# Seismic Evaluation Guidance

## *Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*

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# Product Description

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) established a Near Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations. The NTTF was also tasked with determining if the agency should make additional improvements to its regulatory system.

**Background**
*Place Holder*

**Objectives**
*Place Holder*

**Approach**
*Place Holder*

**Results and Findings**
*Place Holder*

**Applications, Value, and Use**
*Place Holder*

**Keywords**
Augmented Approach
Earthquakes
Fukushima
Seismic hazard
SPRA

# List of Acronyms

| | |
|---|---|
| ACI | American Concrete Institute |
| AISC | American Institute of Steel Construction |
| ANS | American Nuclear Society |
| ASME | American Society of Mechanical Engineers |
| BWR | boiling water reactor |
| CDFM | Conservative Deterministic Failure Margin |
| ESEL | Expedited Seismic Equipment List |
| ESEP | Expedited Seismic Evaluation Process |
| GERS | generic equipment ruggedness spectra |
| GMRS | ground motion response spectrum |
| HCLPF | High Confidence of a Low Probability of Failure |
| ISRS | in-structure response spectra |
| NPP | nuclear power plant |
| NRC | Nuclear Regulatory Commission |
| NTTF | Near Term Task Force |
| PGA | peak ground acceleration |
| PWR | pressurized water reactor |
| RLGM | review level ground motion |
| SMA | seismic margin assessment |
| SPRA | seismic probabilistic risk assessment |
| SRT | seismic review team |
| SSC | structures, systems, and component |
| SSE | safe shutdown earthquake |
| SSI | soil-structure interaction |
| TRS | test response spectrum |
| UHRS | uniform hazard response spectrum |

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# Section 1: Purpose and Approach

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011 Great Tohoku Earthquake and subsequent tsunami, the United States Nuclear Regulatory Commission (NRC) established the Near Term Task Force (NTTF) in response to Commission direction. The NTTF issued a report that made a series of recommendations, some of which were to be acted upon "without unnecessary delay." Subsequently, the NRC issued a 50.54(f) letter that requests information to ensure that these recommendations are addressed by all U.S. nuclear power plants (NPPs). The principal purpose of this report is to provide guidance for responding to the request for information in the 50.54(f) Letter, Enclosure 1, Recommendation 2.1: Seismic [1].

Section 1 of this report provides a summary of the purpose and scope of the Augmented Approach being recommended by the nuclear power industry to fulfill the seismic portions of the 50.54(f) request for information.

## 1.1 Augmented Approach to Responding to Information Request for NTTF Recommendation 2.1

The approach described in this report has been developed by EPRI, working with experts from within the nuclear industry, with the intent of identifying reasonable measures that can be employed to accomplish an effective seismic evaluation in the most expedient manner. More specifically, the approach was designed to constitute a specific path to focus the initial industry efforts on short term evaluations that would lead to prompt modifications to some of the most important components that could improve plant seismic safety. This short term aspect of the Augmented Approach is referred to as the Expedited Seismic Evaluation Process (ESEP) and is described in the subsequent sections of this report. The ESEP addresses the requested information part of the 50.54(f) Letter [1] that requests "interim evaluations and actions taken or planned to address the higher seismic hazard relative to the design basis, as appropriate, prior to completion of the risk evaluation." The seismic risk evaluation portion of the Augmented Approach is documented in EPRI Report 1025287 [2].

This approach reflects careful consideration of the NRC's description of an acceptable approach for the seismic elements of Recommendation 2.1 (documented in Attachment 1 to Seismic Enclosure 1 of the March 12, 2012 Request for Information [1]). In general, the approach described in this report is intended to conform to the structure and philosophy of the nine steps suggested

by the NRC and outlined in that attachment. Key elements of the approach have been added to provide an expedited schedule for implementing key seismic modifications associated with selected equipment as described in Section 3 of this report. As such, this is an "augmented approach" being recommended by the industry that provides additional seismic safety considerations (i.e. reviews and potential seismic upgrades for a select set of equipment) in a more expedited fashion than was requested in the 50.54f [1] request for information.

Figure 1-1 illustrates the timeline for employing the Augmented Approach, with a breakdown shown between the Expedited Seismic Evaluation Process (ESEP) and the seismic risk evaluations. The Augmented Approach response to the seismic portion of the 50.54(f) letter is based on a progressive screening approach and is broken down into six major task areas:

1. Seismic Hazard and Site Response Characterization
2. Ground Motion Response Spectrum (GMRS) Comparisons and Plant Screening
3. ESEP Seismic Evaluations
4. ESEP Seismic Modifications
5. Prioritization of plants for Risk Assessments
6. Seismic Risk Evaluations

Task areas 1, 5 and 6 are described in detail within EPRI 1025287 [2] and the methodology will not be repeated in this report. Task 2 is partially described in EPRI 1025287 [2] and is also discussed in Section 2 of this report as it applies to the ESEP. Tasks 3 and 4 apply to the ESEP and are the subject of the remaining sections of this report.

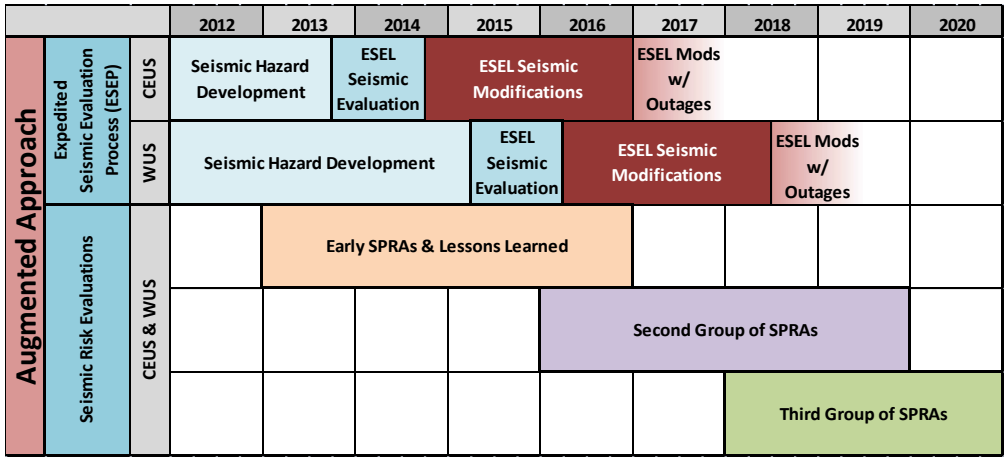



*Figure 1-1*
*Recommended Augmented Approach to Respond to Information Request 2.1 for Seismic*

## 1.2 Expedited Seismic Evaluation Process (ESEP)

The ESEP was developed to focus initial resources on the review of a subset of the plant equipment that can be relied upon to provide protection from beyond design basis seismic events. Figure 1-2 depicts the basic elements of the ESEP. This figure also describes where each of the key elements is discussed within this report (see the grid on the left of the figure).

In selecting the items to be included in an expedited seismic evaluation, the ongoing FLEX process [3, 4, 5] offers an appropriate starting point for consideration. The FLEX process adds an additional layer of defense-in-depth protection for beyond design basis events. The installed equipment and connection points associated with FLEX are therefore considered an appropriate list of items to consider for the expedited seismic evaluation. Section 3 in this report describes the selection criteria for the Expedited Seismic Equipment List (ESEL). The use of the FLEX process to obtain an equipment list for the ESEP does not affect or change any requirements for the FLEX implementation. FLEX is used only as an input to obtain an appropriate set of equipment for ESEP.

All U.S. nuclear plants will conduct this ESEP as described in this guideline on the schedule shown in Table 1-1. The ESEP was developed to be able to promptly assess and address potential seismic safety enhancements.

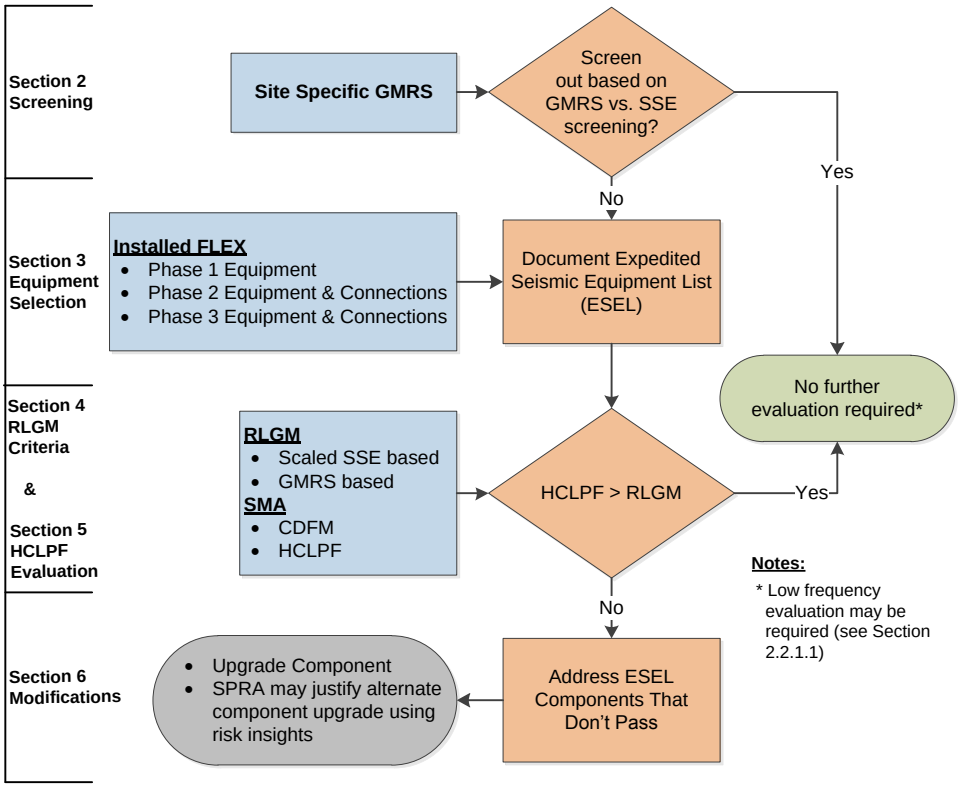


*Figure 1-2*
*Expedited Seismic Evaluation Process for the Augmented Approach*

Figure 1-3 contains a more detailed flow chart of the ESEP actions. A more complete set of actions included within the ESEP are listed. These actions will be referenced in later sections of this report.

Sections 2 through 7 of this report describe the elements of the ESEP. Section 2 contains the description of the screening criteria associated with comparisons of the ground motion response spectra (GMRS) to the safe shutdown earthquake (SSE). Section 3 characterizes the equipment selection criteria for the ESEP. Section 4 describes the elements of the recommended methods to develop the review level ground motion (RLGM). Section 5 describes the seismic capacity criteria based on characterization of the high confidence of a low probability of failure (HCLPF) associated with the equipment reviewed as part of the ESEP. Section 6 contains the description of the modification criteria. Finally, Section 7 documents the submittal criteria for the ESEP.

*Table 1-1*
*Expedited Seismic Evaluation Process Implementation Schedule*

| Region | Activity | Schedule |
|---|---|---|
| Central and Eastern United States (CEUS) Plants | Submit updated seismic hazards and GMRS and screening | September 2013 |
| | Complete ESEL HCLPF Calculations (if necessary) | September 2014 |
| | Complete ESEL modifications not requiring plant outages | December 2016 |
| | Complete ESEL modifications requiring plant outages | Within 2 outages of December 2014 |
| Western United States (WUS) Plants | Submit updated seismic hazards and GMRS and screening | March 2015 |
| | Complete ESEL HCLPF Calculations (if necessary) | January 2016 |
| | Complete ESEL modifications not requiring plant outages | June 2018 |
| | Complete ESEL modifications requiring plant outages | Within 2 outages of January 2016 |

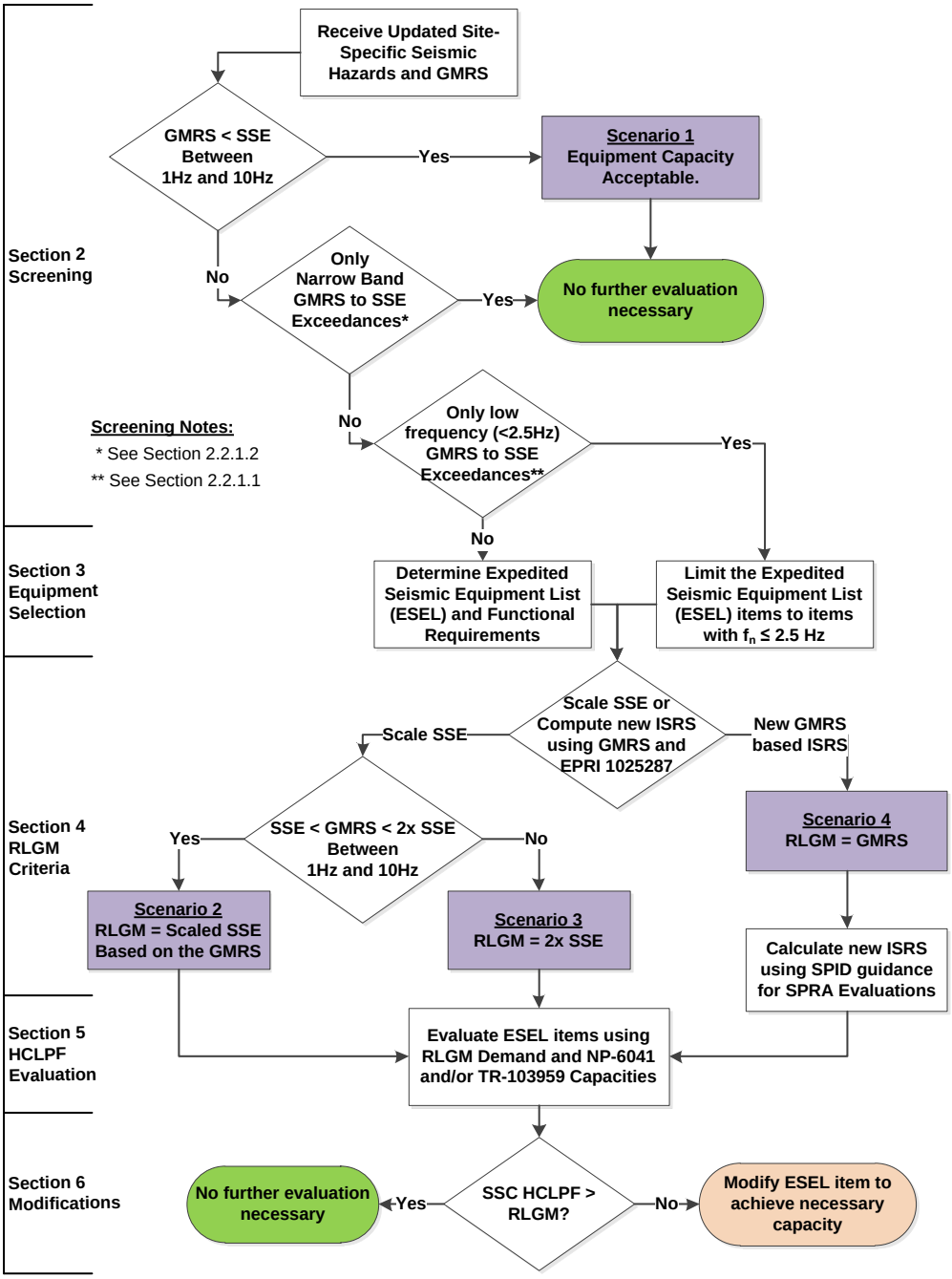



*Figure 1-3*
*Detailed Flow Chart of the ESEP for the Augmented Approach*

# Section 2: Screening for the ESEP (SSE-to-GMRS)

## 2.1 Background on Screening

Screening for application of the ESEP is based on a comparison of the SSE with the GMRS and uses criteria from EPRI 1025287 Section 3 [2]. The horizontal GMRS should be compared to the horizontal 5% damped SSE as outlined in Figure 2-1. This screening process, along with examples, is described in more detail below.

## 2.2 SSE Screening Task (SSE-to-GMRS Comparison)

The SSE is the plant licensing basis earthquake as identified in EPRI 1025287 Section 2 [2]. Similar to Reference 2, the first step in the SSE screening process is to compare the SSE to the GMRS in the 1 to 10 Hz region of the response spectrum. If the SSE envelopes the GMRS between 1 and 10 Hz, then the plant screens out of the ESEP[1].

If the initial comparison of the SSE to GMRS does not demonstrate that the SSE envelops the GMRS in the 1 to 10 Hz region, then the licensees may consider two special screening considerations described below.

### *2.2.1 Special Screening Considerations*

Consistent with EPRI 1025287 Section 3.2.1 [2], there are two special screening considerations:

- GMRS Comparisons and Screening of Plants at Low Seismic Hazard Sites, and
- Narrow Band Exceedances in the 1 to 10 Hz Range.

[1] For Diablo Canyon, the design/licensing basis earthquake (i.e. Hosgri 0.75 g) should be appropriate for this evaluation.

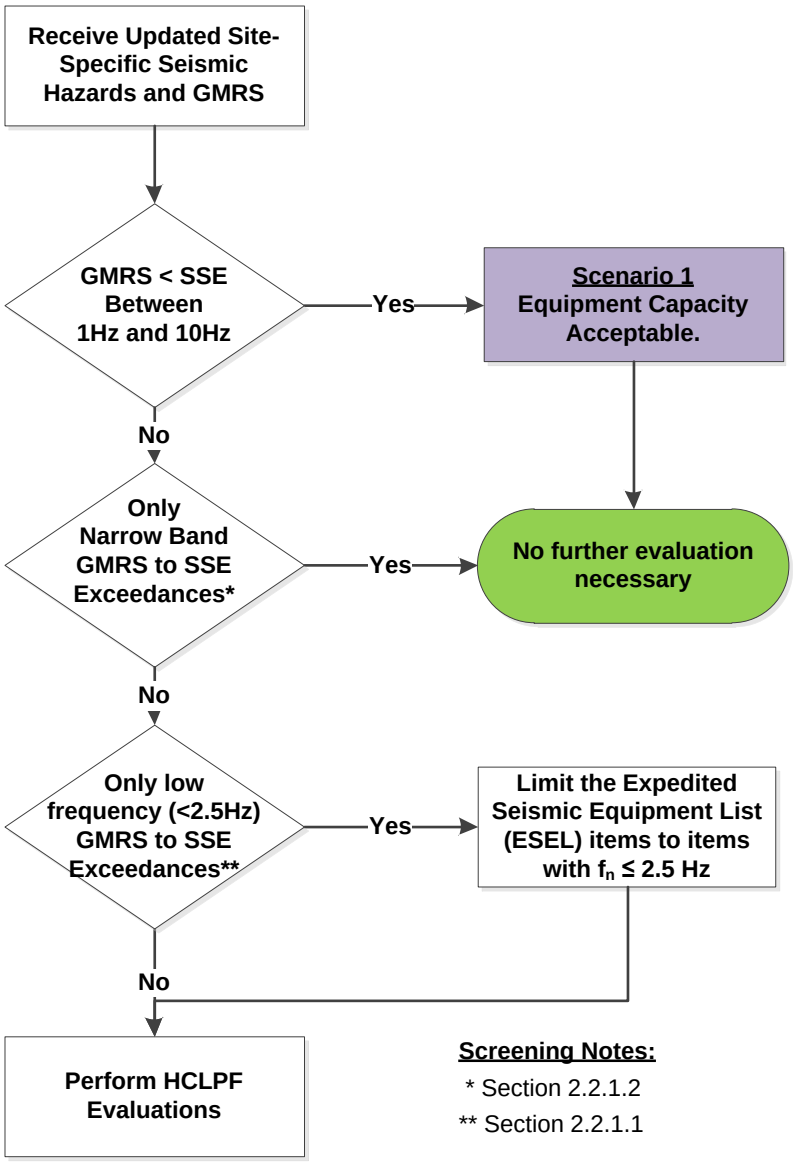



*Figure 2-1*
*Example Comparison of GMRS to SSE (5% Damping)*

### 2.2.1.1 GMRS Comparisons and Screening of Plants at Low Seismic Hazard Sites

The screening process described in EPRI 1025287 Section 3.2.1.1 [2] can be used to determine if the plant can be screened out as a low seismic hazard site.

Low-frequency GMRS exceedances (below 2.5 Hz) at low seismic hazard sites do not require a plant to perform a full ESEP. Instead, it is sufficient to first identify the Expedited Seismic Equipment List (ESEL, see Section 3) items that are potentially susceptible to damage from spectral accelerations at frequencies below which the highest frequency $f_L$ ($f_L$ < 2.5 Hz) acceleration exceeds the SSE

spectral acceleration. Examples of ESEL items and failure modes potentially susceptible to damage from spectral accelerations at low frequencies are:

1) Liquid sloshing in atmospheric pressure storage tanks
2) Sliding and rocking of unanchored components

After identifying the ESEL items that are potentially susceptible to lower frequency accelerations, the ESEL can be limited to items whose natural frequency is below the highest frequency $f_L$ ($f_L$ < 2.5 Hz) where the GMRS spectral acceleration exceeds the SSE spectral acceleration. Other than this limitation, the ESEP should be completed as shown in Figures 1-3 and 2-1.

#### 2.2.1.2 Narrow Band Exceedances in the 1 to 10 Hz Range

The screening process described in EPRI 1025287 Section 3.2.1.2 [2] can be used to determine if the plant can be screened out as having only narrow banded GMRS exceedances between 1 and 10 Hz. If the plant passes this criteria, then the plant screens out of the ESEP.

# Section 3: Equipment Selection

## 3.1 Introduction and Background

In response to Order EA 12-049 [4], all U.S. plants are required to create mitigating strategies for beyond design basis events. Industry has prepared a guidance document [3] that governs the requirements for this diverse and flexible coping capability, referred to by the industry as FLEX. Figure 3.1, below, illustrates how FLEX supplements the existing capabilities to add an additional layer of defense in depth against severe natural events. The ESEP will focus on a subset of key installed equipment using FLEX as a vehicle to develop this equipment list.

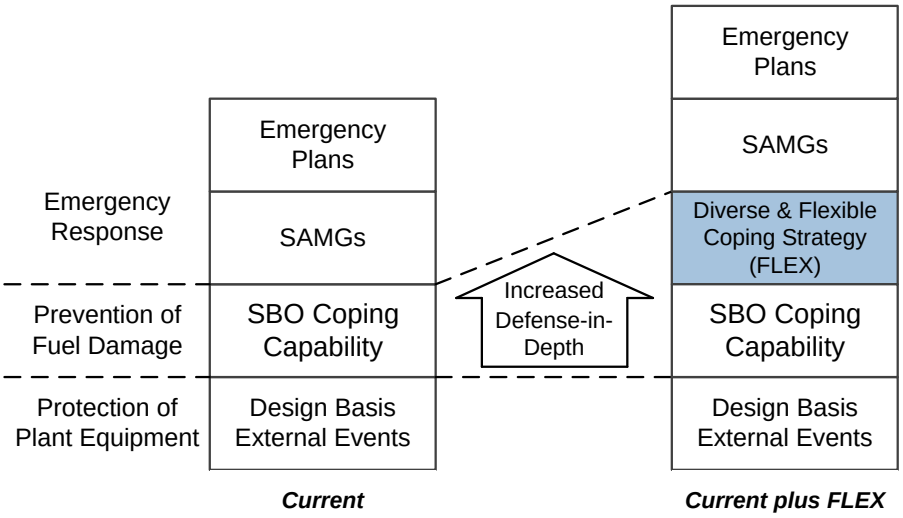



*Figure 3-1*
*FLEX Enhances Defense in Depth*

## 3.2 Selection of Expedited Seismic Equipment List (ESEL)

The selection of the Expedited Seismic Equipment List (ESEL) will be derived from equipment identified in the plant-specific FLEX implementation strategy. In responding to EA 12-049, each plant will have defined an essentially indefinite coping capability for scenarios involving an extended loss of AC power condition. Loss of alternating current (AC) power has been found to be an important contributor in many seismic probabilistic risk assessments (SPRAs).

Thus, by considering the selected FLEX equipment as the source for the ESEL, plant capabilities to mitigate an important contributor to seismic risk are being enhanced.

The underlying strategies for coping with these conditions involve a three-phase approach:

1. Initially cope by relying on installed plant equipment.
2. Transition from installed plant equipment to on-site FLEX equipment.
3. Obtain additional capability and redundancy from off-site equipment until power, water, and coolant injection systems are restored or commissioned.

Plant-specific evaluations for FLEX will determine the specific equipment and strategies to be employed in these three phases. The scope of the ESEL is limited to installed plant equipment and FLEX equipment connections. As described above, Phase 1 relies upon equipment that is installed in the plant. Phases 2 and 3 rely on portable on-site or off-site equipment to supplement installed equipment, but these capabilities tie into and utilize installed plant equipment. Per NEI 12-06 [3], installed plant equipment relied upon to respond to an earthquake as part of FLEX must be seismically robust. NEI 12-06 defines "robust" as "the design of an SSC either meets the current plant design basis" or "has been shown by analysis or test to meet or exceed the current design basis". The purpose of the ESEP is to demonstrate or provide additional seismic margin for ESEL items. It does not redefine any of the terms or criteria in NEI 12-06.

Each plant should review their FLEX implementation approach to identify the installed plant equipment and portions of systems required to accomplish the reactor and containment safety functions identified in NEI 12-06 Tables C-1 and C-2 for Boiling Water Reactors (BWRs) and Tables D-1 and D-2 for Pressurized Water Reactors (PWRs). Tables 3-1 and 3-2 identify these safety functions and provide a summary of the typical equipment and portions of systems that would be included in the ESEL. In addition to the structural failure of specific pieces of installed equipment, the key functional failure modes of electrical portions of the installed Phase 1 equipment should be considered (e.g. RCIC/AFW trips). The selection process for the ESEL should assume the FLEX strategies (modifications, equipment, procedures, etc.) have been implemented.

Some equipment relied upon for implementation of FLEX capabilities need not be included in the ESEL:

- Only a single success path is required for the safety functions identified in Tables 3-1 and 3-2. Equipment required to support an alternative means to accomplish a function are not required to be included in the ESEL.
    1. NEI 12-06 requires primary and alternate connection points for portable equipment. Only one connection point needs to be included, provided the required function can still be accomplished.

2. Limiting instrumentation to one indication per key parameter provided the required function can still be accomplished is acceptable.

3. Plants may have identified additional resources that may be beneficial, but are not required (e.g. multiple water sources available for CST makeup). Only the minimum set of sources to perform the required function need to be considered.

- Some specific SSCs normally considered in SPRAs are excluded. These will be addressed by plants as part of the longer-term seismic risk evaluations, if required.

  1. The following types of SSCs are excluded from the ESEP.

     - Structures, e.g., containment, reactor building, control building auxiliary building, etc.
     - Piping, cabling, conduit, HVAC, and their supports
     - Manual valves, check valves, and rupture disks
     - Power operated valves not required to change state as part of the FLEX mitigation strategies
     - NSSS components (e.g. RPV and internals, RCPs and seals, etc.)

- Portions of SSCs that are not directly relied upon in the FLEX strategy may be excluded, such as:

  1. Portions of systems that are not used as transport mechanisms for delivering required flows are excluded (e.g. piping or components beyond boundary valves).

  2. Electrical equipment components not specifically relied upon to perform the FLEX functions are excluded (e.g. power sources and distribution not directly supporting FLEX active components).

- Controls for which plant procedures provide instructions for manual operation (in the event of control system, component, permissive, or interlock failures) that ensure performance of the required FLEX function are excluded.

- Phase 3 portions of installed equipment (and FLEX connections) that are not directly relied upon in the FLEX strategy to sustain the critical functions of core cooling and containment integrity may be excluded. Recovery strategies in Phase 3 are excluded.

*Table 3-1*
*Summary of NEI 12-06 Performance Attributes for BWR Core Cooling & Containment Function*

| Safety Function | | Method | Baseline Capability | Typical Installed ESEL Equipment | Typical Installed ESEL Support Equipment |
|---|---|---|---|---|---|
| Core Cooling | Reactor Core Cooling | • RCIC/HPCI/IC | • Use of installed equipment for initial coping | • RCIC pump, gland condenser, & lube oil cooler<br>• RCIC valves | • DC Power<br>  • Plant batteries<br>  • DC distribution panels, MCCs & switchgear, as required |
| | | • Depressurize RPV for Injection with Portable Injection Source | • Diverse connection points for portable pump | • ECCS injection valves | • Selected electrical components, if required |
| | | | • Multiple means to depressurize RPV | • SRVs | • Portions of DC power |
| | | • Sustained Source of Water | • Use of alternate water supply up to support core and SFP heat removal | • Onsite water storage tanks, if required | • None |
| | Key Reactor Parameters | • RPV Level<br>• RPV Pressure | • (Re-)Powered instruments | • Selected Instruments | • DC Power and/or<br>• Vital AC Power,<br>  • Selected Vital AC distribution panels<br>  • Inverters<br>• Instrument racks<br>• Instrument panels |
| Containment | Containment Function | • Containment Venting or Alternative | • For Mk I and II a venting capability and, if desired, an alternative capability<br>• For others, a reliable, hardened vent or other capability. | • Containment vent system, if applicable<br>• Selected suppression pool cooling equipment | • DC power<br>• Pneumatic supplies |
| | Containment Integrity | • Hydrogen igniters | • Re-powering of hydrogen igniters with a portable | • Igniter glow plugs | • Distribution panels required to supply power, if any |

| Safety Function | | Method | Baseline Capability | Typical Installed ESEL Equipment | Typical Installed ESEL Support Equipment |
|---|---|---|---|---|---|
| | (BWR Mark III Only) | | power supply. | | |
| | Key Containment Parameters | • Containment Pressure<br>• Suppression Pool Temperature<br>• Suppression Pool Level | • (Re-)Powered instruments | • Selected Instruments | • DC Power and/or<br>• Vital AC Power,<br>  • Selected Vital AC distribution panels<br>  • Inverters<br>• Instrument racks<br>• Instrument panels |

*Table 3-2*
*Summary of NEI 12-06 Performance Attributes for PWR Core Cooling & Containment Function*

| Safety Function | | Method | Baseline Capability | Typical Equipment | Typical Support Equipment |
|---|---|---|---|---|---|
| Core Cooling | Reactor Core Cooling & Heat Removal (steam generators available) | • AFW/EFW | • Use of installed equipment for initial coping | • AFW/EFW pump<br>• AFW/EFW valves | • DC Power<br>  • Plant batteries<br>  • DC distribution panels, MCCs & switchgear, as required |
| | | • Depressurize SG for Makeup with Portable Injection Source | • Connection for portable pump | • SG ADVs/PORVs | • None, typically |
| | | • Sustained Source of Water | • Use of alternate water supply up to support core and SFP heat removal | • Onsite water storage tanks, e.g., Condensate Storage Tank or equivalent, if required | • None |
| | RCS Inventory Control/Long-Term Subcriticality | • Low Leak RCP Seals and/or borated high pressure RCS makeup required | • Site analysis required to determine RCS makeup requirements<br>• Boration and/or letdown path may be required | • Injection path valves<br>• Letdown path valves | • None |
| | Core Cooling and Heat Removal (Modes 5 and 6 with SGs not available) | • All Plants Provide Means to Provide Borated RCS Makeup | • Diverse makeup connections to RCS for long-term RCS makeup and residual heat removal to vented RCS | • Injection path valves (May be same as above) | • None |
| | | | • Source of borated water required | • Onsite tank, if required. | • None |
| | Key Reactor Parameters | • SG Level<br>• SG Pressure<br>• RCS Pressure<br>• RCS Temperature | • (Re-)Powered instruments | • Selected Instruments | • DC Power and/or<br>• Vital AC Power,<br>  • Selected Vital AC distribution panels<br>  • Inverters |

| Safety Function | | Method | Baseline Capability | Typical Equipment | Typical Support Equipment |
|---|---|---|---|---|---|
| | | | | | • Instrument racks<br>• Instrument panels |
| Containment | Containment Function | • Containment Spray | • Connection to containment spray header or alternate capability or Analysis | • Containment spray valves | • None |
| | Containment Integrity (Ice Condenser Containments Only) | • Hydrogen igniters | • Re-powering of hydrogen igniters with a portable power supply. | • Igniter glow plugs | • Distribution panels required to supply power, if any |
| | Key Containment Parameters | • Containment Pressure | • (Re-)Powered instruments | • Selected Instruments | • DC Power and/or<br>• Vital AC Power,<br>  • Selected Vital AC distribution panels<br>  • Inverters<br>• Instrument racks<br>• Instrument panels |

A summary of the anticipated types of equipment expected to be on an ESEL are provided in the tables below:

*Table 3-3*
*Representative BWR Equipment within the Scope of ESEL*

| Mechanical Equipment | Electrical Equipment |
|---|---|
| ▪ RCIC pump and valves<br>▪ RCIC lube oil and gland condenser<br>▪ Safety relief valves (SRVs)<br>▪ SRV accumulators<br>▪ RPV injection valves<br>▪ Reliable hardened vent valves | ▪ Batteries<br>▪ DC distribution panels<br>▪ DC MCCs<br>▪ DC switchgear<br>▪ Vital AC distribution panels<br>▪ Battery charger(s)<br>▪ Inverter(s)<br>▪ Instrument racks<br>▪ Transmitters |

*Table 3-4*
*Representative PWR Equipment within the Scope of ESEL*

| Mechanical Equipment | Electrical Equipment |
|---|---|
| ▪ Turbine driven AFW pump and valves<br>▪ SG Power Operated Relief Valves (PORVs)<br>▪ Condensate Storage Tank<br>▪ SG injection valves<br>▪ RCS injection valves | ▪ Batteries<br>▪ DC distribution panels<br>▪ DC MCCs<br>▪ DC switchgear<br>▪ Vital AC distribution panels<br>▪ Battery charger(s)<br>▪ Inverter(s)<br>▪ Instrument racks<br>▪ Transmitters |

Finally, similar to seismic equipment lists for SPRAs, it is acceptable for the ESEL to be iterative. That is, if during the ESEP process, it is determined that an SSC has a seismic capacity below the RLGM, it may be appropriate to supplement the FLEX implementation to provide an alternative capability. For example, if an installed air accumulator relied upon to supply air for an air-operated valve is determined to have seismic capacity below the RLGM, it is acceptable to provide an alternative supply of air (e.g., air bottles) with a higher seismic capacity provided that capability fits within the overall performance requirements of NEI 12-06. Credit for operator manual actions (i.e. resetting relays or throttling valves) to compensate for items with a seismic capacity below the RLGM must consider the impacts on personnel availability, accessibility, etc. in accordance with NEI 12-06.

## 3.3 Format and Content of Expedited Seismic Equipment List (ESEL)

In order to support the appropriate evaluation of the seismic capacity, the ESEL must include additional information beyond the list of equipment. The needed information includes:

- The unique equipment ID
- A description of the equipment
- The normal and desired operating state of the equipment as evaluated in the site specific FLEX strategies, and
- Other information that may be useful to the evaluation of seismic capacity.

An example of a recommended format for the ESEL is provided in Table 3-5. Additional information may be included useful to the evaluation such as building, elevation, location, etc.

*Table 3-5*
*Example Format of ESEL Summary Table*

| ESEL Item # | Equipment ID | Description | Equipment Normal State | Equipment Desired State | Notes |
|---|---|---|---|---|---|
| 1 | XT15-C001 | TDAFW Turbine | Standby | Operating | AB10000 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**Notes for Table 3-5:**

The column headings are explained below:

- ESEL Item #: This is a record number for each ESEL item on the list. This is typically a unique sequential number that allows ease of reference to a particular SSC.
- Equipment ID: This is a unique equipment identification number for the SSC. This would generally be taken from the plant master equipment list or other common data system used at the plant.
- Description: This is a text description of the SSC. This would generally be taken from the plant master equipment list or other common data system used at the plant.
- Equipment Normal State: This column identifies the normal state of the SSC (e.g., normally energized/de-energized, normally closed/open, normally standby/running, etc.) based on the initial plant conditions defined in the baseline coping capability of NEI 12-06.
- Equipment Desired State: This column identifies the desired state of the equipment evaluated in the site specific FLEX mitigation strategy. For some equipment this will be different than the normal state. For example, a valve that is normally closed during plant operations may need to be opened to support a required function.
- Notes: This is a column field to provide notes and/or comments (reference drawings, specific room location, etc.). Codes may also be defined and used to provide a variety of information (e.g., failure mode of interest).

# Section 4: Review Level Ground Motion (RLGM) Spectrum Criteria

This section of the Expedited Seismic Evaluation Process (ESEP) for the Augmented Approach consists of addressing those plants which cannot be screened out based on the comparisons of the GMRS to the SSE (as described in Section 2 of this report). Plants whose GMRS exceeds the SSE in the 1 to 10 Hz range require further seismic evaluation beyond the design basis. The further seismic evaluation is conducted to a Review Level Ground Motion (RLGM) level, which consists of a response spectrum above the SSE level. Figure 1-3 contains a flowchart that shows how the development of the RLGM fits into the ESEP.

If a plant does not screen out from the ESEP as described in Section 2, then a RLGM would be computed using one of the following criteria:

1. The RLGM will be derived by linearly scaling the SSE by the maximum ratio of the GMRS/SSE between the 1 and 10 Hz range (not to exceed 2 x SSE and 0.75g PGA). In-structure RLGM seismic motions would be derived using existing SSE-based in-structure response spectra (ISRS) scaled with the same factor.
2. Alternatively, licensees who have developed appropriate structural/soil-structure interaction (SSI) models capable of calculating ISRS based on site GMRS/uniform hazard response spectrum (UHRS) input may opt to use these ISRS in lieu of scaled SSE ISRS. In this case, the GMRS would represent the RLGM. EPRI 1025287 [2] and the ASME/ANS PRA Standard [10] give guidance on acceptable methods to compute both the GMRS and the associated ISRS.

Approach number 1 above, where the RLGM is developed based on the SSE, is a much more expedient approach (both in terms of schedule and resources) for developing the floor spectra in the structures housing ESEL items since it involves a simple linear scaling of existing SSE-based floor spectra. Two example cases of implementing approach 1 are depicted in Figures 4-1 and 4-2.

- **Figure 4-1** depicts the case where the GMRS exceeds the SSE but is less than twice the SSE in the 1 to 10 Hz range. The RLGM for this case is developed by linearly scaling up the SSE by the maximum ratio of the

GMRS/SSE between the 1 to 10 Hz range. For this example, that maximum ratio occurs at 10 Hz.

- **Figure 4-2** depicts the case where the RLGM would be set at the maximum of two times the SSE. In this case, the maximum ratio of the GMRS to the SSE over the 1 to 10 Hz range exceeds a value of 2.

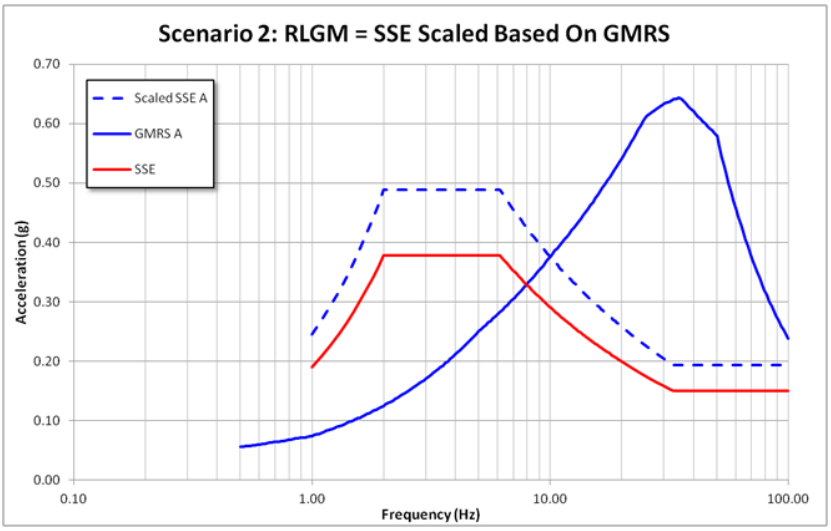



*Figure 4-1*
*RLGM Generated by Scaling Up SSE Spectrum (Scenario 2 from Figure 1-3)*

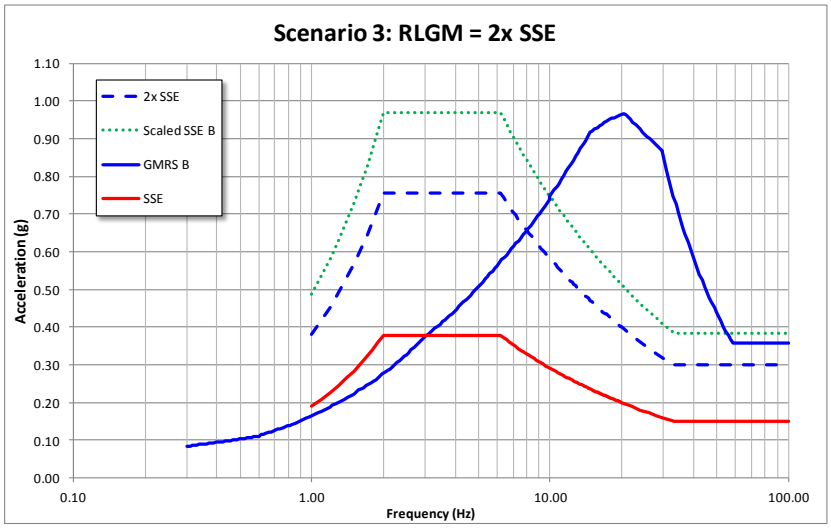



*Figure 4-2*
*RLGM Defined as Twice the SSE (Scenario 3 from Figure 1-3)*

# Section 5: SSC Capacity Criteria for the ESEP

The ESEP consists of first the GMRS/SSE screening assessments (Section 2), followed by generating the scope of equipment (Section 3) and subsequently followed by the development of the RLGM (Section 4). Those plants required to perform the beyond design basis review as part of the ESEP are then required to demonstrate that ESEL items have sufficient capacity to meet or exceed the demand characterized by the RLGM. The criteria for the seismic capacity of the components included within the ESEL for this ESEP consists of calculating a HCLPF seismic capacity and comparing that level to the seismic demand of the RLGM.

Demonstration that the HCLPF capacity exceeds the RLGM for the components within the ESEL will verify adequate seismic ruggedness for this program and would indicate that no further action would be required, as shown in Figures 1-2 and 1-3. Conversely, Section 6 of this report discusses the process for the resolution of those components which cannot demonstrate this margin over the RLGM. The detailed criteria for the development of the HCLPF capacity, along with many examples of the methods used to perform the calculation, are well documented in technical literature and will not be repeated in this document. Several references for HCLPF procedures are listed in Table 5-1.

*Table 5-1*
*Partial List of Fragility and Margin References*

| SPRA Topic | Document Title | Reference |
|---|---|---|
| Seismic Fragility & Margin | Seismic Fragility Applications Guide Update | EPRI Report 1019200 (Dec 2009)[6] |
| | Seismic Fragility Application Guide | EPRI 1002988 (Dec 2002) [7] |
| | Methodology for Developing Seismic Fragilities | EPRI TR-103959 (June 1994) [8] |
| | A Methodology for Assessment of Nuclear Plant Seismic Margin | EPRI NP 6041 (Oct 1988) [9] |

There are two basic approaches for developing the HCLPF values:

- Deterministic Approach

- Probabilistic Approach – generated based on a seismic fragility calculation

The deterministic approach is typically considered to be the easiest to apply, and there are more practitioners with experience with its implementation. As such, a brief summary of some of the salient features of the deterministic approach are provided herein. The deterministic approach to defining the HCLPF of essential components is commonly referred to as the Conservative Deterministic Failure Margin (CDFM) approach.

For this ESEP program, the response is specified as described in Section 4 of this report, and the capacity is generated based on CDFM methods. EPRI NP-6041-SL [9] contains a detailed description of the CDFM process. The basic elements of the CDFM capacity development are summarized in Table 5-2 below.

*Table 5-2*
*Summary of Conservative Deterministic Failure Margin Approach for Seismic Capacity (EPRI NP-6041-SL [9])*

| **Load Combination:** | **Normal + Seismic** |
|---|---|
| Material Strength: | Code-specified minimum strength or 95% exceedance actual strength if test data are available. |
| Static Capacity Equations: | Code ultimate strength (ACI), maximum strength (AISC), Service Level D (ASME), or functional limits. If test data are available to demonstrate excessive conservatism of code equations, then use 84% exceedance of test data for capacity equation. |
| Inelastic Energy Absorption: | For non-brittle failure modes and linear analysis, use 80% of computed seismic stress in capacity evaluation to account for ductility benefits, or perform nonlinear analysis and go to 95% exceedance ductility levels. |

For those structural failure modes which can be evaluated by analysis, a seismic capacity estimate requires an estimate of:

1. material strength,
2. static capacity or failure equation, and
3. inelastic energy absorption capability.

Each of these parameters should be conservatively estimated to achieve the above-recommended level of capacity conservatism.

Material strengths used in the CDFM approach should be the approximately 95% exceedance probability strengths from material test data. Otherwise, code- or design-specified minimum strengths should be used. These values represent the approximately 95% exceedance probability strengths of all materials meeting

the code specifications. As discussed in EPRI NP-6041-SL [9] a higher exceedance probability is needed for brittle failure modes.

Functional failure modes cannot typically be evaluated solely by analysis and have to be assessed using test data or generic equipment ruggedness spectra (GERS). The GERS are always set lower than the lowest test response spectrum (TRS) for which failures were observed, if any such failure test data exists. If either the component-specific test data or the applicable GERS are to be considered to demonstrate operability, then a margin factor is needed between the computed seismic response and the TRS in order to achieve a HCLPF capacity. Recommendations are provided in [9] for the calculation approaches for CDFM capacities for functional failure modes.

### Seismic Capacity Screening Guidelines

The EPRI seismic margins report [9] contains a set of screening criteria tables frequently used in both SPRAs and SMAs, including Table 2-4 titled “Summary of Equipment and Subsystems Screening Criteria for Seismic Margin Evaluation.”

The criteria documented in this table was based primarily on information from SPRA/SMA studies and on available seismic experience data (both actual earthquake experience and testing experience). The NRC-sponsored "Expert Panel" on the Quantification of Seismic Margins developed a consensus seismic capacity screening criteria, which was the starting point for the table. The EPRI Seismic Margin Program reviewed additional data and refined and expanded the NRC Expert Panel recommendations, which resulted in Tables 2-4 [9]. The guidelines are intended to provide generic conservative estimates of the ground motion below which it is generally not necessary to perform a seismic margin review for particular elements. Thus, for a given ground motion level, the guidelines list the equipment which should, in general, be "screened out" from margin review because of their generically good performance in earthquakes or seismic simulation tests at or above this level. These guidelines are to be used only in conjunction with a walkdown of plant-specific elements by the seismic review team (SRT). The guidelines are intended to assist the SRT in "screening out" components during their walkdown, but the SRT must exercise its own collective experience and judgment in the use of these guidelines for any specific component.

Several important considerations associated with the use of this table include:

- Separate criteria are listed depending on the 5% damped peak spectral acceleration associated with the ground motion.
- Caveats and restrictions associated with each specific system, or component type are required to be met. These are documented as notes to the table.
- The table is applicable to equipment up to 40 ft above grade.

It is important to recognize that a major part of an SMA is investigation of equipment anchorage. The screening table given in this report are for the

capacity of the element per se, and do not include consideration of anchorage, which varies from plant to plant. Thus anchorage must be considered in addition to the guidance given in the screening tables.

Nearby block walls should be identified during walkdowns and subsequently evaluated. In addition, piping attached to tanks should be reviewed to address the possibility of failures due to differential displacements. Other potential seismic interaction evaluations will be deferred to the full seismic risk evaluations performed in accordance with EPRI 1025287 [2].

Reference [6] is an update to the EPRI fragility methodology and contains a description of the criteria for application of these screening tables at elevations beyond 40 ft above grade and should be considered as part of this evaluation.

# Section 6: ESEL Modification Criteria

Demonstration that the HCLPF capacity for any ESEL item exceeds the RLGM verifies that the item has adequate seismic ruggedness for the ESEP and that no further action would be required, as shown in Figures 1-2 and 1-3. Conversely, if the ESEL item HCLPF does not exceed the RLGM, modifications should be performed as described below.

Any ESEL item whose HCLPF capacity is less than the RLGM should be modified such that the HCLPF meets or exceeds the RLGM. This criterion applies for ESEL items identified in Section 2.2.1.1, as well as items identified in Section 5. These modifications are intended to provide a near-term improvement of plant safety. They do not impose a long-term commitment to maintain the improved plant conditions beyond the point where the long term plant risk evaluations are completed in accordance with NRC 50.54(f) letter [1] and EPRI 1025287 [2].

Modifications should be completed within 2 years of submitting the plant specific ESEP summary report to the NRC (Section 7). If a plant outage is required to implement the ESEL item modification, the modifications should be completed within 2 outages of submitting the ESEP summary report to the NRC.

Consideration of the ESEL modifications may be revised based on insights from a completed SPRA. The results of a completed SPRA may show that alternate modifications would produce more effective safety enhancements. In that case, the more beneficial modifications identified by the SPRA could be implemented rather than the ESEL modifications. Those alternate modifications would have the same implementation schedule described above. The results of these alternate plant modifications would be expected to provide more beneficial, long-term safety plant improvements.

# Section 7: ESEP Report

A report should be prepared summarizing the ESEP evaluations and results. The report should be submitted to the NRC for review following completion of the evaluations (see Table 1-1). The level of detail provided in the report should be sufficient to enable NRC to understand the inputs used, the evaluations performed, and the decisions made as a result of the interim evaluations. It is not necessary to submit HCLPF calculations. Relevant documentation should be cited in the submittal, and be available for NRC review on-site in easily retrievable form.

The report should include the following information.

- A list of the selected equipment (ESEL)
- A plot of the GMRS submitted by the licensee in accordance with the 50.54(f) letter and EPRI 1025287 [2] and comparison to the SSE
- A description of the RLGM selected and the process to estimate ISRS
- A summary of the methodologies used to perform the HCLPF calculations and the results including:
  - the HCLPF screening process used (e.g. NP 6041)
  - the HCLPF calculation process (s) used
  - tabulated ESEL HCLPF values
- Description of the ESEP results including:
  - identification of required modifications
  - modification implementation schedule

# Section 8: References


1. NRC (E Leeds and M Johnson) Letter to All Power Reactor Licensees et al., "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3 and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," March 12, 2012.
2. EPRI 1025287, Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic EPRI, Palo Alto, CA: 2012.
3. NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide", August 2012
4. Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," March 12, 2012 (ML12054A736)
5. Japan Lessons-Learned Project Directorate, JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," Interim Staff Guidance Revision 0, August 29, 2012,(ML12229A174)
6. EPRI 1019200, "Seismic Fragility Applications Guide Update," December 2009.
7. EPRI 1002988, "Seismic Fragility Application Guide," December 2002
8. EPRI TR-103959, "Methodology for Developing Seismic Fragilities," July 1994.
9. EPRI NP-6041-SL, "A Methodology for Assessment of Nuclear Plant Seismic Margin, Revision 1", Electric Power Research Institute, August 1991.
10. American Society of Mechanical Engineers/American Nuclear Society (ASME/ANS) RA-Sa-2009.