B8, 2nd para, Cat. I.	Permissives should not be used in SRs.	Qualification	**It is acceptable to use** conservative recovery values ~~MAY be used~~.
3.7.2.3, SA-B9	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~CONSIDER~~ **EXAMINE the effect of including** ...
3.7.2.3, SA-B10	---------------	No objection	---------------
3.7.2.3, HLR-SA-C	---------------	No objection	---------------
3.7.2.3, SA-C1	The phrase "demonstrating ... significantly alter..." is permissive and inappropriate for the requirement.	Clarification	To ensure that the systems-analysis models reflect the as-built, as-operated plant, JUSTIFY any important conservatisms or other distortions introduced by demonstrating that ~~they do not significantly alter~~ the seismic-PRA's validity for applications **is maintained**.
3.7.2.3, SA-D1 to SA-E1	---------------	No objection	---------------
3.7.2.3, SA-E2, 2nd para, cat I	Permissives should not be used in SRs.	Qualification	**It is acceptable to use** broad groupings ~~MAY be used~~.
3.7.2.3, SA-E4, 2nd para, cat I and II	Permissives should not be used in SRs.	Qualification	~~The analysis MAY~~ **It is acceptable to use** generic dependency and correlation values **in the analysis and PROVIDE the basis for such application** ~~if justified~~.
3.7.2.3, HLR-SA-F	---------------	No objection	---------------
3.7.2.3, NOTE SA-F1	The tem "dominant risk contributors" is not defined.	Qualification	**NOTE SA-F1:** The major outputs of a seismic PRA, such as mean CDF, mean LERF, uncertainty distributions on CDF and LERF, results of sensitivity studies, **significant**

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			~~dominant risk~~ contributors, and so on are examples of the PRA results that are generally documented.
3.7.2.3, SA-F2 to SA-F3	-------------------	No Objection	-------------------
3.7.3			
3.7.3.1, HLR-FR-A to HLR-FR-B	-------------------	No objection	-------------------
3.7.3.1, HLR-FR-C	Permissives should not be used in SRs.	Qualification	The seismic fragility evaluation SHALL be based on realistic seismic response that the SSCs experience at their failure levels. Depending on the site conditions and response analysis methods used in the plant design, **DEVELOP** realistic seismic response ~~MAY be obtained~~ by an appropriate combination of scaling, new analysis and new structural models.
3.7.3.1, HLR-FR-D thru HLR-FR-G	-------------------	No objection	-------------------
3.7.3.2, HLR-FR-A	-------------------	No objection	-------------------
3.7.3.2, FR-A1 and FR-A2	-------------------	No objection	-------------------
3.7.3.2, HLR-FR-B	-------------------	No objection	-------------------
3.7.3.2, FR-B1	Permissives should not be used in Srs.	Qualification	...For example, **it is acceptable to apply** guidance given in EPRI NP-6041 and NUREG/CR-4334 ~~MAY be used~~ to screen out components...
3.7.3.2, FR-B2	-------------------	No objection	-------------------
3.7.3.2, HLR-FR-C	Permissives should not be used in SRs.	Qualification	The seismic fragility evaluation SHALL be based on realistic seismic response that the SSCs experience at their failure levels. Depending on the site conditions and response analysis methods used in the plant design, **DEVELOP** realistic seismic response ~~MAY be obtained~~ by an appropriate combination of scaling, new analysis and new structural models.

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3.7.3.2, FR-C1	Spectral shape issues for Capability Category I and II	Clarification	ESTIMATE the seismic responses that the components experience at their failure levels on a realistic basis using site-specific earthquake response spectra in three orthogonal directions, anchored to a ground motion parameter such as peak ground acceleration or average spectral acceleration **over a given frequency band**~~, or~~. ENSURE that the spectral shape used reflects or bounds the site-specific ~~considerations~~ **conditions**.
3.7.3.2, FR-C1	Spectral shape issues for Capability Category III	Clarification	ESTIMATE the seismic responses that the components experience at their failure levels on a realistic basis using site-specific earthquake response spectra in three orthogonal directions, anchored to a ground motion parameter such as peak ground acceleration or average spectral acceleration **over a given frequency band**.
3.7.3.2, FR-C2	Probabilistic parameters for Capability Category I	Clarification	If probabilistic response analysis is performed to obtain realistic structural loads and floor response spectra, ENSURE that the number of simulations done (e.g., Monte Carlo simulation and Latin Hypercube Sampling) is large enough to obtain stable median and 85% non-exceedance responses **for free-field site response**. ~~In the responce analysis, appropriately~~ ACCOUNT for the entire spectrum of input ground motion levels displayed in the seismic hazard curves.
3.7.3.2, FR-C2	Probabilistic parameters for Capability Category II	Clarification	If probabilistic response analysis is performed to obtain realistic structural loads and floor response spectra, ENSURE that the number of simulations done (e.g., Monte Carlo simulation and Latin Hypercube Sampling) is large enough to obtain stable median and 85% non-exceedance responses **for free-field site response**. ~~In the responce analysis, appropriately~~ ACCOUNT for the entire spectrum of input ground motion levels displayed in the seismic hazard curves.
3.7.3.2, FR-C2	Probabilistic parameters for Capability Category III	Clarification	PERFORM probabilistic seismic response analysis taking into account the uncertainties in the input ground motion ~~and structural and~~**, site soil properties and structural parameters.** CALCULATE joint probability distributions of the responses of different components in the building.
3.7.3.2, NOTE FR-C2	Update reference	Clarification	NOTE FR-C2: For a description of the probabilistic seismic response analysis, the reader is referred to Ref. 49 **and Ref. 42**

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3.7.3.2, FR-C3 to FR-C5	------------------	No objection	------------------
3.7.3.2, FR-C6, Cat I and II	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... dominate the seismically induced core damage frequency. ~~CONSIDER~~ **ACCOUNT for** the uncertainties in the SSI analysis ... The minimum value of Cv ~~SHALL be~~ **is** 0.5. ...
3.7.3.2, HLR-FR-D	------------------	No objection	------------------
3.7.3.2, FR-D2	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	~~CONSIDER~~ EXAMINE all relevant failure modes of structures ...
3.7.3.2, HLR-FR-E	------------------	No objection	------------------
3.7.3.2, FR-E1	Fragility calculations should incorporate effects of potential seismic interaction including both structural and functional interactions.	Clarification	CONDUCT a detailed walkdown of the plant, focusing on equipment anchorage, lateral seismic support, **spatial interactions** and potential systems interactions **(both structural and functional interactions)**
3.7.3.2, FR-E2	Walkdown team qualifications should be documented.	Clarification	DOCUMENT the walkdown procedures, walkdown team composition **and its members' qualifications**, walkdown observations and conclusions.
3.7.3.2, FR-E3	If a component is screened out by the walkdown team, the basis for the screening should be provided.	Clarification	If components are screened out during or following the walkdown, DOCUMENT anchorage calculations ~~or some other~~ **and PROVIDE the** basis ~~justifying~~ **for** such screening.
3.7.3.2, FR-E4	------------------	No objection	------------------
3.7.3.2, FR-E5	Masonry wall failures and potential sources for seismic-fire interactions should also be examined.	Clarification	During the walkdown, EXAMINE potential sources of interaction (e.g., II/I issues, impact between cabinets, **masonry walls, flammable and combustion sources,** flooding and spray) and consequences of such interactions on equipment contained in the systems model. The list could be endless if we seek to include all instances of interaction that should be reviewed during the review. This should be looked upon as citing examples.
3.7.3.2, NOTE FR-E5	The "II/I issues" should also include situations where a low seismic capacity object falls on and damages an SSC item with higher seismic capacity. In such case, the fragility of the higher capacity SSC item may be	Qualification	A "II/I issue" refers to situations where a non-seismically qualified object could fall on and damage a seismically qualified item of safety equipment, **and also situations where a low seismic capacity object falls on and damages an SSC item with higher seismic capacity. In such case, the fragility of the**

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	controlled by the low capacity object.		***higher capacity SSC item may be controlled by the low capacity object.*** While true and this is typically considered in an SPRA or SMA, it is rare that it actually controls the fragility and it is not clear why it should receive such a focus in this standard.
3.7.3.2, HLR-FR-F	----------------	No objection	----------------
3.7.3.2, FR-F1 to FR-G4	----------------	No objection	----------------
3.8			
3.8.1	The organization of high level requirements is inconsistent with other sections of the Standard	Clarification	Insert: <u>3.8.2 High Level requirements</u> and list all high level requirements consistent with other parts of the Standard.
3.8.2	*Section number should be* changed to 3.8.3. See comment for 3.8.1	Clarification	*Change the section number* to 3.8.3. See Resolution for 3.8.1.
WIND-A1, Cat. II and III and NOTE WIND-A1	The six elements described in NOTE WIND-A1 provide the details required for the tornado wind hazard analysis and should be included in WIND-A1. The word "properly" is superfluous.	Qualification	In the tornado wind hazard analysis, ... ACCOUNT ~~properly~~ for and ...a mean hazard curve can be derived. **INCLUDE the following elements in the *tornado wind hazard analysis:*** **(1) Variation of tornado intensity with occurrence frequency (The frequency of tornado occurrence decreases rapidly with increased intensity);** **(2) Correlation of tornado width and length of damage area; longer tornadoes are usually wider;** **(3) Correlation of tornado area and intensity; stronger tornadoes are usually *larger than weaker tornadoes;*** **(4) Variation in tornado intensity along the damage path length; tornado intensity varies throughout its life cycle;** **(5) Variation of tornado intensity across the tornado path width.** **(6) Variation of tornado differential pressure across the tornado path width.** **NOTE WIND-A1:** State-of-the-art methodologies are given ... can be found in Refs. 13, 56, and 57.

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			~~Tornado wind hazard analysis SHOULD include the following elements:~~ ~~(1) Variation of tornado intensity with occurrence frequency (The frequency of tornado occurrence decreases rapidly with increased intensity);~~ ~~(2) Correlation of tornado width and length of damage area; longer tornadoes are usually wider;~~ ~~(3) Correlation of tornado area and intensity; stronger tornadoes are usually larger than weaker tornadoes;~~ ~~(4) Variation in tornado intensity along the damage path length; tornado intensity varies throughout its life cycle;~~ ~~(5) Variation of tornado intensity across the tornado path width.~~ ~~(6) Variation of tornado differential pressure across the tornado path width.~~
WIND-A4, Cat. II and III	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... ~~CONSIDER~~ EXAMINE specific features ...large early release.
WIND-A4, Cat. II	There is no requirement for calculating the population of missiles.	Qualification	**NEW SR WIND-A4a: SURVEY the plant building and surroundings to assess the number, types, and locations of potential missiles.**
WIND-A4, Cat. III	There is no requirement for calculating the population of missiles.	Qualification	**NEW SR WIND-A4a: SURVEY the plant building and surroundings and to catalog the number, types, and locations of potential missiles.**
HLR-WIND-B	Permissive 'may' should not be used in HLR. A requirement missing for identifying those plant structures, systems and components which are vulnerable to the wind hazards.	Qualification	(HLR-WIND-B): ... whose failure ~~may~~ contribute to core damage or large early release. NEW SR **WIND-B1a: IDENTIFY plant structures, systems and components that are vulnerable to the wind hazards. ACCOUNT for both wind effect and wind-borne missiles effect.**

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WIND-B1	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... In this evaluation, ~~CONSIDER~~ **INCLUDE** the findings of a plant walkdown.
NOTE WIND-B1	In the 5th para., the phrase "...nonseismic Category I structures" should be Category II.	Clarification	...for nonseismic Category I II structures...
HLR-WIND-C	Use of words "All" and "important" is improper.	Qualification	The wind-PRA systems model SHALL include ~~all important~~ **significant** wind-caused initiating events and other ~~important~~ **significant** failures that can lead to core damage or large early release.
WIND-C1	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	ASSESS accident sequences initiated by high winds to estimate CDF and LERF contribution. In the analysis, ~~CONSIDER~~ **USE** the site-specific wind hazard curves and the fragilities of structures and equipment.
WIND C-2 through D-7	---------------	No objection	------------------
3.9			
3.9.1	The organization of high level requirements is inconsistent with other sections of the Standard	Clarification	Insert: **3.9.2 High Level requirements** and list all high level requirements consistent with other parts of the Standard.
3.9.2	Section number should be changed to 3.8.3. See comment for 3.9.1	Clarification	Change the section number to 3.9.3. See Resolution for 3.9.1.
FLOOD-A1	Permissives should not be used in SR.	Qualification	In the hazard analysis for extreme local precipitation, USE up-to-date data for the relevant phenomena, **it is acceptable to utilize** both site-specific and regional data ~~MAY be utilized~~.
FLOOD-A2	Permissives should not be used in SR.	Qualification	In the hazard analysis for extreme river flooding, including floods due to single or cascading dam failures, USE up-to-date data for the relevant phenomena. **It is acceptable to utilize** both site-specific and regional data ~~MAY be used~~.

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NOTE FLOOD-A2	---------------	No objection	---------------
FLOOD-A3	Permissives should not be used in SR.	Qualification	In the hazard analysis for extreme ocean (coastal and estuary) flooding, USE up-to-date data for the relevant phenomena, **it is acceptable to use** both site-specific and regional data ~~MAY be used~~.
FLOOD-A4	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	... ~~CONSIDER~~ **ACCOUNT for** high water levels, ...
FLOOD-A5	Permissives should not be used in SR.	Qualification	In the hazard analysis for extreme tsunami flooding, USE up-to-date data for the relevant phenomena, **it is acceptable to use** both site-specific and regional data ~~MAY be used~~.
HLR-FLOOD-B	Permissives should not be used in HLR.	Qualification	(HLR-FLOOD-B): ... whose failure ~~may~~ contribute to core damage or large early *release, or both.*
FLOOD-B1	The words "consider" and "MAY" are permissives and inappropriate for SRs. Action verbs should be used. A requirement missing for identifying those plant structures, systems and components which are vulnerable to the wind hazards.	Qualification	In the evaluation of flood fragilities of structures and exposed equipment (low-lying equipment on the site, intake and ultimate-heat-sink equipment, etc.), USE plant-specific data. In this evaluation, ~~CONSIDER~~ **INCLUDE** the findings of a plant walkdown. **It is acceptable in the** fragility analysis for both capacity and demand ~~MAY be based on~~ **to apply** the standard methodology used for seismic events, with appropriate modifications unique to the flooding event being studied. NEW SR **FLOOD-B1a: IDENTIFY plant structures, systems and components that are vulnerable to the flood hazards.**
HLR-FLOOD-C	Use of words "All" and "important" is improper.	Qualification	The external-flooding-PRA systems model SHALL include ~~all important~~ **significant** flood-caused initiating events and other ~~important~~ **significant** failures that can lead to core damage or large early release...
FLOOD-C1	The word "consider" is permissive and inappropriate for SRs. Action verbs should be used.	Qualification	To estimate CDF and LERF contributions, ASSESS accident sequences initiated by *external flooding. In the analysis,* ~~CONSIDER~~ **USE where applicable** the appropriate flooding hazard curves and the fragilities of structures and equipment.
FLOOD-C2 to FLOOD- D7	---------------	No objection	---------------
SECTION 4 Table A1of APPENDIX A, Chapter 5 applies.			
SECTION 5 Table A1 of APPENDIX A, Chapter 6 applies.			
5.1	Regarding reference to ASME	Clarification	See comments for R.G. 1.200, APPENDIX A,

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	PRA Standard, see issues for R.G. 1.200, APPENDIX A, Chapter 6 of Table A-1.		Chapter 6 of Table A-1.
5.1, 3rd papa.	The purpose stated lacks clarity.	Clarification	The purpose of the peer review is ~~fundamentally~~ to provide an independent review of the PRA or SMA, **to ensure concurrence with** ~~This means reviewing the analysis vis-à-vis~~ the applicable Requirements in the Standard. The composition and qualifications of the peer review team are important, as is its independence; these aspects are covered in the ASME Standard's requirements (ASME, 2002) that are incorporated here by reference. Other process issues, including the need for a team leader and the need for a methodology for the review, are also covered in the ASME Standard.
5.2-5.4	-------------------	No objection	-------------------
SECTION 6			
6.1	Regarding reference to ASME PRA Standard, see issues for R.G. 1.200, APPENDIX A, Chapter 3 of Table A-1.	Clarification	See comments for R.G. 1.200, APPENDIX A, Chapter 3 of Table A-1.
6.2	See Appendix D, general comment 1	Quantification	Delete 2nd para.
SECTION 7	-------------------	No objection	-------------------
APPENDIX A	-------------------	No objection	-------------------
APPENDIX B	-------------------	No Objection	-------------------
Equation (B2)	This example does not contains non-seismic failures.	Qualification	Select an example of a cutset which will contain both seismic and non-seismic failures.
APPENDIX C			
C.1 Introduction, 2nd para.	Incorrect reference to Section 3.5.1.1	Clarification	Change "3.5.1.1" to "3.6.1".
C.2 Seven Steps (Step 1)	The word "stylized" is not appropriate.	Clarification	Delete the word "stylized".
C.2 Seven Steps (Steps 2 -7)	-------------------	No Objection	-------------------
C.3 Enhancements	-------------------	No Objection	-------------------
C.4 Seven Steps -	Mitigating small LOCA accidents should be an objective of at least one of the	Clarification	(2) select a primary success path and an alternate success path for the SMA, eliminating those elements or paths that cannot be

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Detailed Discussion (C.4.4)	success paths		evaluated for seismic adequacy economically. **Ensure that one of these two paths is capable of mitigating a small loss-of-coolant accident.** It is important...
C.4 Seven Steps - Detailed Discussion (C.4.6)	The last sentence under Step 6 is not correct if only one success path can mitigate a SLOCA and that success path has a lower HCLPF. In this scenario, the plant HCLPF is governed by the SLOCA success path HCLPF.	Clarification	HCLPF capacities are documented for all elements in the primary and alternate success paths which have capacities less than the specified RLE. The element with the lowest HCLPF capacity in a success path establishes the seismic HCLPF capacity for the path. The higher seismic HCLPF capacity of the primary and alternative success paths is the seismic HCLPF capacity of the plant-as-a-whole **if both paths can mitigate an SLOCA or only one path mitigate an SLOCA but the SLOCA path has a higher HCLPF than the other path. However, in the case where only one success path can mitigate an SLOCA and that path also has a lower HCLPF than the other path, then the plant HCLPF is governed by the SLOCA success path HCLPF.**
C.4 Seven Steps - Detailed Discussion (C.4.8 ?)	There is no C.4.7. Looks like C.4.8 should be C.4.7.	Clarification	Change subsection number to C.4.7.
C.5 Four Enhancements - Detailed Discussion (C.5.1 thru 3)	-------------------	No Objection	-------------------
APPENDIX D			
General Comment 1	Appendix D attempts to expand the range of applicability of SMA considerably beyond its stated objectives, in order to support risk-informed applications for regulatory relief. The staff cannot accept a priori the possible enhancements described in the appendix. At the same time, the staff has no basis to reject these enhancements. The staff will need to conduct a case-by-case evaluation of (1) the implementation of a specific enhancement, and (2) the specific results and conclusions obtained. The standard would be vastly improved from a regulatory perspective if	Clarification	Delete Appendix D. Disagree with the statement that the standard would be vastly improved by deleting Appendix D. Appendix D attempts to define the use of SMA in risk informed space. This guidance is sorely needed and it would be a mistake to take it out.

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	Appendix D is deleted from the standard.		
General Comment 2	Assuming that ANS does NOT delete Appendix D from the standard, Appendix D should be rewritten to focus strictly on the risk insights directly derivable from a SMA and present examples of its applicability and limitations. Implementation of any enhancements will require specific staff review.	Clarification	Revise Appendix D to focus on the applicability of SMA and its limitations in developing risk insights. If desired, clearly and concisely list and describe possible enhancements in one section of the appendix, with an introduction clearly stating that implementation of any of these enhancements requires specific peer review, and is subject to regulatory review on a case-by-case basis. I don't believe that the statement that a regulatory review would be required on a case-by-case basis merits inclusion here based on two perspectives: 1) It does not belong in a standard 2) It is not appropriate. The SMA contains insights that can be utilized for risk informed applications. It is no different from the situation of implementing the SPRA to this standard. It can always be reviewed by the NRC on a case-by-case basis.
General Comment 3	Throughout Appendix D, ANS takes the position that the plant HCLPF capacity is defined by the HCLPF capacity of the more seismically rugged success path. The staff takes exception to this position. This is only true if both success paths can mitigate a SLOCA or the SLOCA path has higher HCLPF. The SMA requirement is that only one success path has to be capable of mitigating a SLOCA. This was previously identified under Index No. C.4 (C.4.6).	Clarification	Revise the statements and examples in Appendix D to consider the case where the only success path capable of mitigating a SLOCA has the lower HCLPF capacity.

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