# Compiled Seismic Questions for NRC Response to the March 11, 2011 Japanese Earthquake and Tsunami

**This is current as of 3-19-11 at 8am.**

***The keeper of this file is Annie Kammerer. Please provide comments, additions and updates to Annie with CC to Clifford Munson and Jon Ake.***

***A SharePoint site has been set up so that anyone can download the latest Q&As. The site is found at NRC>NRR>NRR TA or at http://portal.nrc.gov/edo/nrr/NRR%20TA/FAQ%20Related%20to%20Events%20Occuring%20in%20Japan/Forms/AllItems.aspx***

***A list of topics is shown in the Table of Contents at the front of this document.***

***A list of all questions is provided at the end of the document.***

***A list of terms and definitions is included at the end of the document.***

*We greatly appreciate the assistance of the many people who have contributed to this document. Please do not distribute beyond the NRC.*



T1/24

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# Natural Hazards and Ground Shaking Design Levels

### 1) Does the NRC consider earthquakes of magnitude 9?

**Public response:** This earthquake was caused by a "subduction zone" event, which is the type of earthquake that can produce the largest magnitudes. A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington. As a result, magnitude 9 events would only be considered for this particular seismic source. The NRC requires all credible earthquakes that may impact a site to be considered.

**Additional, technical, non-public information:** I changed the above somewhat from a "standard" answer we already had...it would be great if Cliff would review.

### 2) Did the Japanese underestimate the size of the maximum credible earthquake that could affect the plants?

**Public response:** The magnitude of the earthquake was somewhat greater than was expected for that part of the subduction zone. (A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate.) However, the Japanese nuclear plants were recently reassessed using ground shaking levels similar to those that are believed to have occurred at the sites. The review level ground motions were expected to result from earthquakes that were smaller, but were much closer to the sites. The NRC does not currently have information on the height of the tsunami that was expected for the site.

**Additional, technical, non-public information:** A PDF file provided by John Anderson (prepared by Japanese colleagues) indicates that the majority of the recorded ground motions during the main shock were below the attenuation curve by Si & Midorikawa (1999). Most of the recorded motions fit well to median minus 1 sigma of their GMPE. There are also about a dozen stations with the recorded ground motions above 1g. The highest recorded PGA (~3g) is at the K-Net station MYG004. We can use this information to try to estimate motions at the plants as soon as someone catches a breath.

### 3) Can this kind of very large earthquake and tsunami happen here?

**Public response:** See below.

### 4) What if an earthquake like the Sendai earthquake occurred near a US plant?

**Public response:** This earthquake was caused by a "subduction zone" event, which is the type of earthquake that can produce the largest magnitudes. A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington. In addition, only subduction zone earthquakes cause the kind of massive tsunami seen in Japan. So, an earthquake and tsunami this large could only happen in that region. The only plant in that area is Columbia, which is far from the coast and the subduction zone. Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximate 8. Magnitude is measured on a log scale and so a magnitude 9 earthquake is ten times larger than a magnitude 8 earthquake.

**Additional, technical, non-public information:** None.

## 5) What magnitude earthquake are US plants designed to?

**Public Answer:** Each plant is designed to a ground-shaking level that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of an earthquake and the distance from the fault to the site. So actually nuclear plants, and in fact all engineer structures, are actually designed based on ground shaking levels, not magnitudes. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquakes expected in the area around the plant. Several tables that include plant design ground motions are provided as the first table in the "additional information" section of this document.

**Additional, technical non-public information:** In the past, "deterministic" or "scenario based" analyses were used to determine ground shaking (seismic hazard) levels. Now a probabilistic method is used that accounts for possible earthquakes of various magnitudes that come from potential sources (including background seismicity) and the likelihood that each particular hypothetical earthquake occurs. The ground motions that are used as seismic design bases at US nuclear power plants are called the Safe Shutdown Earthquake ground motion (SSE) and are described mathematically through use of a response spectrum. On the west coast of the US, the two nuclear power plants are designed to specific ground motions that are determined from earthquakes of about magnitude 7 (SONGS) and 7.5 (Diablo) on faults located just offshore of the plants. Because the faults are well characterized, the magnitude and distances are known. However the design and licensing bases are still the ground motions...not the earthquakes. The earthquakes on these faults are mainly strike-slip (horizontal motion) type earthquakes, not subduction zone earthquakes. Therefore, the likelihood of a tsunami from these faults is remote.

## 6) How many US reactors are located in active earthquake zones (and which reactors)?

**Public Answer:** Although we often think of the US as having "active" and "non-active" earthquake zones, earthquakes can actually happen almost anywhere. Seismologists typically separate the US into low, moderate, and high seismicity zones. The NRC requires that every plant be designed for site-specific ground motions that are appropriate for their locations. In addition, the NRC has specified a minimum ground shaking level to which plants must be designed.

**Additional, technical non-public information:** Generally, seismic activity in the regions surrounding most US plants is much lower than that for Japan since most US plants are located in the interior of the stable continental US. However, the most widely felt earthquakes within the continental US were the 1811-12 New Madrid sequence and the 1886 Charleston, SC, which were estimated to be between about magnitude 7.0 to 7.75. There are also two plants that are in highly seismically active areas of California.

## 7) Has this changed our perception of earthquake risk to the plants in the US?

**Public Answer:** This does not change the NRC's perception of earthquake hazard (i.e. ground shaking) at US plants. It is too early to tell what the lessons from this earthquake are from an engineering perspective. The NRC will look closely at all aspects of response of the plants to the earthquake and tsunami to determine if any actions need to be taken in US plants and if any changes are necessary to NRC regulations.

**Additional, technical, non-public information:** We expect that there would be lessons learned and we may need to seriously relook at common cause failures, including dam failure and tsunami.

### 8) Can this happen here (i.e., an earthquake that significantly damages a nuclear power plant)? Are the Japanese plants similar to US plants?

**Public Answer:** All US nuclear power plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events. In addition to the design of the plants, significant effort goes into emergency response planning and accident mitigation. This approach is called defense-in-depth.

The Japanese facilities are similar in design to several US facilities.

**Additional technical, non-public information:** Currently operating reactors were designed using a "deterministic" or "maximum credible earthquake" approach. Seismic hazard for the new plants is determined using a probabilistic seismic hazard assessment approach that explicitly addresses uncertainty and the potential for beyond-design-basis earthquakes, as described in Regulatory Guide 1.208. The NRC requires that adequate margin beyond the design basis ground shaking levels is assured. The NRC further enhances seismic safety for beyond-design-basis events through the use of a defense-in-depth approach.

In addition, the NRC reviews the seismic risk at operating reactors as needed when information may have changed. Over the last few years the NRC has undertaken a program called Generic Issue 199, which is focused on assessing hazard for plants in the central and eastern US using the latest techniques and data and determining the possible risk implications of any increase in the anticipated ground shaking levels. This program will help us assure that the plants are safe under exceptionally rare and extreme ground motions that represent beyond-design-basis events.

### 9) If the earthquake in Japan was a larger magnitude than considered by plant design, why can't the same thing happen in the US?

**Public response:** *Discuss in terms of, IPEEE, Seismic PRA to be provided by Nilesh*

**Additional, technical, non-public information:** ADD

### 10) What level of earthquake hazard are the US reactors designed for?

**Public Answer:** Each reactor is designed for a different ground motion that is determined on a site-specific basis. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant. New reactors are designed using probabilistic techniques that characterize the hazard (i.e. ground shaking levels) and uncertainty at the proposed site. Ground motions from all potential seismic sources in the region are estimated and used to develop an appropriate site specific ground motion. Technically speaking this is the ground motion with an annual frequency of $1\times10^{-4}$; but this can be thought of as the ground motion that occurs every 10,000 years on average.

**Additional technical, non-public information:** Note to OPA: This may perhaps seem like an oddly worded general question because the word "hazard" has several meanings, but in fact it is a specific technical question. If you see "earthquake hazard levels" or similar language, check with the seismic staff.

## 11) What is the likelihood of the design basis or "SSE" ground motions being exceeded over the life of the plant?

**Public response:** The ground motions that are used as seismic design bases at US nuclear power plants are called the Safe Shutdown Earthquake ground motion (SSE) and are described mathematically through use of a response spectrum. To estimate the probability of exceeding any specified ground motion level, such as an SSE, during a given time interval, the Poisson model is generally used. The NRC recently performed these types of estimates as part of its Generic Issue199 (GI-199) program. The mean probability value for ground motions exceeding the SSE for the plants in the Central and Eastern United States is less than 2%, with values ranging from a low of 0.1% to a high of 6%.

It is important to remember that structures, systems and components are required to have "adequate margin", meaning that they must be able withstand shaking levels that are above the plant's design basis. In the mid to late 1990s, the NRC staff reviewed the potential for ground motions beyond the design basis as part of the Individual Plant Examination of External Events (IPEEE). From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins for withstanding earthquakes built into the designs. Currently, the NRC is in the process of conducting the GI-199 to again assess the resistance of US nuclear plants to earthquake.

**Additional technical, non-public information:** There is a section of this document focused on questions related to GI-199.

## 12) What is magnitude anyway? What is the Richter Scale? What is intensity?

An earthquake's magnitude is a measure of the strength of the earthquake as determined from seismographic observations. Magnitude is essentially an objective, quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, Surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the commonly used magnitude measurement is the Moment Magnitude, Mw, which is based on the strength of the rock that ruptured, the area of the fault that ruptured, and the average amount of slip. Moment magnitude is, therefore, a direct measure of the energy released during an earthquake. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology and was based on the behavior of a specific seismograph that was manufactured at that time. The instruments are no longer in use and the magnitude scale, therefore, is therefore no longer used in the technical community. However, the Richter Scale is a term that is so commonly used by the public that scientists generally just answer questions about "Richter" magnitude by substituting moment magnitude without correcting the misunderstanding.

The intensity of an earthquake is a qualitative assessment of effects of the earthquake at a particular location. The intensity assigned is based on observed effects on humans, on human-built structures, and on the earth's surface at a particular location. The most commonly used scale in the US is the Modified Mercalli Intensity (MMI) scale, which has values ranging from I to XII in the order of severity. MMI of I indicates an earthquake that was not felt except by a very few, whereas MMI of XII indicates total damage of all works of construction, either partially or completely. While an earthquake has only one magnitude, intensity depends on the effects at each particular location.

### 13) How do magnitude and ground motion relate to each other?

ADD from public documents

### 14) How many reactors are along coastal areas that could be affected by a tsunami (and which ones)?

**Public Answer:** Many plants are located in coastal areas that could potentially be affected by tsunami. Two plants, Diablo Canyon and San Onofre, are on the Pacific Coast, which is known to have tsunami hazard. There are also two plants on the Gulf Coast, South Texas and Crystal River. There are many plants on the Atlantic Coast or on rivers that may be affected by a tidal bore resulting from a tsunami. These include St. Lucie, Turkey Point, Brunswick, Oyster Creek, Millstone, Pilgrim, Seabrook, Calvert Cliffs, Salem/Hope Creek, and Surry. Tsunami on the Gulf and Atlantic Coasts occur, but are very rare. Generally the flooding anticipated from hurricane storm surge exceeds the flooding expected from a tsunami for plants on the Atlantic and Gulf Coast. Regardless, all nuclear plants consider tsunami in their designs.

**Additional, technical non-public information:** A table with information on tsunami design levels is provided in the "Additional Information" section of this document.

### 15) What would be the results of a tsunami generated off the coast of a US plant? (Or why are we confident that large tsunamis will not occur relatively close to US shores?)

**Public response:** *Request for answer by Henry Jones, Goutam Bagchi and/or Richard Raione (once the tsunami fact sheet is done and you have time).*

**Additional, technical, non-public information:** ADD

### 16) How are combined seismic and tsunami events treated in risk space? Are they considered together?

The PRA Standard (ASME/ANS-Ra-Sa2009) does address the technical requirements for both seismic events and tsunamis (tsunami hazard under the technical requirements for external flooding analysis). But together? The standard does note that uncertainties associated with probabilistic analysis of tsunami hazard frequency are large and that an engineering analysis can usually be used to screen out tsunamis.

### 17) How are aftershocks treated in terms of risk assessment?

Seismic PRAs do not consider the affect of aftershocks since there are not methods to predict equipment fragility after the first main shock.

## Design Against Natural Hazards & Plant Safety in the US

### 19) Are nuclear power plants designed for tsunamis?

**Public Answer:** Yes. Plants are built to withstand a variety of environmental hazards and those plants that might face a threat from tsunami are required to withstand large waves and the maximum wave height at the intake structure (which varies by plant.)

**Additional, technical, non-public information:** Tsunami are considered in the design of US nuclear plants. Nuclear plants are designed to withstand flooding from not only tsunami, but also hurricane and storm surge; therefore there is often significant margin against tsunami flooding. However, it should be noted that Japanese experience has shown that drawdown can be a significant problem.

Currently the US NRC has a tsunami research program that is focused on developing modern hazard assessment techniques and additional guidance through cooperation with the National Oceanic and Atmospheric Administration and the United States Geological Survey. This has already lead to several technical reports and an update to NUREG 0-800. The NOAA and USGS contractors are also assisting with NRO reviews of tsunami hazard. A new regulatory guide on tsunami hazard assessment is currently planned in the office of research, although it is not expected to be available in draft form until 2012.

### 20) What level of tsunami are use nuclear plants designed for?

**Public Answer:** Like seismic hazard, the level of tsunami that each plant is designed for is site-specific and is appropriate for what may occur at each location.

**Additional, technical, non-public information:** None.

### 21) Which plants are close to known active faults? What are the faults and how far away are they from the plants?

**Public Answer:** Jon to develop answer with Dogan's help. I created a placeholder table for your use "Table of Plants Near Known Active Faults" to be populated in the additional information section. The plots that Dogan made are in the additional information section under "Plot of Mapped Active Quaternary Faults and Nuclear Plants in the US". This is really high priority after the congressional hearings.

**Additional, technical, non-public information:** ADD

### 22) How was the seismic design basis for an existing nuclear power plant established?

**Public Answer:** The seismic ground motion used for the design basis was determined from the evaluation of the maximum historic earthquake within 200 miles of the site, without explicitly considering the time spans between such earthquakes; safety margin was then added beyond this maximum historic earthquake to form a hypothetical *design basis earthquake*. The relevant regulation for currently operating plants is 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-appa.html).

**Additional, technical, non-public information:** See discussion at end of GI-199 section for discussion of safety margin and design basis.

### 23) Is there margin above the design basis?

**Public Answer:** Yes, there is margin beyond the design basis. In the mid to late 1990s, NRC staff reviewed the plants' assessments of potential consequences of severe earthquakes (earthquakes beyond the safety margin included in each plant's design basis), which licensees performed as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs.

**Additional, technical, non-public information:** None.

### 24) Are US plants safe?

**Public Answer:** US plants are designed for appropriate earthquake shaking levels and are safe. Currently the NRC is also conducting a program called Generic Issue 199 (GI-199), which is reviewing the adequacy of earthquake design of US nuclear power plants in the central and eastern North America based on the latest data and analysis techniques.

**Additional, technical, non-public information:** None.

### 25) Was the Japanese plant designed for this type of accident? Are US nuclear plants?

**Public Answer:** Nuclear plants in both the US and Japan are designed for earthquake shaking. In addition to the design of the plants, significant effort goes into emergency response planning and accident mitigation. This approach is called defense-in-depth.

**Additional, technical, non-public information:** None.

### 26) Why do we have confidence that US nuclear power plants are adequately designed for earthquakes and tsunamis?

**Public Answer:** Nuclear plants in both the US and Japan are designed for earthquake shaking. In addition to the design of the plants, significant effort goes into emergency response planning and accident mitigation. This approach is called defense-in-depth.

**Additional, technical, non-public information:** None.

### 27) Can this happen here (i.e., an earthquake that significantly damages a nuclear power plant)? Are the Japanese plants similar to US plants?

**Public Answer:** All US nuclear power plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events Nuclear power plants are designed to be safe based on the most severe natural phenomena historically reported for the site and surrounding area. The Japanese facilities are similar in design to several US facilities.

**Additional technical, non-public information:** Currently operating reactors were designed using a "deterministic" or "maximum credible earthquake" approach. Seismic hazard for the new plants is determined using a probabilistic seismic hazard assessment approach that explicitly addresses uncertainty, as described in Regulatory Guide 1.208. The NRC requires that adequate margin beyond the design basis ground shaking levels is assured. The NRC further enhances seismic safety for beyond-design-basis events through the use of a defense-in-depth approach.

In addition, the NRC reviews the seismic risk at operating reactors as needed when information may have changed. Over the last few years the NRC has undertaken a program called Generic Issue 199, which is focused on assessing hazard for plants in the central and eastern US using the latest techniques and data and is determining the possible risk implications of any increase in the anticipated ground shaking levels. This program will help us assure that the plants are safe under exceptionally rare and extreme ground motions that represent beyond-design-basis events..

The reactor design is a Boiling Water Reactor that is similar to some US designs, including Oyster Creek, Nine Mile Point and Dresden Units 2 and 3.

### 28) Could an accident sequence like the one at Japan's Fukushima Daiichi nuclear plants happen in the US?

**Public response:** It is difficult to answer this question until we have a better understanding of the precise problems and conditions that faced the operators at Fukushima Daiichi. We do know, however, that Fukushima Daiichi Units 1-3 lost all offsite power and emergency diesel generators. This situation is called "station blackout." US nuclear power plants are designed to cope with a station blackout event that involves a loss of offsite power and onsite emergency power. The Nuclear Regulatory Commission's detailed regulations address this scenario. US nuclear plants are required to conduct a "coping" assessment and develop a strategy to demonstrate to the NRC that they could maintain the plant in a safe condition during a station blackout scenario. These assessments, proposed modifications and operating procedures were reviewed and approved by the NRC. Several plants added additional AC power sources to comply with this regulation.

In addition, US nuclear plant designs and operating practices since the terrorist events of September 11, 2001, are designed to mitigate severe accident scenarios such as aircraft impact, which include the complete loss of offsite power and all on-site emergency power sources.

US nuclear plant designs include consideration of seismic events and tsunamis'. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations.

**Additional technical, non-public information:** None

### 29) Should US nuclear facilities be required to withstand earthquakes and tsunamis of the kind just experienced in Japan? If not, why not?

**Public response:** US nuclear reactors are designed to withstand an earthquake equal to the most significant historical event or the maximum projected seismic event and associated tsunami without any breach of safety systems.

The lessons learned from this experience must be reviewed carefully to see whether they apply to US nuclear power plants. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards, however. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations.

The United States Geological Survey (USGS) conducts continuous research of earthquake history and geology, and publishes updated seismic hazard curves for various regions in the continental US. These curves are updated approximately every six years. NRC identified a generic issue (GI-199) that is currently undergoing an evaluation to assess implications of this new information to nuclear plant sites located in the central and eastern United States. The industry is working with the NRC to address this issue.

**Additional technical, non-public information:** None

**30) Can you summarize the plant seismic design basis for the US plants? Are there any special issues associated with seismic design?**

**Public response:** Please see one of the several tables provided in the "Additional information" section of this document.

**Additional, technical, non-public information:** None

**31) How do we know that the equipment in plants is safe in earthquakes?**

**Public response:** All equipment important to safety (required to safely shutdown a nuclear power plant) is qualified to withstand earthquakes in accordance with plants' licensing basis and NRC regulations.

**Additional, technical, non-public information:** 10 CFR 50, Appendix A, General Design Criterion 2 and 4, 10 Part 100, and Appendix S. Guidance: Regulatory Guides 1.100, IEEE 344 and ASME QME-1

**32) How do we know equipment will work if the magnitude is bigger than expected, like in Japan?**

**Public response:** Nuclear plant systems are designed to mitigate a design basis earthquake which includes margin above the postulated site specific earthquake. (reviewers comment: this needs to be expanded)

**Additional, technical, non-public information:** See part 100 Reactor Site Criteria

**33) Are US plants susceptible to the same kind of loss of power as happened in Japan?**

**Public response:** NRC recognized that there is the possibility of a total loss of AC power at a site, called a 'Station Blackout', or SBO. Existing Regulations require the sites to be prepared for the possibility of an SBO. In addition to battery powered back-up system to immediately provide power for emergency systems, NRC regulations require the sites to have a detailed plan of action to address the loss of AC power while maintaining control of the reactor.

There has also been an understanding that sites can lose offsite power as well. Of course, this can be caused by earthquake. However, hurricane- or tornado-related high winds may potentially damage the transmission network in the vicinity of a nuclear plant as well. Flood waters can also affect transformers used to power station auxiliary system. These types of weather related events have the potential to degrade the offsite power source to a plant.

The onsite Emergency Diesel Generators need fuel oil stored in tanks that are normally buried underground. These tanks and associated pumps and piping require protection from the elements. Above ground tanks have tornado and missile protection.

In case both offsite and onsite power supplies fail, NRC has required all licensee to evaluate for a loss of all AC power (station blackout) scenario and implement coping measures to safely shutdown the plant law 10 CFR 50.63.

**Additional, technical, non-public information:** Some plants have safeguards equipment below sea level and rely on watertight doors or Bilge pumps to remove water from equipment required to support safe shutdown. Overflowing rivers can result in insurmountable volume of water flooding the vulnerable areas. SBO definition in 10CFR50.2, SBO plan requirements in 10CFR50.63

**34) How do we know that the emergency diesel generators in Diablo Canyon and SONGS will not fail to operate like in Japan?**

**Public response:** Emergency Diesel Generators are installed in a seismically qualified structure. Even if these EDGs fail, plants can safely shutdown using station blackout power source law 10 CFR 50.63.

**Additional, technical, non-public information:** None.

**35) Is all equipment at the plant vulnerable to tsunami?**

**Public response:** Nuclear plants are designed to withstand protection against natural phenomena such as tsunami, earthquakes. (reviewers comment: this needs to be expanded. I need assistance with this)

**Additional, technical, non-public information:** ADD

**36) What protection measures do plants have against tsunami?**

**Public response:** Plants are designed to withstand protection against natural phenomena such as tsunami, earthquakes. (note from reviewer: add information on breakwater from songs and Diablo example. I need assistance with this)

**Additional, technical, non-public information:** ADD

**37) Is there a risk of loss of water during tsunami drawdown? Is it considered in design?**

**Public response:** *Goutam, Henry and Rich, can you guys answer this?*

**Additional, technical, non-public information:** ADD

**38) Are nuclear buildings built to withstand earthquakes? What about tsunami?**

**Public response:** *There is language elsewhere in this document that answers that...copy here.*

**Additional, technical, non-public information:** ADD

**39) Are aftershocks considered in the design of equipment at the plants? Are aftershocks considered in design of the structure?**

**Public response:** ADD

**Additional, technical, non-public information:** ADD

**40) Are there any special issues associated with seismic design at the plants? For example, Diablo Canyon has special requirements. Are there any others?**

**Public response:** Both SONGS and Diablo canyon are licensed with an automatic trip for seismic events. *(can this be expanded? any others?) Mike Markley, can your group assist with this?*

**Additional, technical, non-public information:** ADD

**41) Is the NRC planning to require seismic isolators for the next generation of nuclear power plants? How does that differ from current requirements and/or precautions at existing US nuclear power plants?**

**Public response:** The NRC would not require isolators for the next generation of plants. However, it is recognized that a properly designed isolation system can be very effective in mitigating the effect of earthquake. Currently the NRC is preparing guidance for plant designers considering the use of seismic isolation devices.

**Additional, technical, non-public information:** A NUREG is in the works in the office of research. It is expected to be available for comment in 2011.

### 42) Are there any US nuclear power plants that incorporate seismic isolators? What precautions are taken in earthquake-prone areas?

**Public response:** No currently constructed nuclear power plants in the US use seismic isolators. However seismic isolation is being considered for a number of reactor designs under development. Currently seismic design of plants is focused on assuring that design of structures, systems, and components are designed and qualified to assure that there is sufficient margin beyond the design basis ground motion.

**Additional, technical, non-public information:** None.

### 43) Do you think that the recent Japan disaster will cause any rethinking of the planned seismic isolation guidelines, particularly as it regards earthquakes and secondary effects such as tsunamis?

**Public response:** Whenever an event like this happens, the NRC thoroughly reviews the experience and tries to identify any lessons learned. The NRC further considers the need to change guidance or regulations. In this case, the event will be studied and any necessary changes will be made to the guidance under development. However, it should be noted that Japan does not have seismically isolated nuclear plants.

**Additional, technical, non-public information:** None.

## Seismically Induced Fire

### 44) How does the NRC address seismic-induced fire?

The NRC's rules for fire protection are independent of the event that caused the fire. The power plant operators are required to evaluate all the fire hazards in the plant and make sure a fire will not prevent a safe plant shutdown. The NRC's guidance says that power plant operators should assume that a fire can happen at any time. The rules do not require specific consideration of a fire that starts as a result of an earthquake. In addition, we do not require analysis of more than one fire at a time at one reactor.

### 45) Does the NRC require the fire protection water supply system be designed to withstand an earthquake?

Yes, NRC's guidance recommends all areas of the plant that contain equipment required to safely shutdown have at least 2 standpipes for firefighting and a source of water that will work after a severe earthquake. NRC requires that there are enough pumps, even assuming the largest pump fails during a severe earthquake or there is a loss of power, to supply the fire protection system. This can be accomplished, for example, by providing either electric-motor-driven fire pumps and separate diesel-driven fire pumps or two or more electric-motor-driven fire pumps that can survive a severe earthquake or a loss of power.

The NRC's guidance recommends that fire detection, alarm, and suppression systems function as designed after less severe earthquakes that are expected to occur once every 10 years. The guidance recommends plant operators in areas of high seismic activity consider the need to design those fire protection systems to function after a severe earthquake.

### 46) How are safe shutdown equipment protected from an oil spill which can cause potential fire?

The pumps that are used to pump water through the reactor use oil as a lubricant. The NRC requires that plants have a way to collect this oil. The NRC requires this oil collection system to be designed so that a severe earthquake does not cause the oil to start a fire.

### 47) How are safe shutdown equipment protected from a hydrogen fire?

The NRC recommends that pipes that contain hydrogen are designed to withstand a severe earthquake. This design includes a separate pipe wrapped around the hydrogen pipe that vents any leaked hydrogen to the outside.

## Seismically Induced Internal Flooding

### 48) How does the NRC consider seismically induced equipment failures leading to internal flooding?

10 CFR Part 50 Appendix A General Design Criterion (GDC) 2 requires, in part, that structures, systems, and components (SSCs) important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. 10 CFR Part 50 Appendix A, GDC 4 requires the SSCs important to safety being designed to accommodate the effects of the flooding associated with seismic events. NUREG-0800, Standard Review Plan, Section 3.4.1, "Internal Flood Protection for Onsite Equipment Failures," provide guidance for the NRC staff to consider seismically induced equipment failures (pipe breaks, tank failures) that could affect safety-related SSCs to perform their safety functions.

The specific areas of review include the following :

- Identify all safety-related SSCs that must be protected against flooding;
- The location of the safety-related SSCs relative to the **internal flood level** (from internal flood analysis) in various buildings, rooms, and enclosures that house safety-related SSCs;
- Possible flow paths from interconnected non-safety-related areas to rooms that house safety-related SSCs;
- The adequacy of the isolation, if applicable, from sources causing the flood (e.g., tank of water )
- Provisions for protection against possible in-leakage sources (from outside to inside of the structures)
- All SSCs that could be a potential source of internal flooding (e.g. pipe breaks and cracks, tank and vessel failures, backflow through drains), **which includes seismically induced equipment failures,** are included for the internal flood analysis – see Q&A (2);
- Design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.);
- Safety-related structures that are protected from below-grade groundwater seepage by means of a permanent dewatering system.

### 49) How is the potential source of internal flooding from the seismically induced equipment failures postulated in the internal flood analysis?

All of the non-safety-related systems in the room are assumed to fail. However, the analysis systematically considers the flooding condition/level caused by only one system at a time. By considering the pipe size, volume of the source tank, and the isolation valves, the limiting case, which is the one that releases the largest volume of water, is used to determine the internal flood level. All of the safety-related SSCs are designed to be located above the calculated flood level caused by the limiting case.

### 50) Are the non-safety-related equipment failures assumed to occur at the same time?

No. As stated earlier, for design basis flood analysis, it is assumed that a system (containing water source) fails one at a time. Then, the most limiting case, a system breach that causes highest level of flooding, is applied in the design of the location of the safety-related systems.

## About Japanese Hazard, Design and Earthquake Impact

### 51) Was the damage to the plants mostly from the earthquake or the tsunami?

**Public response:** Because this even happened in Japan, it is hard for NRC staff to make a full assessment necessary to tell exactly what happened. In the nuclear plants there seems to have been some damage from the shaking. However, the tsunami appears to have led to the biggest problems in terms of the loss of backup power (i.e., station blackout).

**Additional, technical, non-public information:** None

### 52) What was the disposition of the plant during the time after the earthquake struck and before the tsunami arrived? Was there indication of damage to the plant solely from the earthquake (if so, what systems) and did emergency procedures function during this time.

**Public response:** Given that the Fukushima plant is not in the US, the NRC does not yet have enough information to answer this question.

**Additional, technical, non-public information:** Typically there would be the opportunity to get this data, but given the situation it is not clear.

### 53) What magnitude earthquake was the plant designed to withstand? For example, what magnitude earthquake was the plant expected to sustain with damage but continued operation? And with an expected shutdown but no release of radioactive material?

**Public response:** There are two shaking levels relevant to the Fukushima plant, the original design level ground motion and a newer review level ground motion. As a result of a significant change in seismic regulations in 2006, NISA, the Japanese regulator initiated a program to reassess seismic hazard and seismic risk for all nuclear plants in Japan. This resulted in new assessments of higher ground shaking levels (i.e. seismic hazard) and a review of seismic safety for all Japanese plants. The program is still on-going, but has already resulted in retrofit in some plants. Therefore, it is useful to discuss both the design level and a review level ground motion for the plants. A relevant table is found a few questions down, and also in the "Additional Information: Useful Tables" section.

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Fukushima | Magnitude 7.1 Earthquake near the site | 600 gal (0.62g) | 370 gal (0.37g) |

**Additional, technical, non-public information:** Add

### 54) Did this reactor sustain damage in the July 16, 2007 earthquake, as the Kashiwazaki power plant did? What damage and how serious was it?

**Public response:** Neither Fukushima power plant was affected by the 2007 earthquake.

**Additional, technical, non-public information:** None.

## 55) Was the Fukushima power plant designed to withstand a tsunami of any size? What sort of modeling was done to design the plant to withstand either seismic events or tsunamis? What specific design criteria were applied in both cases?

**Public response:** Japanese plants are designed to withstand both earthquake and tsunami. An English explanation of how Tsunami hazard assessments are undertaken for Japanese plants is found in Annex II to IAEA Guidance on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations Assessment of Tsunami Hazard: Current Practice in Some States in Japan. The design ground motions are as shown above. We do not have information on the design basis tsunami.

**Additional, technical, non-public information:** Annie has a copy of the draft annex and will put them into ADAMS

## 56) What is the design level of the Japanese plants? Was it exceeded?

**Public response:** As a result of a significant change in seismic regulations in 2006, the Japanese regulator initiated a program to reassess seismic hazard and seismic risk for all nuclear plants in Japan. This resulted in new assessments of higher ground shaking levels (i.e. seismic hazard) and a review of seismic safety for all Japanese plants. The program is still on-going, but has already resulted in retrofit in some plants. Therefore, it is useful to discuss both the design level and a review level ground motion for the plants, as shown below.

Currently we do not have official information. However, it appears that the ground motions (in terms of peak ground acceleration) are similar to the $S_s$ shaking levels, although the causative earthquakes are different. Thus the design basis was exceeded, but the review level may not have been.

**Table: Original Design Basis Ground Motions ($S_2$) and New Review Level Ground Motions ($S_s$) Used for Review of Japanese Plants**

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 gal (0.59g) | 375 gal (0.38g) |
| Fukushima | Earthquake near the site (M7.1) | 600 gal (0.62g) | 370 gal (0.37g) |
| Tokai | Earthquakes specifically undefined | 600 gal (0.62g) | 380 gal (0.39g) |
| Hamaoka | Assumed Tokai (M8.0), etc. | 800 gal (0.82g) | 600 gal (0.62g) |

**Additional, technical, non-public information:** None

## 57) What are the Japanese $S_1$ and $S_s$ ground motions and how are they determined?

**Public response:** Japanese nuclear power plants are designed to withstand specified earthquake ground motions, previously specified as $S_1$ and $S_2$, but now simply $S_S$. The design basis earthquake ground motion $S_1$ was defined as the largest earthquake that can reasonably be expected to occur at the site of a nuclear power plant, based on the known seismicity of the area and local faults that have shown activity during the past 10,000 years. A power reactor could continue to operate safely during an $S_1$ level earthquake, though in practice they are set to trip at lower levels. The $S_2$ level ground motion was based on a larger earthquake from faults that have shown activity during the past 50,000 years and assumed to be closer to the site. The revised seismic regulations in May 2007 replaced $S_1$ and $S_2$ with $S_S$. The $S_S$ design basis earthquake is based on evaluating potential earthquakes from faults that have shown activity during the past 130,000 years. The ground motion from these potential earthquakes are simulated for each of the sites and used to determine the revised $S_S$ design basis ground motion level. Along with the change in definition, came a requirement to consider "residual risk", which is a consideration of the beyond-design-basis event.

**Additional, technical, non-public information:** None

### 58) Did this earthquake affect the Kashiwazaki-Kariwa nuclear power plant?

**Public response:** No, this earthquake did not affect Kashiwazaki-Kariwa nuclear power plant and all reactors remained in the state of operation prior to the March 11, 2011, Japan earthquake. It also did not trip during an earthquake of magnitude XX that occurred on the western side subsequent to the 8.9 earthquake. This is very important for the stability of Japan's energy supply due to the loss of production at TEPCO's Fukushima nuclear power plants.

**Additional, technical, non-public information:** None

### 59) How high was the tsunami at the Fukushima nuclear power plants?

**Public response:** The actual tsunami height at the plants is not currently known. However, NOAA has publically information on the recordings at sea for many areas.

**Additional, technical, non-public information:** A preliminary rough estimate of tsunami height at the plant locations was provided to NRC by NOAA shortly after the earthquake. This was developed using NOAA's global ocean model and is shown in the "additional information" section. Most notably, there was a 6 meter wave at Fukushima and the wave at Onogawa may have been between 18 and 23 meters.

### 60) Wikileaks has a story that quotes US embassy correspondence and some un-named IAEA expert stating that the Japanese were warned about this ... Does the NRC want to comment?

http://www.dailymail.co.uk/news/article-1366721/Japan-tsunami-Government-warned-nuclear-plants-withstand-earthquake.html

**Public response:** TBD Annie to explain the history of their recent retrofit program.

**Additional, technical, non-public information:** The article talks about that the plants and that they were checked for a magnitude 7, but the earthquake was a 9. The reality is that they assumed the magnitude 7 close in had similar ground motions to a 9 farther away. They did check (and retrofit) the plant to the ground motions that they probably saw (or nearly). The problem was the tsunami. We probably need a small write up so that staff understands, even if we keep it internal.

# Impact at US Nuclear Power Plants During the March 11, 2011 Earthquake and Tsunami?

### 61) Was there any damage to US reactors from either the earthquake or the resulting tsunami?

**Public Answer:** No

**Additional, technical non-public information**: Two US plants on the Pacific Ocean (Diablo Canyon and San Onofre) experienced higher than normal sea level due to tsunami. However, the wave heights were consistent with previously predicted levels and this had no negative impact to the plants. In response, Diablo Canyon Units 1 and 2 declared an "unusual event" based on tsunami warning following the Japanese earthquake. They have since exited the "unusual event" declaration, based on a downgrade to a tsunami advisory.

### 62) Have any lessons for US plants been identified?

**Public Answer:** The NRC is in the process of following and reviewing the event in real time. This will undoubtedly lead to the identification of issues that warrant further study. However, a complete understanding of lessons learned will require more information than is currently available to NRC staff.

**Additional, technical non-public information:** We need to take a closer look at common cause failures, such as earthquake and tsunami, and earthquake and dam failure.

## Response and Future Licensing Actions

### 63) What is the NRC doing about the emergencies at the nuclear power plants in Japan? Are you sending staff over there?

**Public Answer:** We are closely following events in Japan, working with other agencies of the federal government, and have been in direct contact with our counterparts in that country. In addition, we are ready to provide assistance if there is a specific request. An NRC staffer is participating in the USAID team headed to Japan.

**Additional technical, non-public information:** We are taking the knowledge that the staff has about the design of the US nuclear plants and we are applying this knowledge to the Japan situation. For example, this includes calculations of severe accident mitigation that have been performed.

### 64) With NRC moving to design certification, at what point is seismic capability tested – during design or modified to be site-specific? If in design, what strength seismic event must these be built to withstand?

**Public Answer:** During design certification, vendors propose a seismic design in terms of a ground motion spectrum for their nuclear facility. This spectrum is called a standard design response spectrum and is developed so that the proposed nuclear facility can be sited at most locations in the central and eastern United States. The vendors show that this design ground motion is suitable for a variety of different subsurface conditions such as hard rock, deep soil, or shallow soil over rock. Combined License and Early Site Permits applicants are required to develop a site specific ground motion response spectrum that takes into account all of the earthquakes in the region surrounding their site as well as the local site geologic conditions. Applicants estimate the ground motion from these postulated earthquakes to develop seismic hazard curves. These seismic hazard curves are then used to determine a site specific ground motion response spectrum that has a maximum annual likelihood of $1x10^{-4}$ of being exceeded. This can be thought of as a ground motion with a 10,000 year return period. This site specific ground motion response spectrum is then compared to the standard design response spectrum for the proposed design. If the standard design ground motion spectrum envelopes the site specific ground motion spectrum then the site is considered to be suitable for the proposed design. If the standard design spectrum does not completely envelope the site specific ground motion spectrum, then the COL applicant must do further detailed structural analysis to show that the design capacity is adequate. Margin beyond the standard design and site specific ground motions must also be demonstrated before fuel loading can begin.

**Additional technical, non-public information:** None.

## Reassessment of US Plants and Generic Issue 199 (GI-199)

### 65) Can we get the rankings of the plants in terms of safety? (Actually this answer should be considered any time GI-199 data is used to "rank" plants)

**Public Response:** The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted consistent with NRC directives. The results of the GI-199 SRA should not be interpreted as definitive estimates of plant-specific seismic risk. The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool. The NRC does not rank plants by seismic risk.

Currently operating nuclear plants in the United States remain safe, with no need for immediate action. This determination is based on NRC staff reviews of updated seismic hazard information and the conclusions of the Generic Issue 199 Screening Panel. Existing plants were designed with considerable margin to be able to withstand the ground motions from the "deterministic" or "scenario earthquake" that accounted for the largest earthquake expected in the area around the plant. During the mid-to late-1990s, the NRC staff reassessed the margin beyond the design basis as part of the Individual Plant Examination of External Events (IPEEE) program. The results of the GI-199 assessment demonstrate that the probability of exceeding the design basis ground motion may have increased at some sites, but only by a relatively small amount. In addition, the Safety/Risk Assessment stage results indicate that the probabilities of seismic core damage are lower than the guidelines for taking immediate action.

**Additional, technical, non-public information:** None.

### 66) If the plants are designed to withstand the ground shaking why is there so much risk from the design level earthquake

Much of the risk in the total risk levels provided in the report comes from earthquakes stronger than the safe shutdown ground motion. The anything indicated in the geologic record used to determine the design requirements at these sites. The numbers are based on an evaluation of all of the potential seismic sources in the CEUS and are used to produce seismic hazard estimates (curves) for each site. The GI-199 effort to date has performed a screening assessment to determine if further, more detailed studies are warranted. This study has utilized information from plant-specific evaluation of external hazards, including earthquakes. That information was gathered to identify potential seismic vulnerabilities, not to produce robust risk estimates. Therefore, the GI-199 results should be viewed as preliminary and not definitive.

### 67) Does the NRC have a position on the MSNBC article that ranked the safety of US plants?

**Public Response:** The NRC is preparing to issue a press release responding to MSNBC article. The content below.

THE BELOW IS STILL DRAFT

A recent article by MSNBC (add reference) cites results of a US Nuclear Regulatory Commission study released in September, 2010. The study investigated the implications of updated seismic hazard estimates in the central and eastern United States. The study was prepared as a screening assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The report clearly states that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." Accordingly, the results were not used to rank or compare plants. The study produced plant-specific results of the estimated change in risk from seismic hazards. The study did not rely on the absolute value of the seismic risk except to assure that all operating plants are safe. The plant-specific results were used in aggregate to determine the need for continued evaluation and were included in the report for openness and transparency. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

The report reached three main conclusions: 1) Seismic hazard estimates have increased at some operating plants in the central and eastern US; 2) there is no immediate safety concern, plants have significant safety margin and overall seismic risk estimates remain small; and 3) assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** ADD.

### 68) Overall, how would the NRC characterize the CDF numbers? A quirk of numbers? A serious concern?

**Public Response:** The study is still underway and it is too early to predict the final outcome. However, staff has determined that there is no immediate safety concern and that overall seismic risk estimates remain small. If at any time the NRC determines that an immediate safety concern exists, action to address the issue will be taken. However, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** None.

### 69) Describe the study and what it factored in – plant design, soils, previous quakes, etc.

**Public Response:** The study considers the factors that impact estimates of both the seismic hazard (i.e. ground shaking levels) at the site and the plants resistance to earthquakes (mathematically represented by the plant level fragility curve). Previous quakes, the tectonic environment, and the soils that underlie the site are all used in the development of the ground shaking estimates used in the analyses. Plant design and the seismic resistance of the important structures, systems, and components are all used in the development of plant level fragility curves.

**Additional, technical, non-public information:** None.

### 70) Explain "seismic curve" and "plant level fragility curve".

**Public Response:** A seismic curve is a graphical representation of seismic hazard. Seismic hazard in this context is the highest level of ground motion expected to occur (on average) at a site over different periods of time. Plant level fragility is the probability of damage to plant structures, systems and components as a function of ground shaking levels.

**Additional, technical, non-public information:** None.

### 71) Eplain the "weakest link model".

**Public Response:** The weakest link model is a method for evaluating the importance of different frequencies of ground vibration to the overall plant performance. The model and its details are not integral to understanding the fundamental conclusions of the study.

**Additional, technical, non-public information:** None.

## 72) What would constitute fragility at a plant?

**Public Response:** Fragility is a term that relates the probability of failure of an individual structure, system or component to the level of seismic shaking it experiences. Plant level fragility is the probability of damage to sets of plant structures, systems and components as a function of ground shaking levels.

**Additional, technical, non-public information:** None.

## 73) The 1-in-18,868 risk for Limerick: What is the risk for? A jostling? A crack? Significant core damage leading to a meltdown?

**Public Response:** The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted consistent with NRC directives. The results of the GI-199 SRA should not be interpreted as definitive estimates of plant-specific seismic risk. The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

**Additional, technical, non-public information:** None.

## 74) Can someone put that risk factor into perspective, using something other than MSNBC's chances of winning the lottery?

**Public Response:** As noted above, the risk factors determined in GI-199 were conservative estimates of risk intended for use as a screening tool. Use of these factors beyond this intended purpose is inappropriate.

**Additional, technical, non-public information:** None.

## 75) What, if anything, can be done at a site experiencing such a risk? (Or at Limerick in particular.)

**Public Response:** The probabilistic seismic risk analyses (SPRA) that are performed to determine the core damage frequency (CDF) numbers also provides a significant amount of information on what the plant vulnerabilities are. This allows the analyst to determine what can be done to the plant to address the risk.

**Additional, technical, non-public information:** None.

## 76) Has anyone determined that anything SHOULD be done at Limerick or any of the other PA plants?

**Public Response:** The fundamental conclusion of the report is that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." The NRC is planning to issue a Generic Communication to operating reactor licensees in the CEUS requesting additional information. This includes the plants in PA.

**Additional, technical, non-public information:** None.

**77) I noted the language on Page 20 of the report: This result confirms NRR's conclusion that currently operating plants are adequately protected against the change in seismic hazard estimates because the guidelines in NRR Office Instruction LIC-504 "Integrated Risk-Informed Decision Making Process for Emergent Issues" are not exceeded. Can someone please explain?**

**Public response:** Can someone help with this?

**Additional, technical, non-public information:** None.

**78) Is the earthquake safety of US plants reviewed once the plants are constructed?**

**Public response:** Yes, earthquake safety is reviewed during focused design inspections, under the Generic Issues Program (GI-199) and as part of the Individual Plant Evaluation of External Events program (IPEEE) that was conducted in response to Generic Letter 88-20 Supplement 4.

**Additional, technical, non-public information:** None.

**79) Does the NRC ever review tsunami risk for existing plants?**

**Public Answer:** The NRC has not conducted a generic issue program on tsunami risk to date. However, some plants have been reviewed as a result of the application for a license for a new reactor. In the ASME/ANS 2009 seismic probabilistic risk assessment standard, all external hazards are included.

**Additional, technical, non-public information:** None.

**80) Does GI-199 consider tsunami?**

**Public response:** GI-199 stems from the increased in perceived seismic hazard focused on understanding the impact of increased ground motion on the risk at a plant. GI-199 does not consider tsunami

**Additional, technical, non-public information:** In the past there has been discussion about a GI program on tsunami, but the NRC's research and guidance was not yet at the point it would be effective. We are just getting to this stage and the topic should be revisited.

**81) What is Generic Issue 199 about?**

**Public Answer:** Generic Issue 199 (GI-199) investigates the safety and risk implications of updated earthquake-related data and models. These data and models suggest that the probability for earthquake ground shaking above the seismic design basis for some nuclear power plants in the Central and Eastern United States is still low, but larger than previous estimates.

**Additional, technical, non-public information:** See additional summary/discussion of GI-199 and terms below.

**82) Where can I get current information about Generic Issue 199?**

**Public Answer:** The public NRC Generic Issues Program (GIP) website (http://www.nrc.gov/about-nrc/regulatory/gen-issues.html) contains program information and documents, background and historical information, generic issue status information, and links to related programs. The latest Generic Issue Management Control System quarterly report, which has regularly updated GI-199 information, is publicly available at http://www.nrc.gov/reading-rm/doc-collections/generic-issues/quarterly/index.html. Additionally, the US Geological Survey provides data and results that are publicly available at http://earthquake.usgs.gov/hazards/products/conterminous/2008/.

**Additional, technical, non-public information:** The GI-199 section of the NRC internal GIP website (http://www.internal.nrc.gov/RES/projects/GIP/Individual%20GIs/GI-0199.html) contains additional information about Generic Issue 199 (GI-199) and is available to NRC staff.

### 83) How was the seismic design basis for an existing nuclear power plant established?

**Public Answer:** The seismic ground motion used for the design basis was determined from the evaluation of the maximum historic earthquake within 200 miles of the site, without explicitly considering the time spans between such earthquakes; safety margin was then added beyond this maximum historic earthquake to form a hypothetical *design basis earthquake*. The relevant regulation for currently operating plants is 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-appa.html).

**Additional, technical, non-public information: See** discussion at end of GI-199 section for discussion of safety margin and design basis.

### 84) Is there margin above the design basis?

**Public Answer**: Yes, there is margin beyond the design basis. In the mid to late 1990s, NRC staff reviewed the plants' assessments of potential ground motion beyond the safety margin included in each plant's design basis, which licensees performed as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs.

**Additional, technical, non-public information:** The goal of seismic engineering is to design structures, systems and components that explicitly do not fail at the design level. The application of specific codes, standards, and analysis techniques results in margin beyond the design level. The assessments carried out as part of the IPEEE program demonstrated that margin exists in the operating reactors against seismic demand.

### 85) Are all US plants being evaluated as a part of Generic Issue 199?

**Public Answer:** The scope of the Generic Issue 199 (GI-199) Safety/Risk Assessment is limited to all plants in the Central and Eastern United States. Although plants at the Columbia, Diablo Canyon, Palo Verde, and San Onofre sites are not included in the GI-199 Safety/Risk Assessment, the Information Notice on GI-199 is addressed to all operating power plants in the US (as well as all independent spent fuel storage installation licensees). The staff will also consider inclusion of operating reactors in the Western US in its future generic communication information requests.

**Additional, technical, non-public information:** The staff is currently developing specific information needs to be included in a Generic Letter to licensees in the CEUS.

### 86) Are the plants safe? If you are not sure they are safe, why are they not being shut down? If you are sure they are safe, why are you continuing evaluations related to this generic issue?

**Public Answer:** Yes, currently operating nuclear plants in the United States remain safe, with no need for immediate action. This determination is based on NRC staff reviews associated with Early Site Permits (ESP) and updated seismic hazard information, the conclusions of the Generic Issue 199 Screening Panel (comprised of technical experts), and the conclusions of the Safety/Risk Assessment Panel (also comprised of technical experts).

No immediate action is needed because: (1) existing plants were designed to withstand anticipated earthquakes with substantial design margins, as confirmed by the results of the Individual Plant Examination of External Events program; (2) the probability of exceeding the *safe shutdown earthquake* ground motion may have increased at some sites, but only by a relatively small amount; and (3) the Safety/Risk Assessment Stage results indicate that the probabilities of seismic core damage are lower than the guidelines for taking immediate action.

Even though the staff has determined that existing plants remain safe, the Generic Issues Program criteria (Management Directive 6.4) direct staff to continue their analysis to determine whether any cost-justified plant improvements can be identified to make plants enhance plant safety.

**Additional, technical, non-public information :** The Safety/Risk Assessment results confirm that plants are safe. The relevant risk criterion for GI-199 is total *core damage frequency* (CDF). The threshold for taking immediate regulatory action (found in NRR Office Instruction LIC-504, see below) is a total CDF greater than or on the order of $10^{-3}$ (0.001) per year. For GI-199, the staff calculated seismic CDFs of $10^{-4}$ (0.0001) per year and below for nuclear power plants operating in the Central and Eastern US (CEUS) (based on the new US Geological Survey seismic hazard curves). The CDF from internal events (estimated using the staff-developed Standardized Plant Analysis of Risk models) and fires (as reported by licensees during the IPEEE process and documented in NUREG-1742), when added to the seismic CDF estimates results in the total risk for each plant to be, at most, $4 \times 10^{-4}$ (0.0004) per year or below. This is well below the threshold (a CDF of $10^{-3}$ [0.001] per year) for taking immediate action. Based on the determination that there is no need for immediate action, and that this issue has not changed the licensing basis for any operating plant, the CEUS operating nuclear power plants are considered safe. In addition, as detailed in the GI-199 Safety/Risk Assessment there are additional, qualitative considerations that provide further support to the conclusion that plants are safe.

Note: The NRC has an integrated, risk-informed decision-making process for emergent reactor issues (NRR Office Instruction LIC-504, ADAMS Accession No. ML100541776 [not publically available]). In addition to deterministic criteria, LIC-504 contains risk criteria for determining when an emergent issue requires regulatory action to place or maintain a plant in a safe condition.

### 87) What do you mean by "increased estimates of seismic hazards" at nuclear power plant sites?

**Public Answer:** *Seismic hazard* (earthquake hazard) represents the chance (or probability) that a specific level of ground shaking could be observed or exceeded at a given location. Our estimates of seismic hazard at some Central and Eastern United States locations have changed based on results from recent research, indicating that earthquakes occurred more often in some locations than previously estimated. Our estimates of seismic hazard have also changed because the models used to predict the level of ground shaking, as caused by a specific magnitude earthquake at a certain distance from a site, changed. The increased estimates of seismic hazard at some locations in the Central and Eastern United States were discussed in a memorandum to the Commission, dated July 26, 2006. (The memorandum is available in the NRC Agencywide Documents Access and Management System [ADAMS] under Accession No. ML052360044).

**Additional, technical, non-public information:** See additional discussion of terms at the end of the document.

### 88) Does the SCDF represent a measurement of the risk of radiation RELEASE or only the risk of core damage (not accounting for secondary containment, etc.)?

**Public Response:** Seismic CDF is the probability of damage to the core resulting from a seismic initiating event. It does not imply either a meltdown or the loss of containment, which would be required for radiological release to occur. The likelihood of radiation release is far lower.

**89) Did an NRC spokesperson tell MSNBC's Bill Dedman that the weighted risk average was invalid and useless? He contends to us that this is the case.**

**Public Response:** No. See Answers below.

**90) 3. If it was "invalid" as he claims, why would the USGS include that metric?**

**Public Response:** The weighted average is not invalid (see Answer 5 below). All of the values in Appendix D were developed by NRC staff. Table D-1 in Appendix D uses the (2008) US Geological Survey (USGS) seismic source model, but the Seismic Core Damage Frequency results were developed by US NRC staff. The USGS seismic source model is the same one used to develop the USGS National Seismic Hazard Maps.

**91) Can you explain the weighted average and how it compares to the weakest link average?**

**Public Response:** Tables D-1 through D-3 in Appendix D of the US NRC study show the "simple" average of the four spectral frequencies (1, Hz, 5 Hz, 10 Hz, peak ground acceleration (PGA)), the "IPEEE weighted" average and the "weakest link" model. These different averaging approaches are explained in Appendix A.3 (simple average and IPEEE weighted average) and Appendix A.4 (weakest link model). The weighted average uses a combination of the three spectral frequencies (1, 5, and 10 Hz) at which most important structures, systems, and components of nuclear power plants will resonate. The weakest link is the largest SCDF value from among the four spectral frequencies noted above.

**92) Ultimately would you suggest using one of the models (average, weighted, weakest link) or to combine the information from all three?**

**Public Response:** Most nuclear power plant structures, systems, and components resonate at frequencies between 1 and 10 Hz, so there are different approaches to averaging the Seismic Core Damage Frequency (SCDF) values. By using multiple approaches, the NRC staff gains a better understanding of the uncertainties involved in the assessments.

**93) Were there any other factual inaccuracies or flaws in Mr. Dedman's piece you would like clarify/point out.**

**Public Response:** The US Nuclear Regulatory Commission study, released in September, 2010, was prepared as a screening assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The report clearly states that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." Accordingly, the results were not used to rank or compare plants. The study produced plant-specific results of the estimated change in risk from seismic hazards. The study did not rely on the absolute value of the seismic risk except to assure that all operating plants are safe. The plant-specific results were used in aggregate to determine the need for continued evaluation and were included in the report for openness and transparency. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

**94) Mr. Dedman infers that the plant quake risk has grown (between the 1989 and 2008 estimates) to the threshold of danger and may cross it in the next study. Is this the NRC's position?**

**Public Response:** The US NRC evaluation is still underway and it is too early to predict the final outcome. However, staff has determined that there is no immediate safety concern and that overall seismic risk estimates remain small. If at any time the NRC determines that an immediate safety concern exists, action to address the issue will be taken. However, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue

**95) Let's say there's an estimate expressed as "2.5E-06." (I'm looking at Table D-2 of the safety/risk assessment of August 2010.) I believe that this expression means the same as 2.5 x 10^-06, or 0.0000025, or 2.5 divided by one million. In layman's terms, that means an expectation, on average, of 2.5 events every million years, or once every 400,000 years. Similarly, "2.5E-05" would be 2.5 divided by 100,000, or 2.5 events every 100,000 years, on average, or once every 40,000 years. Is this correct?**

**Public Response:** Yes, at least partly. In the subject documents the frequencies for core damage or ground motion exceedance have been expressed in the form "2.5E-06". As you noted this is equivalent to 2.5x10-6, or 0.000025 per year. If, for example, the core damage frequency was estimated as 2.5E-06, this would be equivalent to an expectation of 2.5 divided by a million per year. It is not really correct to think of these values as "once every 400,000 years," the two numbers are mathematically equivalent but do not convey the same statistical meaning within this context. Rather, you could characterize it as 1 in 400,000 per year of something occurring.

**Additional, technical, non-public information:** None

**96) The GI-199 documents give updated probabilistic seismic hazard estimates for existing nuclear power plants in the central and eastern US What document has the latest seismic hazard estimates (probabilistic or not) for existing nuclear power plants in the western US?**

**Public Response:** At this time the staff has not formally developed updated probabilistic seismic hazard estimates for the existing nuclear power plants in the Western US However, NRC staff during the mid- to late-1990's reviewed the plants' assessments of potential consequences of severe ground motion from earthquakes beyond the plant design basis as part of the Individual Plant Examination of External Events (IPEEE) program. From this review, the NRC staff determined that the seismic designs of operating plants in the US have adequate safety margin. NRC staff has continued to stay abreast of the latest research on seismic hazards in the Western US and interface with colleagues at the US Geological Survey. The focus of Generic Issue 199 has been on the CEUS. However, the Information Notice that summarized the results of the Safety/Risk Assessment was sent to all existing power reactor licensees. The documents that summarize existing hazard estimates are contained in the Final Safety Analysis Reports (FSARS) and in the IPEEE submittals. It must be noted that following 9/11 the IPEEE documents are no longer publicly available.

**Additional, technical, non-public information:** None

**97) The GI-199 documents refer to newer data on the way. Have NRC, USGS et al. released those? I'm referring to this: "New consensus seismic-hazard estimates will become available in late 2010 or early 2011 (these are a product of a joint NRC, US Department of Energy, US Geological Survey (USGS) and Electric Power Research Institute (EPRI) project). These consensus seismic hazard estimates will supersede the existing EPRI, Lawrence Livermore National Laboratory, and USGS hazard estimates used in the GI-199 Safety/Risk Assessment."**

**Public Response:** The new consensus hazard curves are being developed in a cooperative project that has NRC, US Department of Energy, US Geological Survey (USGS) and Electric Power Research Institute (EPRI) participation. The title is: The Central and Eastern US Seismic Source Characterization (CEUS-SSC) project. The project is being conducted following comprehensive standards to ensure quality and regulatory defensibility. It is in its final phase and is expected to be publicly released in the fall of 2011. The project manager is Larry Salamone (Lawrence.salamone@srs.gov, 803-645-9195) and the technical lead on the project is Dr. Kevin Coppersmith (925-974-3335, kcoppersmith@earthlink.net). Additional information on this project can be found at: http://mydocs.epri.com/docs/ANT/2008-04.pdf, and http://my.epri.com/portal/server.pt?open=512&objID=319&&PageID=218833&mode=2&in_hi_userid=2&cached=true.

**Additional, technical, non-public information:** None

**98) What is the timetable now for consideration of any regulatory changes from the GI-199 research?**

**Public Response:** The NRC is working on developing a Generic Letter (GL) to request information from affected licensees. The GL will likely be issued in a draft form within the next 2 months to stimulate discussions with industry in a public meeting. After that it has to be approved by the Committee to Review Generic Requirements, presented to the Advisory Committee on Reactor Safeguards and issued as a draft for formal public comments (60 days). After evaluation of the public comments it can then be finalized for issuance. We expect to issue the GL by the end of this calendar year, as the new consensus seismic hazard estimates become available. The information from licensees will likely require 3 to 6 months to complete. Staff's review will commence after receiving licensees' responses. Based on staff's review, a determination can be made regarding cost beneficial backfits where it can be justified.

**Additional, technical, non-public information:** None

1. Please explain in plain language how the NRC determined plants are safe with regard to the results of our GI199 assessment report..

2. The GI199 Safety/Risk Assessment states 24 plants "lie in the continue zone" (pg 23) These plants "need more assessment." What are these 24 plants? Why are these plants that require further evaluation safe? (pg 23 and Figure 8)

3. Why is the list of plants identified by the NRC for further evaluation under GI199 different than those identified by MSNBC as the "top 10" likely to fail due to seismic event?

4. Why are plants safe when MSNBC calculations indicate several hundred percent increases in the risk of a seismic event that damages the core?

5. Why do Indian Point 2 and Indian Point 3 plants have different probabilities of failing due to a seismic event when the plants are located next to each other? Is IP3 calculated to be the most

likely to fail due to a seismic event? Why? Why is IP2 different? Aren't these plant at the same location and very similar design?

6. Why is Pilgrim not in the NRC "continue to evaluate zone" but second on the MSNBC list as moist likely to fail due to a seismic event?

## Seismic Probabilistic Risk Assessment (SPRA)

**99) The NRC increasingly uses risk-information in regulatory decisions. Are risk-informed PRAs useful in assessing an event such as this?**

**Public response:** Nilesh Chokshi to provide Q&As on SPRA

**Additional, technical, non-public information:** None

# Plant-Specific Questions

## San Onofre Nuclear Generating Station (SONGS) Questions

### 100) SONGS received a white finding in 2008 for 125VDC battery issue related to the EDGs that went undetected for 4 years. NRC issued the white finding as there was increased risk that one EDG may not have started due to a low voltage condition on the battery on one Unit (Unit 2). Aren't all plants susceptible to the unknown? Is there any assurance the emergency cooling systems will function as desired in a Japan-like emergency?

**Public response:** The low voltage condition was caused by a failure to properly tighten bolts on a electrical breaker that connected the battery to the electrical bus that would be relied on to start the EDG in case of a loss of off-site power. This was corrected immediately on identification and actions taken to prevent its reoccurrence. The 3 other EDGs at SONGS were not affected.

**Additional, technical, non-public information:** None

### 101) Has the earthquake hazard at SONGS been reviewed like Diablo Canyon nuclear power plant (DCNPP) is doing? Are they planning on doing an update before relicensing?

**Public Answer:** Relicensing does not evaluate the potential change to seismic siting of a plant. If there is a seismic design concern, it would be addressed for the plant as it is currently operating.

The closest active fault is approximately five miles offshore from San Onofre, a system of folds and faults exist called the OZD need to write out full name. The Cristianitos fault is ½ mile southeast, but is an inactive fault. Other faults such as the San Andreas and San Jacinto, which can generate a larger magnitude earthquake, are far enough away that they would produce ground motions much less severe than the OZD for San Onofre.

Past history relative to nearby major quakes have been of no consequences to San Onofre. In fact, three major earthquakes from 1992 to 1994 (Big Bear, Landers and Northridge), ranging in distance from 70-90 miles away and registering approximately 6.5 to 7.3 magnitude, did not disrupt power production at San Onofre. The plant is expected to safely shutdown if a major earthquake occurs nearby. Safety related structures, systems and components have been designed and qualified to remain functional and not fail during and after an earthquake.

**Additional, technical, non-public information:** None

### 102) Is possible to have a tsunami at songs that is capable of damaging the plant?

**Public Information**: The San Onofre Units 2 and 3 plant grade is elevation +30.0 feet MLLW. The controlling tsunami for San Onofre occurring during simultaneous high tide and storm surge produces a maximum runup to elevation +15.6 feet MLLW at the Unit 2 and 3 seawall. When storm waves are superimposed, the predicted maximum runup is to elevation +27 MLLW. Tsunami protection for the SONGS site is provided by a reinforced concrete seawall constructed to elevation +30.0 MLLW. A tsunami greater than this height is extremely unlikely.

**Additional, technical, non-public information:** None

### 103) Does SONGS have an emergency plan for tsunami?

**Public Response**: The SONGS emergency plan does initiate the emergency response organization and results in declaration of emergency conditions via their EALs. The facility would then make protective action recommendations to the Governor, who would then decide on what protective actions would be ordered for the residents around SONGS.

**Additional, technical, non-public information:** None

### 104) Has evacuation planning at SONGS considered tsunami?

**Public Response:** These considerations would be contained in the State and local (City, County) emergency plans, which are reviewed by FEMA. FEMA then certifies to the NRC that they have "reasonable assurance" that the off-site facilities can support operation of SONGS in an emergency.

**Additional, technical, non-public information:** None

### 105) Is SONGS designed against tsunami and earthquake?

**Public Response:** Yes. SONGS is designed against both tsunami and earthquake.

**Additional, technical, non-public information:** None

### 106) What is the height of water that SONGS is designed to withstand?

**Public Response:** 30 feet (9.1 meters). Information for all plants can be found in the "Additional Information' section of this document.

**Additional, technical, non-public information:** None

### 107) What about drawdown and debris?

**Public Response:** *Good question...can HQ answer? Goutam, Henry, or Rich...can you help with this one?*

**Additional, technical, non-public information:** None

### 108) Will this be reviewed in light of the Japan earthquake.

**Public Response:** The NRC will do a thorough assessment of the lessons learned from this event and will review all potential issues at US nuclear plants as a result.

**Additional, technical, non-public information:** None

### 109) Could all onsite and offsite power be disrupted from SONGS in the event of a tsunami, and if that happened, could the plant be safely cooled down if power wasn't restored for days after?

**Public Response:** Seismic Category I equipment is equipment that is essential to the safe shutdown and isolation of the reactor or whose failure or damage could result in significant release of radioactive material. All Seismic Category I equipment at SONGS is designed to function following a DBE with ground acceleration of 0.67g.

The operating basis earthquake (1/2 of the DBE) is characterized by maximum ground shaking of 0.33g. Historically, even this level of ground shaking has not been observed at the site. Based on expert analysis, the average recurrence interval for 0.33g ground shaking at the San Onofre site would be in excess of 1000 years and, thus, the probability of occurrence in the 40-year design life of the plant would be less than 1 in 25. The frequency of the DBE would be much more infrequent, and very unlikely to occur during the life of the plant. Even if an earthquake resulted in greater than the DBE movement/acceleration at SONGS, the containment structure would ultimately protect the public from harmful radiation release, in the event significant damage occurred to Seismic category 1 equipment.

**Additional, technical, non-public information:** None

### 110) Are there any faults nearby SONGS that could generate a significant tsunami?

**Public Response:** Current expert evaluations estimate a magnitude 7 earthquake about 4 miles (6.4 km) from SONGS. This is significantly less than the Japan earthquake, and SONGS has been designed to withstand this size earthquake without incident. Should discuss the different tectonic nature (not a subduction zone like Japan)?

**Additional, technical, non-public information:** None

### 111) What magnitude or shaking level is SONGS designed to withstand? How likely is an earthquake of that magnitude for the SONGS site?

**Public Response:** The design basis earthquake (DBE) is defined as that earthquake producing the maximum vibratory ground motion that the nuclear power generating station is designed to withstand without functional impairment of those features necessary to shut down the reactor, maintain the station in a safe condition, and prevent undue risk to the health and safety of the public. The DBE for SONGS was assessed during the construction permit phase of the project. The DBE is postulated to occur near the site (5 miles (8km)), and the ground accelerations are postulated to be quite high (0.67g), when compared to other nuclear plant sites in the U.S (0.25g or less is typical for plants in the eastern US). Based on the unique seismic characteristics of the SONGS site, the site tends to amplify long-period motions, and to attenuate short-period motions. These site-specific characteristics were accounted for in the SONGS site-specific seismic analyses.

**Additional, technical, non-public information:** None

### 112) Could SONGS withstand an earthquake of the magnitude of the Japanese earthquake?

**Public Response:** We do not have current information on the ground motion at the Japanese reactors. SONGS was designed for approximately a 7.0 magnitude earthquake 4 miles (6.4 km) away. The Japanese earthquake was much larger (8.9), but was also almost 9 miles (14.5 km) away. The local ground motion at a particular plant is significantly affected by the local soil and bedrock conditions. SONGS was designed (0.67g) to withstand more than 2 times the design motion at average US plants.

**Additional, technical, non-public information:** None

### 113) What about the evacuation routes at SONGS? How do we know they are reasonable?

**Public Response:** FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at SONGS. The next such exercise is planned for April 12, 2011.

**Additional, technical, non-public information:** None

### 114) Regarding tsunami at DCNPP and SONGS, is the tsunami considered separately from flooding in licensing? And from the design perspective, is the flood still the controlling event for those plants rather than the tsunami?

Public response: See below

### 115) What is the design level flooding for DNCPP and SONGS? Can a tsunami be larger?

**Public response:** Both the Diablo Canyon (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at Diablo canyon are designed for combination of tsunami-storm wave activity. SONGS has reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action

**Additional, technical, non-public information:** None

### 116) Is there potential linkage between the South Coast Offshore fault near SONGS and the Newport-Inglewood Fault system and/or the Rose Canyon fault? Does this potential linkage impact the maximum magnitude that would be assigned to the South Coast Offshore fault and ultimately to the design basis ground motions for this facility?

**Public response:** Stephanie and Jon to answer (you may want to change the question) based on the discussions in the articles sent by Lara U.

**Additional, technical, non-public information:** Proposed action is to check the FSAR for San Onofre and read the discussion on characterization of the offshore fault. A quick look at discussion of the Newport Ingelwood from other sources suggest this is part of the "system". It would be helpful to check the basis for segmenting the fault in the FSAR. Probably have to dig on this a bit, may need to look at the USGS/SCEC/ model for this area.

## Diablo Canyon Nuclear Power Plant (DCNPP) Questions

**117) Now after the Japan tragedy, will the NRC finally hear us (A4NR) and postpone DC license renewal until seismic studies are complete? How can you be sure that what happened there is not going to happen at Diablo with a worse cast earthquake and tsunami?**

**Public response:** ADD

**Additional, technical, non-public information:** ADD

**118) The evacuation routes at DCNPP see are not realistic. Highway 101 is small...and can you imagine what it will be like with 40K people on it? Has the evacuation plan been updated w/ all the population growth?**

**Public Response:** FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at DCNPP.

**Additional, technical, non-public information:** None

**119) Are there local offshore fault sources capable of producing a tsunami with very short warning times?**

**Public Response:** ADD- question forwarded to region

**Additional, technical, non-public information:** ADD

**120) Are there other seismically induced failure modes (other than tsunami) that would yield LTSBO? Flooding due to dam failure or widespread liquefaction are examples.**

**Public Response:** ADD question forwarded to region

**Additional, technical, non-public information:** ADD

**121) Ramifications of beyond design basis events (seismic and tsunami) and potential LTSBO on spent fuel storage facilities?**

**Public Response:** ADD question forwarded to region

**Additional, technical, non-public information:** ADD

**122) Why did the Emergency Warning go out for a 'tsunami' that was only 6 ft (1.8 m) high? Do these guys really know what they're doing? Would they know it if a big one was really coming? Crying wolf all the time doesn't instill a lot of confidence.**

**Public Response:** The warning system performed well. The 6 foot (1.8 meters) wave was predicted many hours before and arrived at the time it was predicted. Federal officials to accurately predicted the tsunami arrival time and size; allowing local official to take appropriate measures as they saw necessary to warn and protect the public. It should be understood that even a 6 foot tsunami is very dangerous. Tsunamis have far more energy and power than wind-driven waves.

**Additional, technical, non-public information:** ADD

**123) How big did the Japanese think an earthquake and tsunami could be before March 11, 2011? Why were they so wrong (assuming this earthquake/tsunami was bigger than what they had designed the plant for)?**

**Public Response:** ADD can HQ answer?

**Additional, technical, non-public information:** ADD

**The Japanese were supposed to have one of the best tsunami warning systems around. What went wrong last week (both with the reactors and getting the people out...see #1, evacuation plan above)?**

**Public Response:** ADD can HQ answer?

**Additional, technical, non-public information:** ADD

**124) Regarding the tsunami at DCNPP and SONGS, is the tsunami considered separately from flooding in licensing? And from the design perspective, is the flood still the controlling event for those plants rather than the tsunami?**

**Public Response:** Both the Diablo Canyon (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at Diablo canyon are designed for combination of tsunami-storm wave activity. SONGS has reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action

**Additional, technical, non-public information:** ADD

*NOTE: need to add to SONGS and DCNPP... Canyon and San Onofre IPEEEs - based on the Technical Evaluation Reports, Diablo did consider a locally induced tsunami in a limited way (the aux service water pumps were assumed to become flooded following a seismic event) while SONGS did not consider a coupled seismic/tsunami event.*

**125) Shouldn't the NRC make licensees consider a Tsunami coincident with a seismic event that triggers the Tsunami?**

ADD

**126) Given that SSCs get fatigued over time, shouldn't the NRC consider after-shocks in seismic hazard analyses?**

ADD

**127) Did the Japanese also consider an 8.9 magnitude earthquake and resulting tsunami "way too low a probability for consideration"?**

ADD

**128) GI-199 shows that the scientific community doesn't know everything about the seismicity of CEUS. And isn't there a prediction that the West coast is likely to get hit with some huge earthquake in the next 30 years or so? Why does the NRC continue to license plants on the west coast?**

Work the following into Q&As as time permits.

After an earthquake, in order to restart, In practice a licensee needs to determine from engineering analysis that the stresses on the plant did not exceed their licensed limits. That would be a very tall order for a plant that experienced a beyond design basis earthquake, and probably is why it had taken Japan so long to restore the KK plants following the earlier earthquake.

**129) Has industry done anything on tsunami hazards? Also, has anyone done work to look at the effect of numerous cycles of low amplitude acceleration following a larger event. I would expect we would have some information because how do we know a plant would be fit to start back up after an event? We cannot possibly do NDE on everything to determine if flaws have propagated to the point where they need to be replaced.**

## Indian Point Questions

### 130) Why is Indian Point safe if there is a fault line so close to it?

**Public Response**: The Ramapo fault system, located near the Indian Point Nuclear Power Plant, is an example of an old fault system that, based on geologic field evidence, has not been active in the last 65.5 million years. The Ramapo fault system extends primarily from southeastern New York to northern New Jersey and is made up of a series of northeast- oriented faults. Even though there is minor earthquake activity in the vicinity of the Ramapo faults, this earthquake activity cannot be directly correlated with any individual fault within the Ramapo fault system.

US nuclear power plants are designed and built to withstand the largest expected earthquake in the site region, based on observed historical seismicity and field evidence for prehistoric earthquakes, and are also designed to incorporate seismic safety margins. A potential earthquake in and around the vicinity of the Ramapo fault system was taken into account during the NRC licensing process for the Indian Point plants, and the plant design incorporated the largest expected earthquake in the site region. In summary, the Ramapo fault system exhibits no definitive evidence for recent fault displacement (i.e., no evidence for fault activity in the last 65.5 million years) and the Indian Point nuclear power plant was designed and built to safely shutdown in the event of an earthquake having the highest magnitude observed in the site region. Therefore, the NRC concluded that the risk of significant damage to the Indian Point reactors due to a potential earthquake is acceptable.

**Additional, technical, non-public information:** The information above and following is consistent with the literature and the UFSAR for IP related to the Ramapo fault. The Ramapo fault system, which passes through the Indian Point area, is a group of Mesozoic age faults, extending from southeastern New York to northern New Jersey, as well as further southwest. The fault system is composed of a series of southeast-dipping, northeast-striking faults. Various faults of the system contain evidence of repeated slip in various directions since Proterozoic time, including Mesozoic extensional reactivation. However, the USGS staff, who reviewed 31 geologic features in the Appalachian Mountains and Coastal Plain and compiled a National Database on Quaternary Faulting (Crone and Wheeler, 2000), listed the Ramapo fault system as low risk because the fault system lacks evidence for Quaternary slip. They further pointed out that the Ramapo fault system, and 17 other geologic features, "have little or no published geologic evidence of Quaternary tectonic faulting that could indicate the likely occurrence of earthquakes larger than those observed historically" (Wheeler and Crone, 2004). Among these faults, the Ramapo fault system is one of the three that underwent a paleoseismological study. In two trenches excavated across the Ramapo fault, no evidence of Quaternary tectonic faulting was found (Wheeler and Crone, 2000). Because the Ramapo fault system is relatively inactive, , and because the plants are designed to safely shutdown in the event of an earthquake of the highest intensity ever recorded in that area, the NRC has concluded that the risk of significant damage to the reactors due to a probable earthquake in the area is extremely small.

The letter that was sent to the NRC from Rep Lowey refers to the Ramapo seismic zone (RSZ) and the Dobbs Ferry fault. The letter incorrectly states that the Dobbs Ferry fault is located within the Ramapo seismic zone. Based on the literature, it is not. It is close, but it is considered to be in the Manhattan Prong more to the east (more like 10-15 miles away) while the Ramapo fault system is considered to be in the Reading Prong (a couple of miles away from IP). Also for clarification, the seismicity is considered to be within the Precambrian/Paleozoic basement at depths greater than the Mesozoic Newark Basin where the RSZ is situated.

# Pending and Unanswered Questions from Members of Congress

The below questions are gleaned from the congressional letters coming into the NRC. Because they generally cover different topics, they are being kept together as sets to assist the office assigned with response. Once a formal response is developed and sent, the questions will be moved to the appropriate sections.

## 131) Received 3/16/11 from Congresswoman Lowey

The key elements of the congresswoman's letter are as follows:

The Ramapo Seismic Zone is a particular threat because the zone passes within two miles of Indian Point. The Ramapo Seismic zone includes the Dobbs Ferry fault in Westchester, which generated a 4.1 magnitude earthquake in 19S5. The Columbia University study suggests that this pattern of subtle but active faults increases the risk to the New York City area and that an earthquake with a magnitude of 7.0 on the Richter scale is within reach. Disturbingly, Entergy measures the risk of an earthquake near Indian Point to be between 1.0 and 3.0 on the Richter scale, despite evidence to the contrary.

The NRC should study Indian Point's risk of, and ability to sustain a disaster, including the impact of earthquakes and hurricanes, as well as collateral impacts such as loss of power, inability to cool reactors and emergency evacuation routes. The NRC should evaluate how a similar incident in the New York metropolitan area could be further complicated due to a dramatically higher population and the effectiveness of the proposed evacuation routes.

**Public Response:** Please see technical elements in the above question. NRR has the lead for developing the formal response

**Additional, technical, non-public information:** please see the significant amount of information above

## 132) From 3/16/11 Press Release from Senators Boxer and Feinstein

Plant Design and Operations

1. What changes to the design or operation of the Diablo Canyon and SONGS facilities have improved safety at the plants since they began operating in the mid-1980s?

   **Public Response:** NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

2. What emergency notification systems have been installed at California nuclear power plants? Has there ever been a lapse of these systems during previous earthquakes or emergencies?

   **Public Response:** NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

3. What safety measures are in place to ensure continued power to California reactors in the event of an extended power failure?

   **Public Response:** NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

Type of Reactor

4. What are the differences and similarities between the reactors being used in California (pressurized water reactors) and those in Japan (boiling water reactors), as well as the facilities used to house the reactors, including the standards to which they were built and their ability to withstand natural and manmade disasters?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

Earthquakes and Tsunamis

5. We have been told that both Diablo Canyon and San Onofre Nuclear Generating Station are designed to withstand the maximum credible threat at both plants, which we understand to be much less than the 9.0 earthquake that hit Japan. What assumptions have you made about the ability of both plants to withstand an earthquake or tsunami? Given the disaster in Japan, what are our options to provide these plants with a greater margin for safety?

**Public Response:** Annie and Kamal developing response

**Additional, technical, non-public information:** ADD

6. Have new faults been discovered near Diablo Canyon or San Onofre Nuclear Generating Station since those plants began operations? If so, how have the plants been modified to account for the increased risk of an earthquake? How will the NRC consider information on ways to address risks posed by faults near these plants that is produced pursuant to state law or recommendations by state agencies during the NRC relicensing process?

**Public Response:** Annie and Kamal developing response

**Additional, technical, non-public information:** ADD

7. What are the evacuation plans for both plants in the event of an emergency? We understand that Highway 1 is the main route out of San Luis Obispo, what is the plan for evacuation of the nearby population if an earthquake takes out portions of the highway and a nuclear emergency occurs simultaneously?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

8. What is the NRC's role in monitoring radiation in the event of a nuclear accident both here and abroad? What is the role of EPA and other federal agencies?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

9. What monitoring systems currently are in place to track potential impacts on the US, including California, associated with the events in Japan?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

10. 6. Which federal agency is leading the monitoring effort and which agencies have responsibility for assessing human health impacts? What impacts have occurred to date on the health or environment of the US or are currently projected or modeled in connection with the events in Japan?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

11. What contingency plans are in place to ensure that the American public is notified in the event that hazardous materials associated with the events in Japan pose an imminent threat to the US?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

## 133) From 3/15/11 Press Release from Congresspeople Markey and Capps

Note that these are only the seismic questions. There are other questions that are structural

1. Provide the Richter or moment magnitude scale rating for each operating nuclear reactor in the United States. If no such information exists, on what basis can such an assertion be made regarding the design of any single nuclear power plant?

**Public Response:** US nuclear power plants are designed for different ground motions determined on a site-specific basis, which are called the Safe Shutdown Earthquake ground motions (SSE). Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location. Ground motion, or shaking, is a function of both earthquake magnitude and distance from the fault to the site. The magnitude alone cannot be used to predict ground motions. Currently operating nuclear power plants developed their SSEs based on a "deterministic" or "scenario earthquake" basis that account for the largest earthquake expected in the area around the plant.

Please see the available table of Design Basis Ground Motions for US Plants in the Additional Information: Useful Tables.

**Additional, technical, non-public information:** ADD

2. The San Onofre reactor is reportedly designed to withstand a 7.0 earthquake, and the Diablo Canyon reactor is designed to withstand a 7.5 magnitude. According to the Southern California Earthquake Center (SCEC), there is an 82% probability of an earthquake 7.0 magnitude in the next 30 years, and a 37 percent probability that an earthquake of 7.5 magnitude will occur. Shouldn't these reactors be retrofitted to ensure that they can withstand a stronger earthquake than a 7.5? If not, why not?

**Public Response:** This needs to be edited and enhanced. The noted SCEC magnitudes and probabilities are sourced from Uniform California Earthquake Rupture Forecast (UCERF) Figure 2 (http://www.scec.org/core/public/sceccontext.php/3935/13662). The value quoted describes the probability that an earthquake of that magnitude will occur somewhere in Southern California. The probability that earthquakes of those magnitudes occur near the plants is far smaller. Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location.

**Additional, technical, non-public information:** The colors in UCERF Figure 2 represent the probabilities of having a nearby earthquake rupture (within 3 or 4 miles) of magnitude 6.7 or larger in the next 30 years. Therefore, reading the colors off of Figure 2, the San Onofre and Diablo Canyon NPPs have a ≤10% probability of having a ≥M6.7 earthquake rupture within 3 to 4 miles in the next 30 years. Therefore, retrofitting these reactors to withstand earthquakes of M7.5 or stronger based on the UCERF study would put an unnecessary burden on the licensees.

3. Provide specific information regarding the differences in safety-significant structures between a nuclear power plant that is located in a seismically active area and one that is not. Provide, for each operating nuclear reactor in a seismically active area, a full list and description of the safety-significant design features that are included that are not included in similar models that are not located in seismically active areas.

**Public Response**: This is a rough draft. We need to get some reviews of this. Assumed NRR will have ultimate responsibility for the response.

There are no differences in safety requirements for nuclear power plants located in seismically active areas and ones that are not. Regardless of site seismicity, Appendix S to 10 CFR Part 50 requires for site-specific SSE ground motions, structures, systems, and components will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motions. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation elevation of structures must be an appropriate response spectrum with peak ground acceleration (PGA) of at least 0.10g. Design basis loads for nuclear power plant structures, important to safety, include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Institute of Concrete (ACI-349) and the American Institute of Steel Construction (AISC N690), are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads. In addition to the nominal seismic design, all new generation reactors have to demonstrate a seismic margin of 1.67 relative to the site-specific seismic demands.

For the current operating fleet of nuclear power reactors, site-to-site differences in structural design can result from differences in external site hazards such as seismic, wind, tornado, and tsunami. For a low-seismicity region, wind or tornado loads may control the design. Conversely, for a high-seismicity region, seismic loads will likely control. Structures in high-seismicity regions have robust designs with typically higher capacity shear walls, as an example. Systems and components will also be more robust and are designed and tested to higher levels of acceleration.

**Additional, technical, non-public information:** ADD

4. In your opinion, can any operating nuclear reactors in the United States withstand an earthquake of the magnitude experience in Japan?

**Public Response**: The March 11, 2011, magnitude 9 earthquake that recently affected Japan is different than earthquakes that could affect US nuclear plants. Each US nuclear plant is designed to a ground-shaking level that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. The Japan earthquake was caused by a "subduction zone" event, which is the type of mechanism that produces the largest possible magnitude earthquakes. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington, so an earthquake this large could only happen in that region. The only plant in that area is Columbia Generating Station, which is approximately 225 miles (363 km) from the coast and the subduction zone. Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximate 8, which is 10 times smaller than a magnitude 9.

**Additional, technical, non-public information:** ADD

## Questions for the Japanese

**NOTE: These were all collected from what we produced after the KKNPP earthquake. These need to be gone through and revised for this event. We should separate into high, medium and low priorities:**

**The below is pulled from an KKNPP summary...to be reviewed...**

What seismic monitoring equipment exists at the plants? Can we get the recordings from the
Are there recordings of the tsunami at the plant location?
What is the geology and soil profile at the plants?
NOAA has a prediction of very large tsunami waves at Onagawa. Are these accurate?

**The below is pulled from an KKNPP summary...to be reviewed...**

DESIGN BASES: Exactly what is the design basis ground motion for each of the plants? Did it change through time (i.e. from the first plant to the seventh)? Where was the design basis motion defined, at the top of rock, at the ground surface, at the floor level or somewhere else? Were the site-specific geotechnical properties used in the development of the design basis ground motions for each plant?

SEISMIC HAZARDS: What assumptions were used in the seismic hazard evaluation to arrive at the design basis ground motions? What faults were considered, what magnitudes and geometries were assumed? What activity rates were assumed for both fault sources and "background" earthquakes?

OBSERVATIONS-GROUND MOTIONS: What ground motions were recorded and where were they recorded? Specifically, what free-field, in-structure and down-hole recordings were obtained? What are the locations of the instruments that obtained records? Did all the instruments respond as planned, or are there lessons to be learned? Can the digital data be shared with the NRC? Is there any way of evaluating how well the existing analysis methods predicted the observed motions at different points within the plant?

OBSERVATIONS-DAMAGE: What damage was observed at the plants? How well did equipment such as cranes perform? Were there observations of displacements of equipment from anchorages, were cracks observed in any of the buildings? How well did non-nuclear safety type of buildings and equipment perform? What types of geotechnical phenomena were observed, was there ground deformation/slope failures, lateral spreading or liquefaction near the facility? Did the ABWRs perform better or similar to the older designs?

**And another set from the KKNPP earthquake...to be reviewed...**

Please provide the following information in the time frame indicated:

Highest Priority Questions – as soon as possible

- A timeline describing the order of events and the individual plant responses to the earthquake
- Confirmation that all operating and shut down units achieved or maintained safe-shutdown conditions without manual operator intervention or complications. Did all safety-related systems respond to the seismic scram as designed? Please note if there were any unexpected plant responses to the event, including any spurious signals.
- A more detailed description of the impacts of the earthquake on the plant (e.g., what systems were involved, which pipes were damaged, where did the leakage occur (pipe wall, joints, fittings,,etc).
- A description of seismic instrumentation at the site and at each of the 7 units, soil/rock shear wave properties through depth, instrument location and mounting condition, all the recorded

data on the basis of unified starting time, such that the coherency of motion through the surface or the foundations and at depth can be determined

- Full spectrum seismic design basis for the plant.
- What actually caused the Unit 3B house transformer fire?

Additional Questions – please provide answers as more information is developed

- Damage to buildings, slope failures, intake structure failure, if any
- Behavior of cranes, cables and conduits
- Failures of any large pumps and valves, pipe mounted control or valve failure
- Instances of any relay or vibration sensitive components malfunctioning
- Nature of damage to service water and fire-suppression piping - their diameter, material they are made of including their elastic properties, design standards used for the piping design, nature of failure (at support, anchor motion, failure of anchors, subsidence differential movement etc)
- Were there any systems that changed state?
- Impact on physical security, and any vulnerabilities identified
- Were there any impacts on the grid because of the event?
- Please describe the switchyard performance?
- What emergency preparedness concerns have been identified as a result of the event?

3B Transformer Specific Questions – please respond when there is time and other issues have been addressed

- What are the primary and secondary voltages of the transformer?
- What type of transformer - liquid or dry-type (air-cooled)?
- Who was the manufacturer of the transformer?
- What are the physical dimensions of the transformer?
- How are the transformer coils restrained within the cabinet?
- What is the clearance between transformer energized component and cabinet?
- What is the relative displacement for connection between the high voltage leads and the first anchor point (adequate slack?) in the transformer?
- What was the natural frequency of the burned transformer, if known?
- What was the acceleration level (or the response spectrum, if available) at the support location of the burned transformer?
- What seismic requirements exist for the burned transformer? Was the transformer tested or analyzed to a specific acceleration or response spectra, and if so, what are they?
- Are there any of the same type of transformer installed at other locations in the plant?

# Additional Information: Useful Tables

## Table of Design Basis Ground Motions for US Plants

| Design Basis Earthquake Information | | | | | |
|---|---|---|---|---|---|
| **Nuclear Plant By State/Location** | **Maximum Observed Or Inferred Intensity (MMI Scale)** | **Relative Distance Of Seismic Source** | **Design SSE Peak Acceleration, *g*** | **OBE Peak Acceleration, *g*** | **Soil Condition** |
| **New York** | | | | | |
| Fitzpatrick | VI | Near | 0.15 | 0.08 | Soil |
| Ginna 1 | VIII/IX | >60 miles | 0.2 | 0.08 | Rock |
| Indian Point 2, 3 | VII | Near | 0.15 | 0.1 | Rock |
| Nine Mile Point 1 | IX-X | >60 miles | 0.11 | 0.06 | Rock |
| Nine Mile Point 2 | VI | Near | 0.15 | 0.075 | Rock |
| **New Jersey** | | | | | |
| Salem 1,2 | VII-VIII | Near | 0.2 | 0.1 | Deep Soil |
| **Connecticut** | | | | | |
| Millstone 1, 2, 3 | VII | Near | 0.17 | 0.07 | Rock |
| **Vermont** | | | | | |
| Vermont Yankee | VI | Near | 0.14 | 0.07 | Rock |
| **Ohio** | | | | | |
| Davis Besse 1 | VII | Near | 0.15 | 0.08 | Rock |
| Perry 1 | VII | Near | 0.15 | 0.08 | Rock |
| **Georgia** | | | | | |
| Hatch 1, 2 | VII | Near | 0.15 | 0.08 | Deep Soil |
| Vogtle 1, 2 | VII-VIII | Near | 0.2 | 0.12 | Deep Soil |
| **Tennessee** | | | | | |
| Seqouyah 1, 2 | VIII | Near | 0.18 | 0.09 | Rock |
| Watts Bar 1 | VIII | Near | 0.18 | 0.09 | Rock |
| **California** | | | | | |
| San Onofre 2, 3 | IX-X | Near | 0.67 | 0.34 | Soil |
| Diablo Canyon 1, 2 | X-XI | Near | 0.75 | 0.20 | Rock |
| **Florida** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Crystal River 3 | V | Near | 0.10 | 0.05 | Rock |
| St. Lucie 1, 2 | VI | Near | 0.10 | 0.05 | Soil |
| Turkey Point 3, 4 | VII | Near | 0.15 | 0.05 | Rock |

**NOTES:**

MMI=Modified Mercalli Intensity, a measure of observed/reported damage and severity of shaking.
Relative distance measure used in FSAR to develop SSE acceleration, "Near" indicates distance less than 10 miles.
SSE=Safe Shutdown Earthquake ground motion, for horizontal acceleration, in units of earth's gravity, *g*.
OBE=Operating Basis Earthquake ground motion, level of horizontal acceleration, which if exceeded requires plant shutdown.

## Table of SSE, OBE and Tsunami Water Levels

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Alabama | | | |
| Browns Ferry | 0.200 | 0.100 | N/A (Non-Coastal) |
| Farley | 0.100 | 0.050 | N/A (Non-Coastal) |
| Arkansas | | | |
| Arkansas Nuclear | 0.200 | | N/A (Non-Coastal) |
| Arizona | | | |
| Palo Verde | 0.200 | 0.100 | N/A (Non-Coastal) |
| California | | | |
| Diablo Canyon | 0.400 | 0.200 | The design basis maximum combined wave runup is the greater of that determined for near-shore or distantly-generated tsunamis, and results from near-shore tsunamis. For distantly-generated tsunamis, the combined runup is 30 feet. For near-shore tsunamis, the combined wave runup is 34.6 feet, as determined by hydraulic model testing. The safety-related equipment is installed in watertight compartments to protect it from adverse sea wave events to elevation +48 feet above mean lower low water line (MLLWL). |
| San Onofre | 0.670 | 0.340 | The controlling tsunami occurs during simultaneous high tide and storm surge produces a maximum runup to elevation +15.6 feet mean lower low water line (MLLWL) at the Unit 2 and 3 seawall. When storm waves are superimposed, the predicted maximum runup is to elevation +27 MLLWL. Tsunami protection for the SONGS site is provided by a reinforced concrete seawall constructed to elevation +30.0 MLLWL. |
| Connecticut | | | |
| Millstone | 0.170 | 0.090 | 18 ft SWL |
| Florida | | | |
| Crystal River | 0.050 | 0.025 | N/A (Non-Coastal) |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| St. Lucie | 0.100 | 0.050 | No maximum tsunami level, bounded by PMH surge of +18 MLW wave runup, with plant openings at +19.5 MLW |
| Turkey Point | 0.150 | 0.050 | No maximum tsunami level, bounded by PMH surge of +18.3 MLW water level, site protected to +20 MLW with vital equipment protected to +22 MLW |
| Georgia | | | |
| Hatch | 0.150 | 0.080 | N/A (Non-Coastal) |
| Vogtle | 0.200 | 0.120 | N/A (Non-Coastal) |
| Illinois | | | |
| Braidwood | 0.200 | 0.090 | N/A (Non-Coastal) |
| Byron | 0.200 | 0.090 | N/A (Non-Coastal) |
| Clinton | 0.250 | 0.100 | N/A (Non-Coastal) |
| Dresden | 0.200 | 0.100 | N/A (Non-Coastal) |
| LaSalle | 0.200 | 0.100 | N/A (Non-Coastal) |
| Quad Cities | 0.240 | 0.120 | N/A (Non-Coastal) |
| Iowa | | | |
| Duane Arnold | 0.120 | 0.060 | N/A (Non-Coastal) |
| Kansas | | | |
| Wolf Creek | 0.120 | 0.060 | N/A (Non-Coastal) |
| Louisiana | | | |
| River Bend | 0.100 | 0.050 | |
| Waterford | 0.100 | | Floods – 30 feet MSL |
| Maryland | | | |
| Calvert Cliffs | 0.150 | 0.080 | 14 ft design wave |
| Massachusetts | | | |
| Pilgrim | 0.150 | 0.080 | *Storm flooding design basis - 18.3ft |
| Michigan | | | |
| D.C. Cook | 0.200 | 0.100 | N/A |
| Fermi | 0.150 | 0.080 | N/A |
| Palisades | 0.200 | 0.100 | N/A |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Missouri | | | |
| Callaway | 0.200 | | N/A (Non-Coastal) |
| Mississippi | | | |
| Grand Gulf | 0.150 | 0.075 | N/A |
| Minnesota | | | |
| Monticello | 0.120 | 0.060 | N/A (Non-Coastal) |
| Prarie Island | 0.120 | 0.060 | N/A (Non-Coastal) |
| Nebraska | | | |
| Cooper | 0.200 | 0.100 | N/A (Non-Coastal) |
| Fort Calhoun | 0.170 | 0.080 | N/A (Non-Coastal) |
| New York | | | |
| Fitzpatrick | 0.150 | 0.080 | N/A (Non-Coastal) |
| Ginna | 0.200 | 0.080 | N/A |
| Indian Point | 0.150 | 0.100 | 15 ft msl |
| Nine Mile Point, Unit 1 | 0.110 | 0.060 | N/A |
| Nine Mile Point, Unit 2 | 0.150 | 0.075 | N/A |
| New Hampshire | | | |
| Seabrook | 0.250 | 0.125 | (+) 15.6' MSL Still Water Level (Tsunami Flooding -Such activity is extremely rare on the US Atlantic coast and would result in only minor wave action inside the harbor.) |
| New Jersey | | | |
| Hope Creek | 0.200 | 0.100 | 35.4 MSL The maximum probable tsunami produces relatively minor water level changes at the site. The maximum runup height reaches an elevation of 18.1 feet MSL with coincident 10 percent exceedance high tide) |
| Oyster Creek | 0.184 | 0.092 | (+) 23.5' MSL Still Water Level (Probable Maximum Tsunami - Tsunami events are not typical of the eastern coast of the United States and have not, therefore, been addressed.) |

| Nuclear Plant Name<br>By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration<br>(g) | Operating Basis Earthquake (OBE) Peak Acceleration,<br>(g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Salem | 0.200 | 0.100 | 21.9 MSL (There is no evidence of surface rupture in East Coast earthquakes and no history of significant tsunami activity in the region) |
| North Carolina | | | |
| Brunswick | 0.160 | 0.030 | N/A |
| McGuire | 0.150 | 0.080 | N/A (Non-Coastal) |
| Shearon Harris | 0.150 | | N/A (Non-Coastal) |
| Ohio | | | |
| Davis-Besse | 0.150 | 0.080 | N/A |
| Perry | 0.150 | 0.080 | N/A |
| Pennsylvania | | | |
| Beaver Valley | 0.130 | 0.060 | N/A (Non-Coastal) |
| Limerick | 0.150 | 0.075 | N/A (Non-Coastal) |
| Peach Bottom | 0.120 | 0.050 | N/A (Non-Coastal) |
| Three Mile Island | 0.120 | 0.060 | N/A (Non-Coastal) |
| Susquehanna | 0.150 | 0.080 | N/A (Non-Coastal) |
| South Carolina | | | |
| Catawba | 0.150 | 0.080 | N/A (Non-Coastal) |
| Oconee | 0.150 | 0.050 | N/A (Non-Coastal) |
| Robinson | 0.200 | 0.100 | N/A (Non-Coastal) |
| V.C. Summer | 0.250 | 0.150 | N/A (Non-Coastal) |
| Tennessee | | | |
| Sequoyah | 0.180 | 0.090 | N/A (Non-Coastal) |
| Watts Bar, Unit 1 | 0.180 | 0.090 | N/A (Non-Coastal) |
| Texas | | | |
| Comanche Peak | 0.120 | 0.060 | N/A |
| South Texas Project | 0.100 | 0.050 | N/A |
| Vermont | | | |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Vermont Yankee | 0.140 | 0.070 | N/A |
| Virginia | | | |
| North Anna | 0.180 | | N/A |
| Surry | 0.150 | 0.080 | N/A |
| Washington | | | |
| Columbia | 0.250 | | N/A (Non-Coastal) |
| Wisconsin | | | |
| Kawaunee | 0.120 | 0.060 | N/A |
| Point Beach | 0.120 | | N/A |
| **Definition of Safe Shutdown Earthquake** | The safe-shutdown earthquake (SSE) for the site is the ground motion response spectra (GMRS), which also satisfies the minimum requirement of paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Code of Federal Regulations (10 CFR Part 50). | | |
| **Definition of Operating Basis Earthquake:** | To satisfy the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE) ground motion is defined as follows:<br>(i) For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.<br>(ii) For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in design control document (DCD).<br>(iii) The spectrum ordinate criterion to be used in conjunction with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," issued March 1997, is the lowest of (i) and (ii). | | |

## Table of Plants Near Known Active Faults

It should be noted that in much of the Central and Eastern US, the seismicity comes from "background" seismicity. Background seismicity is earthquake activity, where the earthquakes cannot be tied to known faults.

Jon Ake and Dogan Seber to complete. High priority to support chairman in response to questions asked by congress.

PLACEHOLDER ONLY....TO BE COMPLETED ON 3/17/11 PLEASE DON'T USE!!!

| Plant (state) | Nearest Active Fault or Fault Zone | Distance to Fault or Range of Distances to Zones | Type of Faulting Mechanism | Range of Maximum Magnitude ($M_w$) | OBE (g) | SSE (g) |
|---|---|---|---|---|---|---|
| Columbia | | | | | | |
| Diablo Canyon (CA) | Hosgri Fault | 5 miles | Predominantly Strike Slip | 7.5 | | |
| | Shoreline Fault | 0.5 miles | Strike Slip | 6.25 to 6.75 best estimate by NRC staff in RIL 09-001. Final report on the fault in review by NRC staff | | |
| San Onofre (CA) | | | | | | |
| Comanche Peak | Meers | | | | | |

## Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes, and Seismic Core Damage Frequencies

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Arkansas 1 | 05000313 | 0.2 | 2.8E-04 | 0.3 | 4.1E-06 | 0.3g full-scope EPRI SMA | GI-199 |
| Arkansas 2 | 05000368 | 0.2 | 9.7E-05 | 0.3 | 4.1E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Beaver Valley 1 | 05000334 | 0.12 | 3.3E-04 | n/a | 4.8E-05 | seismic PRA | GI-199 |
| Beaver Valley 2 | 05000412 | 0.12 | 2.7E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Braidwood 1 | 05000456 | 0.2 | 6.7E-05 | 0.3 | 7.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Braidwood 2 | 05000457 | 0.2 | 6.7E-05 | 0.3 | 7.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 1 | 05000259 | 0.2 | 2.5E-04 | 0.3 | 3.7E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 2 | 05000260 | 0.2 | 2.5E-04 | 0.26 | 5.4E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 3 | 05000296 | 0.2 | 2.5E-04 | 0.26 | 5.4E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Brunswick 1 | 05000325 | 0.16 | 7.3E-04 | 0.3 | 1.5E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Brunswick 2 | 05000324 | 0.16 | 7.3E-04 | 0.3 | 1.5E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Byron 1 | 05000454 | 0.2 | 5.2E-05 | 0.3 | 5.8E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Byron 2 | 05000455 | 0.2 | 5.2E-05 | 0.3 | 5.8E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Callaway | 05000483 | 0.2 | 3.8E-05 | 0.3 | 2.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Calvert Cliffs 1 | 05000317 | 0.15 | 1.9E-04 | n/a | 1.0E-05 | seismic PRA | GI-199 |
| Calvert Cliffs 2 | 05000318 | 0.15 | 1.9E-04 | n/a | 1.2E-05 | seismic PRA | GI-199 |
| Catawba 1 | 05000413 | 0.15 | 1.4E-04 | n/a | 3.7E-05 | seismic PRA | GI-199 |
| Catawba 2 | 05000414 | 0.15 | 1.4E-04 | n/a | 3.7E-05 | seismic PRA | GI-199 |
| Clinton | 05000461 | 0.25 | 5.8E-05 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Columbia | 05000397 | 0.25 | 1.7E-04 | n/a | 2.1E-05 | seismic PRA | IPEEE |
| Comanche Peak 1 | 05000445 | 0.12 | 1.6E-05 | 0.12 | 4.0E-06 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |
| Comanche | 05000446 | 0.12 | 1.6E-05 | 0.12 | 4.0E-06 | reduced-scope EPRI SMA; SSE = | GI-199 |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Peak 2 | | | | | | 0.12g | |
| Cooper | 05000298 | 0.2 | 1.5E-04 | 0.3 | 7.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Crystal River 3 | 05000302 | 0.1 | 8.9E-05 | 0.1 | 2.2E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| D.C. Cook 1 | 05000315 | 0.2 | 2.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| D.C. Cook 2 | 05000316 | 0.2 | 2.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Davis Besse | 05000346 | 0.15 | 6.3E-05 | 0.26 | 6.7E-06 | reduced-scope EPRI SMA | GI-199 |
| Diablo Canyon 1 | 05000275 | 0.75 | 2.0E-04 | n/a | 4.1E-05 | seismic PRA | IPEEE |
| Diablo Canyon 2 | 05000323 | 0.75 | 2.0E-04 | n/a | 4.1E-05 | seismic PRA | IPEEE |
| Dresden 2 | 05000237 | 0.2 | 9.7E-05 | 0.26 | 1.9E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Dresden 3 | 05000249 | 0.2 | 9.7E-05 | 0.26 | 1.9E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Duane Arnold | 05000331 | 0.12 | 2.3E-04 | 0.12 | 3.2E-05 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |
| Farley 1 | 05000348 | 0.1 | 1.0E-04 | 0.1 | 2.8E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Farley 2 | 05000364 | 0.1 | 1.0E-04 | 0.1 | 2.8E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Fermi 2 | 05000341 | 0.15 | 1.0E-04 | 0.3 | 4.2E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Fitzpatrick | 05000333 | 0.15 | 3.2E-04 | 0.22 | 6.1E-06 | 0.3g focused-scope NRC SMA | GI-199 |
| Fort Calhoun 1 | 05000285 | 0.17 | 3.7E-04 | 0.25 | 5.4E-06 | 0.3g focused-scope NRC SMA | GI-199 |
| Ginna | 05000244 | 0.2 | 1.0E-04 | 0.2 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Grand Gulf | 05000416 | 0.15 | 1.0E-04 | 0.15 | 1.2E-05 | reduced-scope EPRI SMA; SSE = 0.15g | GI-199 |
| Hatch 1 | 05000400 | 0.148 | 3.9E-04 | 0.29 | 2.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Hatch 2 | 05000321 | 0.15 | 2.7E-04 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Hope Creek | 05000366 | 0.2 | 9.7E-05 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Indian Point 2 | 05000354 | 0.15 | 4.9E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Indian Point 3 | 05000247 | 0.15 | 4.9E-04 | n/a | 3.3E-05 | seismic PRA | GI-199 |
| Kewaunee | 05000286 | 0.12 | 2.8E-04 | n/a | 1.0E-04 | seismic PRA | GI-199 |
| LaSalle 1 | 05000305 | 0.2 | 1.7E-04 | n/a | 5.1E-06 | seismic PRA | GI-199 |
| LaSalle 2 | 05000373 | 0.2 | 1.7E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Limerick 1 | 05000374 | 0.15 | 1.8E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Limerick 2 | 05000352 | 0.15 | 1.8E-04 | 0.15 | 5.3E-05 | reduced-scope EPRI SMA | GI-199 |
| McGuire 1 | 05000353 | 0.15 | 9.5E-05 | 0.15 | 5.3E-05 | reduced-scope EPRI SMA | GI-199 |
| McGuire 2 | 05000369 | 0.15 | 9.5E-05 | n/a | 3.1E-05 | seismic PRA | GI-199 |
| Millstone 1 | 05000370 | 0.254 | 9.3E-05 | n/a | 3.1E-05 | seismic PRA | GI-199 |
| Millstone 2 | 05000336 | 0.17 | 8.3E-05 | 0.25 | 1.1E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Millstone 3 | 05000423 | 0.17 | 8.3E-05 | n/a | 1.5E-05 | seismic PRA | GI-199 |
| Monticello | 05000263 | 0.12 | 9.3E-05 | 0.12 | 1.9E-05 | modified focused/expended reduced-scope EPRI SMA | GI-199 |
| Nine Mile Point 1 | 05000220 | 0.11 | 1.5E-04 | 0.27 | 4.2E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Nine Mile Point 2 | 05000410 | 0.15 | 4.8E-05 | 0.23 | 5.6E-06 | SPRA and focused-scope EPRI SMA | GI-199 |
| North Anna 1 | 05000338 | 0.12 | 2.1E-04 | 0.16 | 4.4E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| North Anna 2 | 05000339 | 0.12 | 2.1E-04 | 0.16 | 4.4E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Oconee 1 | 05000269 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oconee 2 | 05000270 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oconee 3 | 05000287 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oyster Creek | 05000219 | 0.17 | 1.5E-04 | n/a | 1.4E-05 | seismic PRA | GI-199 |
| Palisades | 05000255 | 0.2 | 1.4E-04 | n/a | 6.4E-06 | seismic PRA | GI-199 |
| Palo Verde 1 | 05000528 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Palo Verde 2 | 05000529 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Palo Verde 3 | 05000530 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Peach Bottom 2 | 05000277 | 0.12 | 2.0E-04 | 0.2 | 2.4E-05 | modified focused-scope EPRI SMA | GI-199 |
| Peach Bottom 3 | 05000278 | 0.12 | 2.0E-04 | 0.2 | 2.4E-05 | modified focused-scope EPRI SMA | GI-199 |
| Perry | 05000440 | 0.15 | 2.2E-04 | 0.3 | 2.1E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Pilgrim 1 | 05000293 | 0.15 | 8.1E-04 | n/a | 6.9E-05 | seismic PRA | GI-199 |
| Point Beach 1 | 05000266 | 0.12 | 2.0E-04 | n/a | 1.1E-05 | seismic PRA | GI-199 |
| Point Beach 2 | 05000301 | 0.12 | 2.0E-04 | n/a | 1.1E-05 | seismic PRA | GI-199 |
| Prairie Island 1 | 05000282 | 0.12 | 2.0E-04 | 0.28 | 3.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Prairie Island 2 | 05000306 | 0.12 | 2.0E-04 | 0.28 | 3.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Quad Cities 1 | 05000254 | 0.24 | 8.2E-04 | 0.09 | 2.7E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Quad Cities 2 | 05000265 | 0.24 | 8.2E-04 | 0.09 | 2.7E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| River Bend | 05000458 | 0.1 | 2.4E-04 | 0.1 | 2.5E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Robinson (HR) | 05000261 | 0.2 | 1.1E-03 | 0.28 | 1.5E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| Saint Lucie | 05000335 | 0.1 | 1.4E-04 | 0.1 | 4.6E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Salem 1 | 05000389 | 0.2 | 2.6E-04 | 0.1 | 4.6E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Salem 2 | 05000272 | 0.2 | 2.6E-04 | n/a | 9.3E-06 | seismic PRA | GI-199 |
| San Onofre 2 | 05000361 | 0.67 | 1.2E-04 | n/a | 1.7E-05 | seismic PRA | IPEEE |
| San Onofre 3 | 05000362 | 0.67 | 1.2E-04 | n/a | 1.7E-05 | seismic PRA | IPEEE |
| Seabrook | 05000311 | 0.25 | 1.3E-04 | n/a | 9.3E-06 | seismic PRA | GI-199 |
| Sequoyah 1 | 05000443 | 0.18 | 7.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Sequoyah 2 | 05000327 | 0.18 | 7.1E-04 | 0.27 | 5.1E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| Shearon Harris 1 | 05000328 | 0.15 | 4.6E-05 | 0.27 | 5.1E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| South Texas 1 | 05000498 | 0.1 | 3.0E-05 | n/a | 6.2E-06 | seismic PRA | GI-199 |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| South Texas 2 | 05000499 | 0.1 | 3.0E-05 | n/a | 6.2E-06 | seismic PRA | GI-199 |
| Summer | 05000395 | 0.15 | 3.9E-04 | 0.22 | 3.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Surry 1 | 05000280 | 0.15 | 2.2E-04 | n/a | 5.7E-06 | seismic PRA | GI-199 |
| Surry 2 | 05000281 | 0.15 | 2.2E-04 | n/a | 5.7E-06 | seismic PRA | GI-199 |
| Susquehanna 1 | 05000387 | 0.1 | 1.9E-04 | 0.21 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Susquehanna 2 | 05000388 | 0.1 | 1.9E-04 | 0.21 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Three Mile Island 1 | 05000289 | 0.12 | 1.0E-04 | n/a | 4.0E-05 | seismic PRA | GI-199 |
| Turkey Point 3 | 05000250 | 0.15 | 3.8E-05 | 0.15 | 1.0E-05 | site-specific approach; SSE=0.15g | GI-199 |
| Turkey Point 4 | 05000251 | 0.15 | 3.8E-05 | 0.15 | 1.0E-05 | site-specific approach; SSE=0.15g | GI-199 |
| Vermont Yankee | 05000271 | 0.14 | 1.2E-04 | 0.25 | 8.1E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Vogtle 1 | 05000424 | 0.2 | 1.5E-04 | 0.3 | 1.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Vogtle 2 | 05000425 | 0.2 | 1.5E-04 | 0.3 | 1.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Waterford 3 | 05000382 | 0.1 | 1.1E-04 | 0.1 | 2.0E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Watts Bar | 05000390 | 0.18 | 2.9E-04 | 0.3 | 3.6E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Wolf Creek | 05000482 | 0.12 | 3.7E-05 | 0.2 | 1.8E-05 | reduced-scope EPRI SMA | GI-199 |
| | | 25th percentile | 9.6E-05 | | 6.0E-06 | | |
| | | min | 1.6E-05 | | 2.0E-06 | | |
| | | median | 1.7E-04 | | 1.5E-05 | | |
| | | mean | 3.1E-04 | | 2.1E-05 | | |
| | | max | 3.9E-03 | | 1.0E-04 | | |
| | | 75th percentile | 2.6E-04 | | 3.2E-05 | | |

## Design Basis Ground Motions and New Review Level Ground Motions Used for Review of Japanese Plants

| Plant sites | Contributing earthquakes | New DBGM $S_s$ | Original DBGM $S_2$ |
|---|---|---|---|
| Tomari | Earthquakes undefined specifically | 550 Gal | 370 Gal |
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 | 375 |
| Higashidoori | Earthquakes undefined specifically | 450 | 375 |
| Fukushima | Earthquake near the site (M7.1) | 600 | 370 |
| Tokai | Earthquakes undefined specifically | 600 | 380 |
| Hamaoka | Assumed Tokai (M8.0), etc. | 800 | 600 |
| Shika | Sasanami-oki Fault (M7.6) | 600 | 490 |
| Tsuruga | Urazoko-Uchiikemi Fault (M6.9), etc. →Mera-Kareizaki - Kaburagi(M7.8), Shelf edge+B+Nosaka (M7.7) | 800 | 532 |
| Mihama | C, Fo-A Fault (M6.9)→ Shelf edge+B+Nosaka(M7.7) | 750 | 405 |
| Ohi | C, Fo-A Fault (M6.9)→Fo-A+Fo-B （M7.4) | 700 | 405 |
| Takahama | Fo-A Fault (M6.9) →Fo-A+Fo-B(M7.4) | 550 | 370 |
| Shimane | Shinji Fault (M7.1) | 600 | 456 |
| Ikata | Central Tectonic Structure (M7.6) | 570 | 473 |
| Genkai | Takekoba F. （M6.9) → Enhanced uncertainty consideration | 540 | 370 |
| Sendai | Gotandagawa F.(M6.9), F-A(M6.9) | 540 | 372 |
| Kashiwazaki-Kariwa | F-B Fault (M7.0), Nagaoka-plain-west Fault (M8.1) | 2300 (R1 side)<br>1209 (R5 side) | 450 |
| Monjyu (Proto Type FBR) | Shiraki-Niu F.(M6.9) , C F.(M6.9)→Shelf edge+B+Nosaka(M7.7), Small Damping | 760 | 408 |
| Shimokita Reprocessing F. | Deto-Seiho F.(M6.8), Yokohama F.(M6.8) | 450 | 320 |

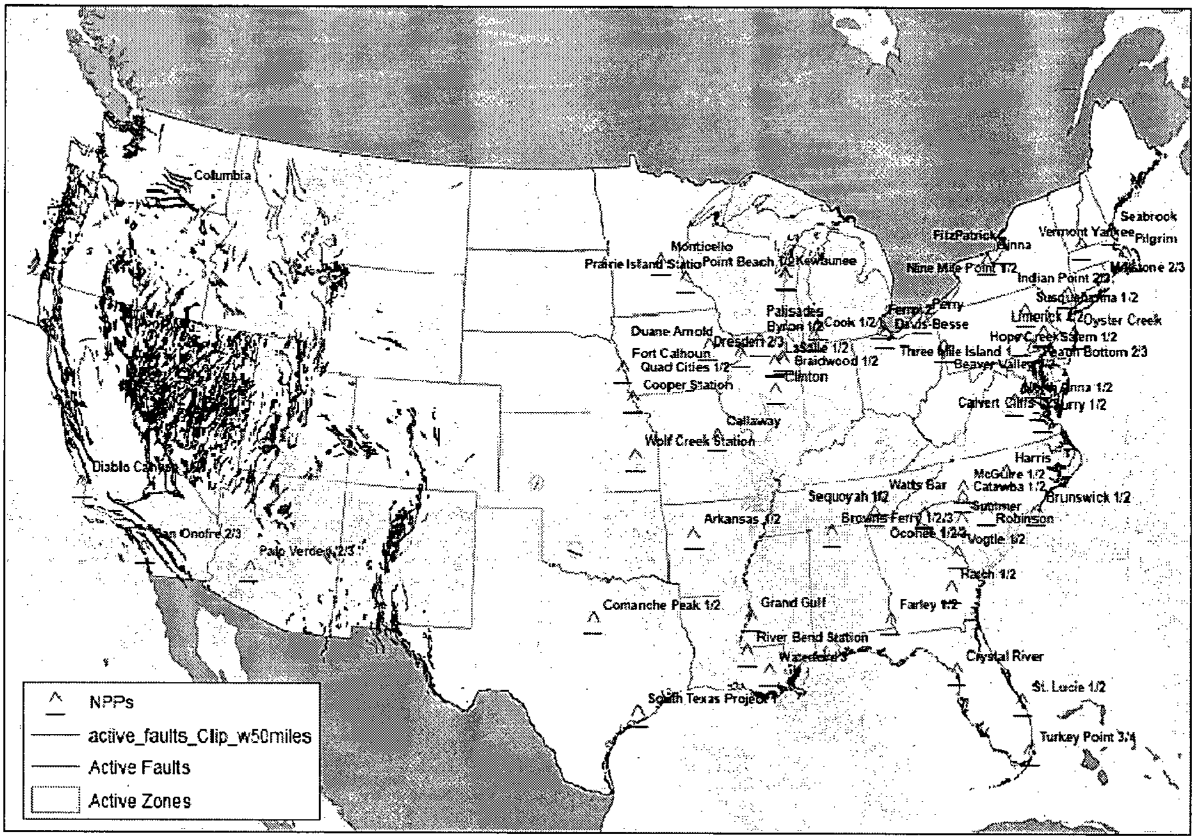
## Status of Review of Japanese NPPs to New Earthquake Levels Based on 2006 Guidance

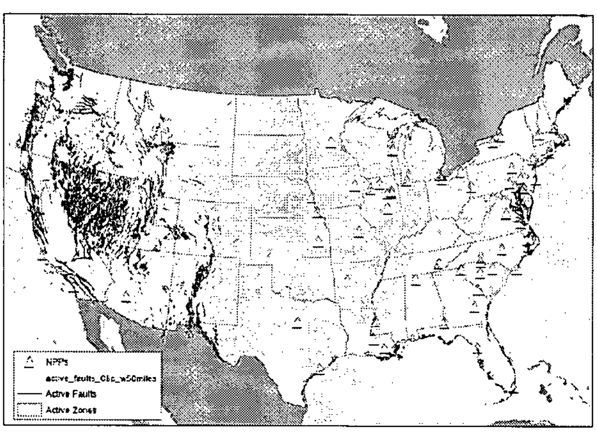
| Utility | Site (Unit) | Type | Dec.2010 |
|---|---|---|---|
| Hokkaido | Tomari | PWR | △ |
| Tohoku | Onagawa (Unit1) | BWR | ◎ |
| | Higashi-dori | BWR | △ |
| Tokyo | Kashiwazaki-Kariwa | BWR | Unit 1,5,6,7 ◎ |
| | Fukushima-No1 | BWR | Unit 3 ◇, 5 ◎ |
| | Fukushima-No2 | BWR | Unit 4,5 ◎ |
| Chubu | Hamaoka | BWR | △ |
| Hokuriku | Shika (Unit 2) | BWR | ◎ |
| Kansai | Mihama(Unit 1) | PWR | ◎ |
| | Ohi(Unit 3,4) | PWR | ◎ |
| | Takahama （Unit 3,4) | PWR | ◎ |
| Chugoku | Shimane (Unit 1, 2) | BWR | ◎ |
| Shikoku | Ikata (Unit 3) | PWR | ◎ |
| Kyushu | Genkai (Unit 3 ) | PWR | ◎ |
| | Sendai (Unit 1) | PWR | ◎ |
| Japan Atomic Power | Tokai-Daini | BWR | ○ |
| | Tsuruga | BWR/PWR | △ |
| JAEA | Monjyu | Proto Type FBR | ◎ |
| Japan Nuc. Fuel | Rokkasyo | Reprocessing | ◎ |
| ◎: NSC review finished, ○: NISA review finished and in NSC review, △: Under review by NISA | | | |

## Additional Information: Useful Plots

### Plot of Mapped Active Quaternary Faults and Nuclear Plants in the US

It is important to note that this plot somewhat misleading as faults in the central and eastern US are not well characterized. For example, the faults responsible for very large historic events, such as the 1811 and 1812 New Madrid Earthquakes, and the 1886 Charleston Earthquakes have not been conclusively located.



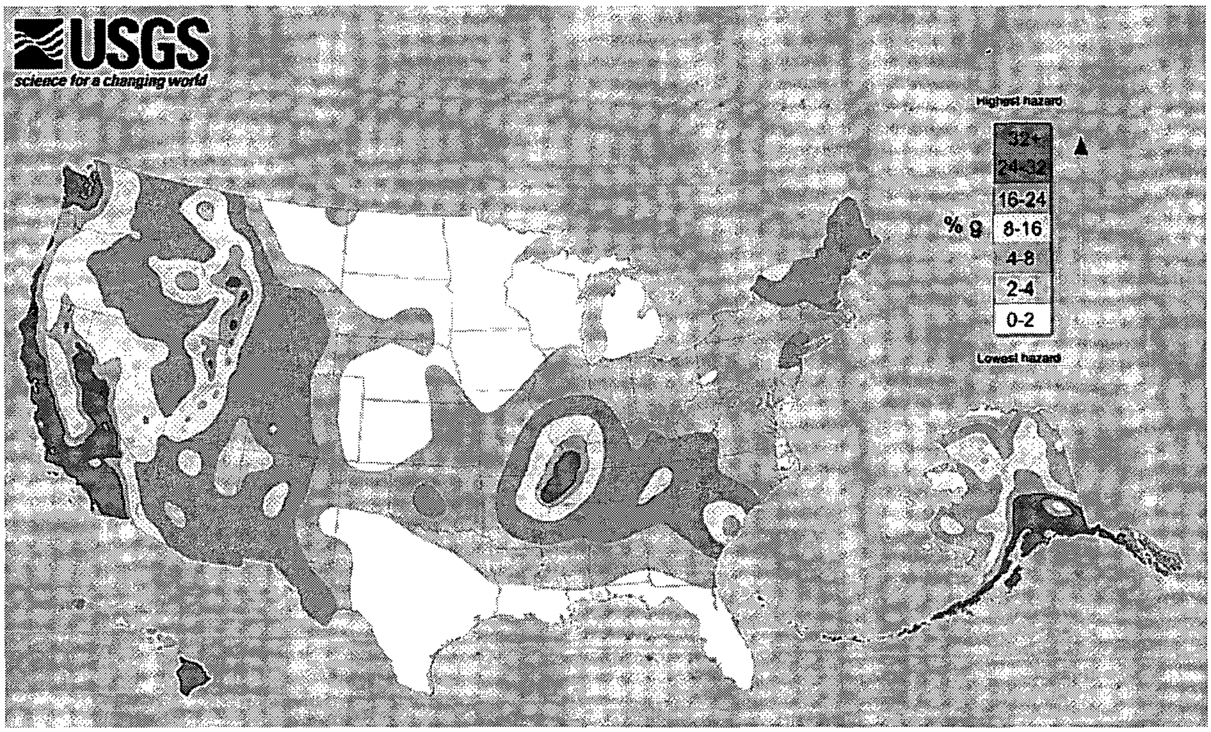



## Nuclear Plants in the US Compared to the USGS National Seismic Hazard Maps

Dogan to create the map

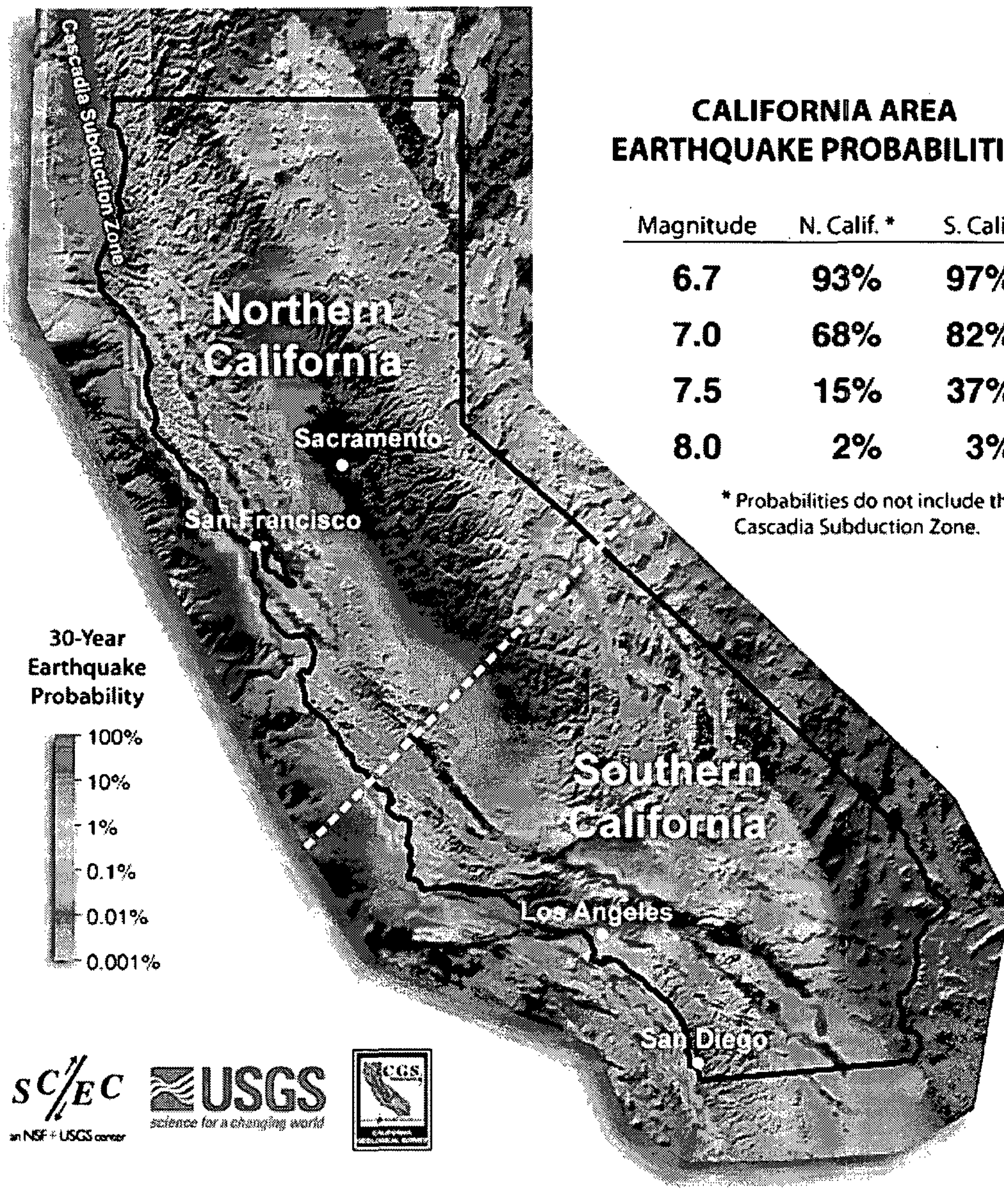
## USGS US National Seismic Hazard Maps

Many version of this map are available at the USGS website at http://earthquake.usgs.gov/hazards/



## UCERF Map of California Earthquake Probabilities for Northern versus Southern California

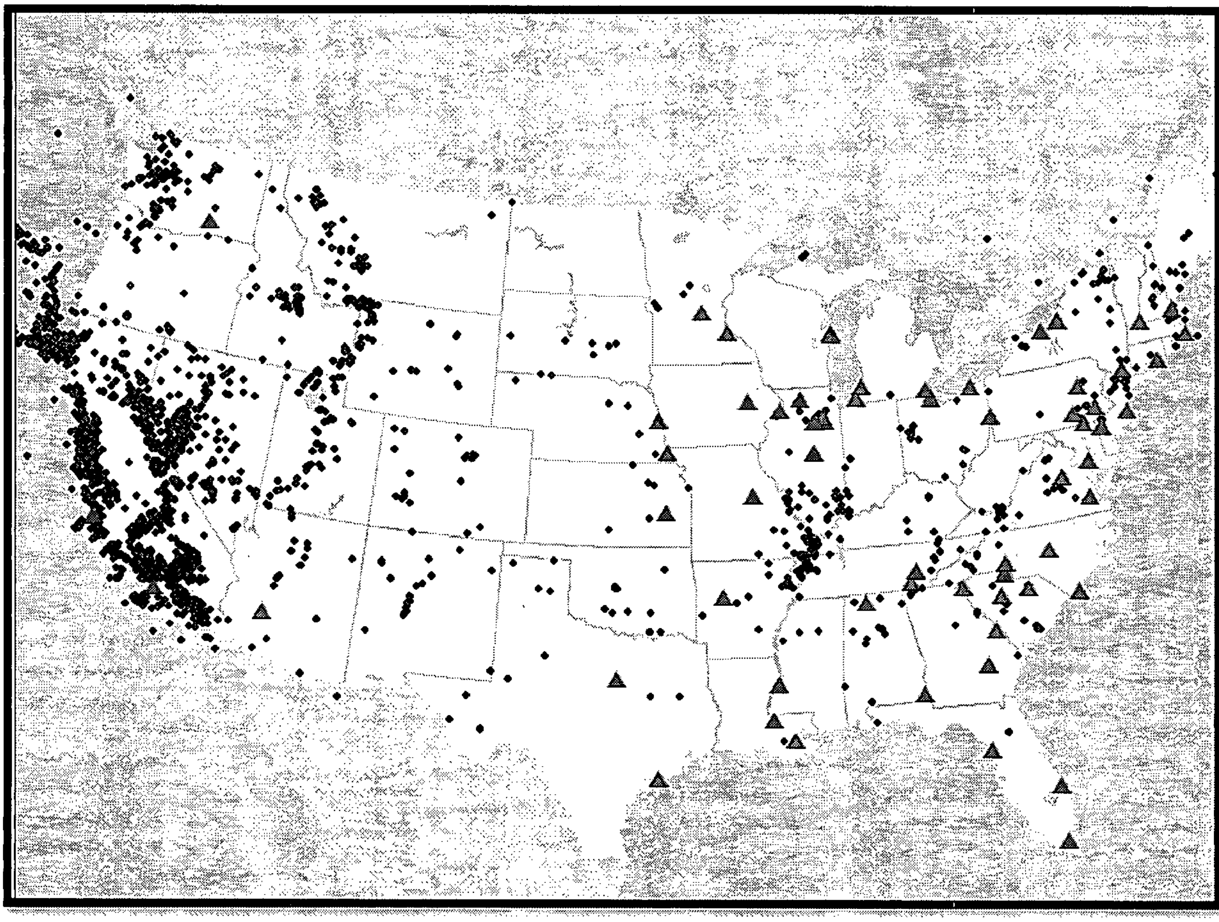
This is included in this document as Markey (inappropriately) used the below statistics to say that the probability of a magnitude 7 at SONGS was 82%. The dashed line of this California map is the boundary between northern and southern California used in the UCERF study. As shown in the table, the 30-year probability of an earthquake of magnitude 7.5 or larger is higher in the southern half of the state (37%) than in the northern half (15%).




| Magnitude | N. Calif. * | S. Calif. |
|---|---|---|
| 6.7 | 93% | 97% |
| 7.0 | 68% | 82% |
| 7.5 | 15% | 37% |
| 8.0 | 2% | 3% |

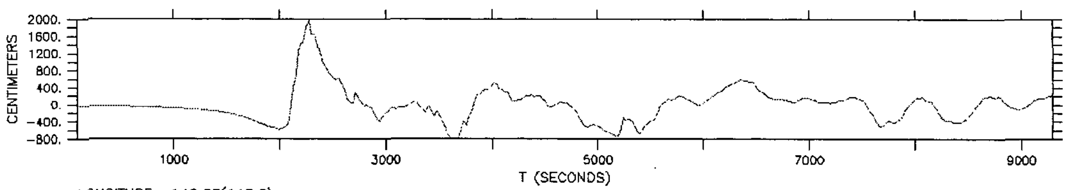
## Plot of Nuclear Plants in the US Compared to Recent Earthquakes

Not sure of the date on this...It's an awesome plot. can we get this updated with a date? Who made this originally (NRO?RES?)



## Plot of Tsunami Wave Heights at the Japanese Plants (NOAA)

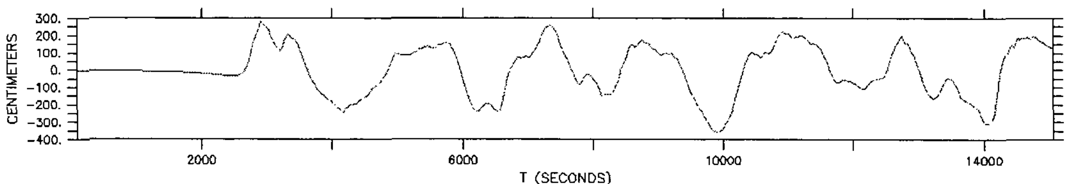
These are results from high-resolution models run by PMEL NOAA staff, who do modeling for the tsunami warning system. While the available bathymetry and topography data used in the model are not of the highest quality at that location, NOAA has confidence in the results, which show good comparisons between model flooding estimates and inundation observations inferred from satellite images. DART measurements are used in the modeling. The images show model time series very close to a shoreline, at about 5m depth. The runup heights (maximum elevation of flooded area) may be different from these amplitudes at shoreline (can be higher or lower, depending on the topographic profile).




LONGITUDE : 140.6E(140.6)
LATITUDE : 36.5N

Onagawa
Linear Combination of files

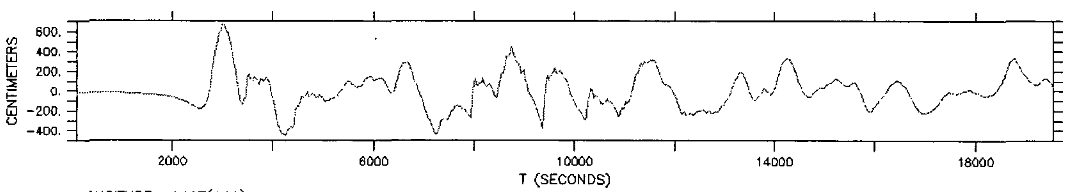
DATA SET: tokai2_runup_ha




LONGITUDE : 141E(141)
LATITUDE : 37.3N

Tokai
Linear Combination of files

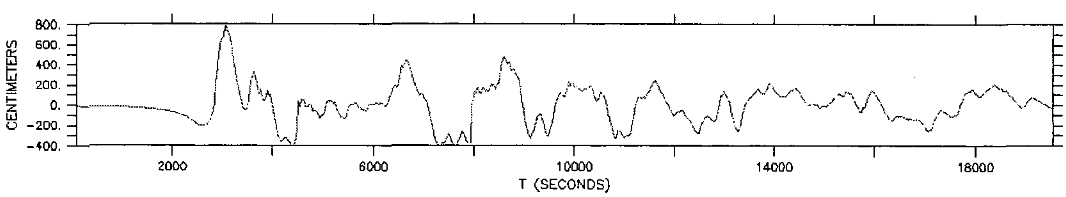
DATA SET: sendai2_runup_ha



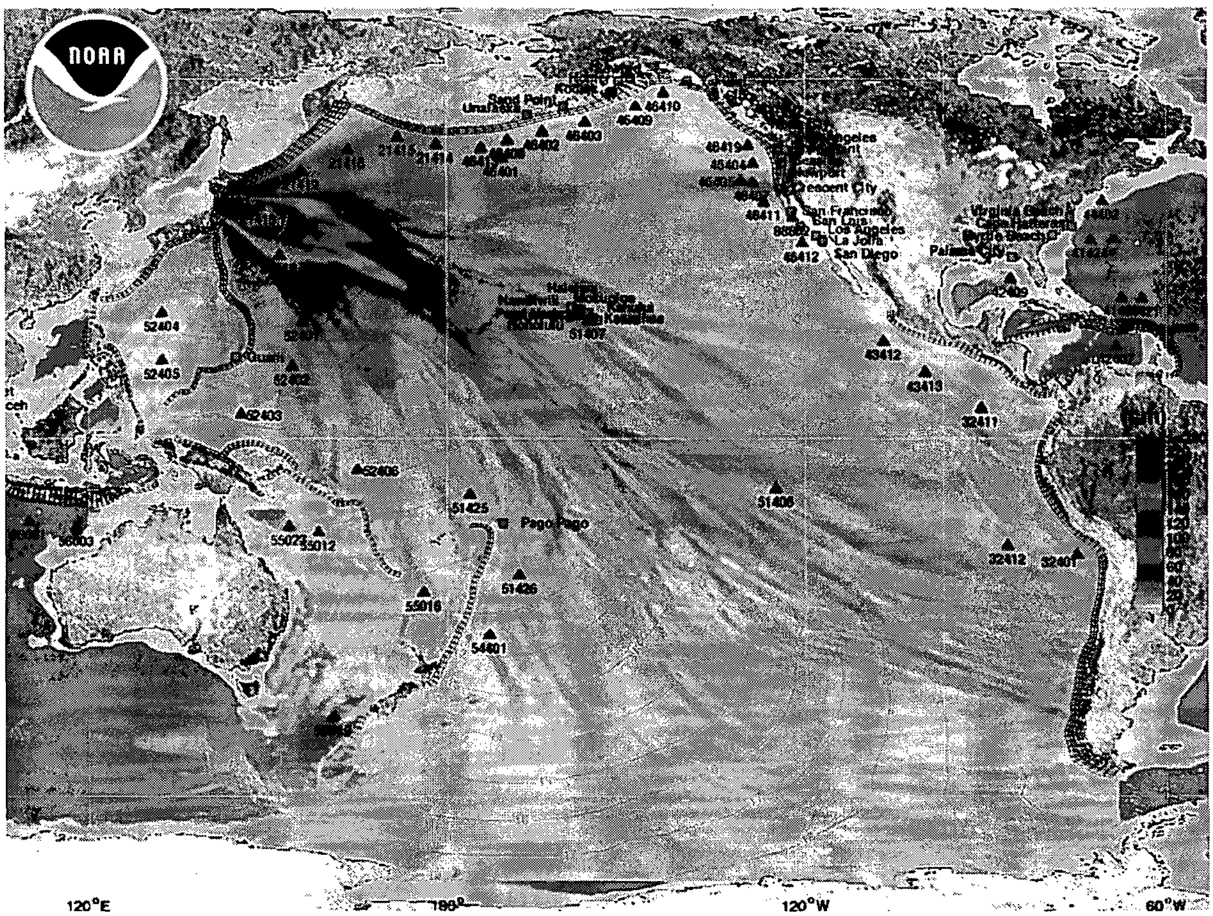

LONGITUDE : 141E(141)
LATITUDE : 37.4N

Fukushima Daini
Linear Combination of files

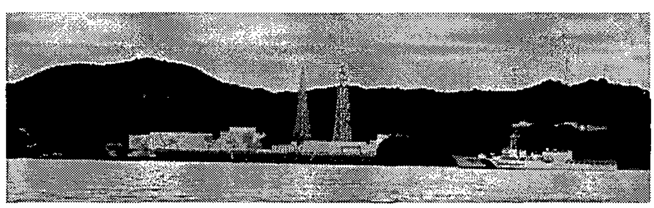
DATA SET: sendai2_runup_ha




Fukushima Daiichi




This shows the effect on the US coastline.



I found the numbers at the Onagawa plant unimaginable, so I found a side view picture. It's hard to tell the elevation.

# Additional Information: Fact Sheets

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (High level overview)

The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations: 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part, which describes the general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that that the structures and components in nuclear power plants be designed to withstand the effects of natural phenomena, including earthquakes and tsunamis, without loss of capability to perform their intended safety functions. GDC 2 also requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The earthquake which could cause the maximum vibratory ground motion at the site is designated as the **Safe Shutdown Earthquake (SSE)**. Under SSE ground motions, nuclear power plant structures and components must remain functional and within applicable stress, strain, and deformation limits. Each plant must also have seismic instrumentation to determine if the **Operating Basis Earthquake (OBE)**, typically one-half or one-third the level of the SSE, has been exceeded. If the OBE is exceeded or significant plant damage has occurred, then the nuclear power plant must be shutdown.

Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of the earthquake, the distance of the earthquake to the site, and the local geology. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant. This required an assessment of earthquakes that had occurred in the region around each plant site.

Design basis loads for nuclear power plant structures include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Society of Mechanical Engineers, the American Concrete Institute, and the American Institute of Steel Construction, are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

In the mid to late 1990s, NRC staff reviewed the potential consequences of severe earthquakes (earthquakes beyond the safety margin included in each plant's design basis), as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs. Currently, the NRC staff is reassessing the seismic designs of operating plants through our Generic Issues program. The initial results of this assessment found that: 1) seismic hazard estimates have increased at some operating plants in the central and eastern US; 2) there is no immediate safety concern, plants have significant safety margin and overall seismic risk estimates remain small; and 3) assessment of updated seismic hazards and plant performance should continue.

# Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (The policy wonk version)

(Jon to clean up upon his return from vaca) NRC's regulatory framework for seismic safety of nuclear reactors and facilities is based on: reactor site suitability with respect to geological, seismological, hydrological and other site specific hazards; classification of structures, systems and componenets (SSCs) as Seismic Category I, seismic design of Seismic Category I SSCs, seismic and environmental qualification of Category I SSCs; and maintenance and in-service inspection of equipment and structures, including the containment structure. The NRC's regulatory framework with respect to seismic issues has evolved through time.

**Currently Operating Reactors (licensed prior to 1997):**

The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations: 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part which describes general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that that the SSCs important to safety be designed to withstand the effects of natural phenomena, including earthquakes, tsunamis, and seiches without loss of capability to perform their intended safety functions. GDC 2 requires that the design bases shall include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, and shall consider appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena. The earthquake which could cause the maximum vibratory ground motion at the site is designated the **Safe Shutdown Earthquake (SSE)**.

Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of an earthquake and the distance from the fault to the site. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant based on an assessment of earthquakes that had occurred in the region historically. There is no specification of frequency of occurrence in the deterministic approach. There is no requirement for a periodic reassessment of the seismic design basis.

Paragraph VI(a)(3) of Appendix A requires that suitable seismic instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be determined promptly after an earthquake to permit comparison of such response to that used as the design basis. Such a comparison is needed to decide whether the plant can continue to be operated safely and to permit appropriate action in a timely manner. Appendix A requires thatin addition to seismic loads, including aftershocks, applicable concurrent functional and accident induced loads shall be taken into account in the design of safety-related SSCs. Paragraph VI(c) requires that seismically induced flood, water waves from either locally or distantly generated seismic activity and other design conditions shall be taken into account in nuclear power plant design.

**Proposed New Reactors (submitted after 1997):**

In 1997 new rules governing reactor siting were established. 10 CFR Part 50 Appendix A (GDC 2), 100.23 and Appendix S establish the seismic design basis for plants licensed after January 10,1997. Similar to

pre-1997, Appendix S defines the SSE as *"the Safe-shutdown earthquake ground motion* is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional." 10 CFR Part 100.23 "Geologic and Seismic Siting Criteria" requires that the applicant determine the SSE **and its uncertainty**, the potential for surface tectonic and nontectonic deformations. Regulatory Guide 1.165 (and subsequently Regulatory Guide 1.208) provides guidance on satisfying 10 CFR Part 100.23, one of which is performing a probabilistic seismic hazard assessment (**PSHA**).

Appendix S to 10 CFR Part 50 requires for SSE ground motions, SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motions. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation elevation of structures must be an appropriate response spectrum with a peak ground acceleration (PGA) of at least 0.10g. Design basis loads for nuclear power plant structures, important to safety, include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the ASME B&PV Code, the American ~~Institute of~~ Concrete Institute (ACI-359/ASME Section III Division 2, ACI-349) and the American Institute of Steel Construction (AISC N690), are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

In contrast to the deterministic approach used prior to 1997, the probabilistic method is used and explicitly accounts for possible earthquakes of various magnitudes that come from all plausible potential sources (including background seismicity) and the likelihood that each particular hypothetical earthquake occurs. The PSHA process provides a complete characterization of the ground motion and comprehensively addresses uncertainties in nuclear power plant seismic demands. The PSHA results are major input to seismic risk evaluation using either SPRA or SMA approaches. As for plants licensed prior-to 1997, there is no requirement for a periodic reassessment of the seismic design basis.

In addition to the nominal seismic design, all new generation reactors have to demonstrate a **Seismic margin of 1.67** relative to the site-specific seismic demands. These designs are required to perform a Probabilistic Risk Assessment (PRA) based seismic margins analysis (SMA) to identify the vulnerabilities of their design to seismic events. The minimum high confidence, low probability of failure (HCLPF) for the plant should be at least 1.67 times the ground motion acceleration of the design basis safe-shutdown earthquake (SSE).

The Standard Review Plan (NUREG-0800), Regulatory Guides and Interim Staff Guidance provide the basis for staff reviews of existing reactors and new license applications. Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. Paragraph 10 CFR 50.54(ff) and Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) occurs. The OBE is typically one-half or one-third the level of the SSE. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after occurrence of the OBE, the licensee must consult with the NRC and must propose a plan for the timely, safe shutdown of the nuclear power plant. Paragraph IV(c) requires that seismically induced flood, water waves from either locally or distantly generated seismic activity and other design conditions shall be taken into account in nuclear power plant design so as to prevent undue risk to health and safety of the public.

# Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (The cliff notes)

NRC Regulations and Guidelines for Seismic Safety:

- The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations:
  - 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and
  - 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part, which describes the general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.
- In addition, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that:
  - The structures and components in nuclear power plants be designed to withstand the effects of natural phenomena, including earthquakes and tsunamis, without loss of capability to perform their intended safety functions.
  - GDC 2 also requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
    - The earthquake which could cause the maximum vibratory ground motion at the site is designated as the **Safe Shutdown Earthquake (SSE)**. Under SSE ground motions, nuclear power plant structures and components must remain functional and within applicable stress, strain, and deformation limits.
    - Each plant must also have seismic instrumentation to determine if the **Operating Basis Earthquake (OBE)**, typically one-half or one-third the level of the SSE, has been exceeded. If the OBE is exceeded or significant plant damage has occurred, then the nuclear power plant must be shutdown.

Plant Design /Design Basis (Seismic):

- Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of the earthquake, the distance of the earthquake to the site, and the local geology. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant.. This required an assessment of earthquakes that had occurred in the region around each plant site.
- Design basis loads for nuclear power plant structures include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Society of Mechanical Engineers, the American Concrete Institute, and the American Institute of Steel Construction, are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

# Fact Sheet: Summarization of the NRC's Regulatory Framework for Tsunami

**Review Guidance and Guidelines Related to Tsunami:**

1. General Design Criterion 2 (GDC 2), 10CFR50, requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Design bases for these SSCs are also required to reflect:
2. 10 CFR 100.23, requires, in part, that the size of seismically induced floods and water waves that could affect a site from either locally or distantly generated seismic activity must be determined.
3. RG 1.102 – Flood Protection for Nuclear Power Plants, describes types of flood protection acceptable to the NRC staff
    a. Exterior Barriers (e.g.)
        i. Levee – embankment to protect land from inundation
        ii. Seawall or floodwall - a structure separating land and water areas, primarily to prevent erosion and other damages due to wave action
        iii. Bulkhead – similar to seawall, purpose is to restrain the land area
    b. Incorporated Barriers
        i. Protection provided by specially designed walls and penetration closures. Walls are usually reinforced concrete designed to resist static and dynamic forces of a Design Basis Flood Level of a Probable Maximum Flood.
4. RG 1.59 – Design Basis Floods for Nuclear Power Plants
    a. The most severe seismically induced floods reasonably possible should be considered for each site.
    b. Tsunami requires consideration of seismic events of the severity of the Safe Shutdown Earthquake occurring at the location that would produce the worst such flood at the nuclear power plant site.
5. US NRC, Standard Review Plan, "Probable Maximum Tsunami Flooding," Section 2.4.6, Rev. 2
    a. Areas of Review
        i. Probable maximum tsunami postulated for a site should include wave runup and drawdown
        ii. Hydrologic characteristics of maximum locally and distantly generated tsunami (e.g., volcanoes, landslides)
        iii. Geological and seismic characteristics of potential tsunami faults (e.g., magnitude, focal depth, source dimensions, fault orientation, and vertical displacement)

**Questions and Answers for Tsunami Issues**

### 134) Why do we have confidence that US nuclear power plants are adequately designed for earthquakes and tsunamis?

Nuclear plants in both the US and Japan are designed for earthquake shaking. In addition to the design of the plants, significant effort goes into emergency response planning and accident mitigation. This approach is called defense-in-depth.

### 135) Are nuclear power plants designed for tsunamis?

Yes. Plants are built to withstand a variety of environmental hazards and those plants that might face a threat from tsunami are required to withstand large waves and the maximum wave height at the intake structure (which varies by plant.)

### 136) What level of tsunami are we designed for?

Like seismic hazard, the level of tsunami that each plant is designed for is site-specific and is appropriate for what may occur at each location.

### 137) Can this happen here (i.e., an earthquake that significantly damages a nuclear powerplant)? Are the Japanese plants similar to US plants?

All US nuclear power plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events.

The Japanese facilities are similar in design to several US facilities

### 138) How many reactors are along coastal areas that could be affected by a tsunami (and which ones)?

Many plants are located in coastal areas that could potentially be affected by tsunami. Two plants, Diablo Canyon and San Onofre, are on the Pacific Coast, which is known to have tsunami hazard. There are also two plants on the Gulf Coast, South Texas and Crystal River. There are many plants on the Atlantic Coast or on rivers that may be affected by a tidal bore resulting from a tsunami. These include St. Lucie, Turkey Point, Brunswick, Oyster Creek, Millstone, Pilgrim, Seabrook, Calvert Cliffs, Salem/Hope Creek, and Surry. Tsunami on the Gulf and Atlantic Coasts occur, but are very rare.

Generally the flooding anticipated from hurricane storm surge exceeds the flooding expected from a tsunami for plants on the Atlantic and Gulf Coast.

# Fact Sheet: Summarization of the NRC's Regulatory Framework for Flooding

**Flooding Issues:**

1. General Design Criterion 2 (GDC 2), 10CFR50, requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Design bases for these SSCs are also required to reflect:
   b. Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding region, with sufficient margin for the limited accuracy and quantity of the historical data and the period of time in which the data have been accumulated.
   c. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.
   d. The importance of the safety functions to be performed.
6. Design basis floods for most of the present fleet of operating reactors were calculated using deterministic methods to determine the maximum credible flood levels at the site. These deterministic methods include the site specific calculation of parameters such as the probable maximum precipitation, which is defined as the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin. Other potential flooding hazards such as flooding due to storm surge, river flooding, coastal flooding including tsunamis, are evaluated at each site using maximum credible levels from each hazard. Over the life of the operating reactor, if new information becomes available that could affect the design basis, licensees are required to evaluate the new information. Based on this review, if needed, licensees are required to take appropriate mitigation measures, update their final safety analysis report and submit it to the NRC for review and approval.
7. In order to impose new requirements on existing plants, the NRC must be able to justify the new requirements in accordance with the "Backfit Rule" (10 CFR 50.109).

**Questions and Answers for Flooding Issues**

### 139) Does the NRC consider severe floods in the design of nuclear power plants?

Yes. NRC regulations require that nuclear power plants are, at all times, capable of safely shutting down and maintaining a safe shutdown condition under severe flooding situations. Safety-related Structures, Systems and Components (SSCs) of Nuclear reactors in the U.S. are required to withstand the design basis flood (DBF). The design basis flood may be caused by the following natural Phenomena:

1) Intense rainfall occurring at the site (known as local intense precipitation).
2) Intense rainfall (known as the Probable Maximum Precipitation) occurring on other areas of the watershed leading to riverine or coastal flooding (known as Probable Maximum Flood" or "PMF".
3) Floods from upstream dam failure or a combination of upstream dam failures.
4) Failure of On-site Water Control or Storage Structures (i.e. tanks).
5) Storm Surge, Seiche and Tsunami including wave effects.(**See Tsunami Q&A Sheet**)
6) Flooding caused by ice effects (i.e. ice dams both upstream and downstream).
7) Floods caused by diversions of stream channels toward the site.

8) Other potential site specific flood hazard(s).

**140) What about droughts and conditions which lead to low water? Are these considered?**

Yes. Impacts to the plant from low water conditions brought about by ice effects, downstream dam breach, tsunamis, hurricanes and channel diversions away from the site are reviewed to ensure the plant remains safe under these scenerios.

**141) Periods of long rainfall can cause the groundwater elevation to rise which can cause structures such as deeply embedded tanks to fail due to buoyancy. Are nuclear power plants designed to withstand this effect?**

Yes. Worst-case groundwater levels are estimated for each site and the impacts of these levels are considered in the design of the plant to ensure the plant remains safe under these conditions. During the safety review, impacts due to groundwater levels and other hydrodynamic effects on the design bases of plant foundations and other safety-related structures systems and components (SSCs) are evaluated. Impacts to a safety-related structure such as a deeply embedded tank or a structure containing a deeply embedded tank are considered in the safety review.

**142) Some of the Reports from the National Weather Service used to estimate the design precipitation are 30-40 years old. Are these estimates still valid?**

The NRC has funded research by the U.S. Bureau of Reclamation to review the information and methods developed by the National Weather Service and the U.S. Army Corps of Engineers (HMR 51), focusing on South and North Carolina. To date, reviews of precipitation records from extreme storm events (e.g., tropical storms, hurricanes) since the publication of HMR 51 does not indicate any exceedance or potential for exceedance of those precipitation (PMP) estimates in this region. We have not seen any information or data that would indicate that HMR precipitation (PMP) estimates for the U.S. have been exceeded. As expected, individual point rainfall gauges have recorded rainfall amounts that have exceeded these areal estimates.

## Fact Sheet: Summarization of Seismological Information from Regional Instrumentation

Placeholder: to be developed.

## Fact Sheet: Protection of Nuclear Power Plants against Tsunami Flooding

Nuclear power plants are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The word tsunami literally means harbor wave. Tsunamis can be generated by large offshore earthquakes (usually greater than magnitude 6.5), submarine or on shore land slides or volcanoes. Some large onshore earthquakes close to the shoreline can generate tsunami. The Nuclear Regulatory Commission (NRC) requires all nuclear power plants to be protected against earthquakes, tsunamis and other natural hazards.

**Background**

Protection against tsunami effects was required for all operating plants and is required for all new reactors. Following the Indian Ocean tsunami on December 26, 2004, the President moved to protect lives and property by launching an initiative to improve domestic tsunami warning capabilities. This plan was placed under the auspices of the National Science and Technology Council through the President's initiative in July 2005 in the context of a broad national effort of tsunami risk reduction, and United States participated in international efforts to reduce tsunami risk worldwide. In response to the president's initiative, the NRC reviewed its licensing criteria and conducted independent studies and participated in international forums under the auspices of the International Atomic Energy Agency with many participating countries including India and Japan. The final report of the study was published in April 2009 as NUREG/CR 6966, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America," ADAMS Accession # ML0915901933. NRC revised its Standard Review Plan for conducting safety reviews of nuclear power plants in 2007. Section 2.4.6 specifically addresses tsunamis. The Office of Nuclear Regulatory Research is conducting tsunami studies in collaboration with the United States Geological Survey and has published a report on tsunami hazard in the Atlantic, Gulf and Pacific coastal areas. Selected nuclear power plants now get tsunami warning notification. The agency requires plant designs to withstand the effects of natural phenomena including effects of tsunamis. The agency's requirements, including General Design Criteria for licensing a plant, are described in Title 10 of the *Code of Federal Regulations* (10 CFR). These license requirements consist of incorporating margins in the initiating hazard and additional margins are due to traditional engineering practices such as "safety factors." Practices such as these add an extra element of safety into design, construction, and operations.

The NRC has always required licensees to design, operate, and maintain safety-significant structures, systems, and components to withstand the effects of natural hazards and to maintain the capability to perform their intended safety functions. The agency ensures these requirements are satisfied through the licensing, reactor oversight, and enforcement processes.

**Tsunami Hazard Evaluation**

Tsunami hazard evaluation is one component of the complete hydrological review requirements provided in the Standard Review Plan under Chapter 2.4. The safety determination of reactor sites require consideration of major flood causing events, including consideration of combined flood causing conditions. These conditions include Probable Maximum Flood (PMF) on Streams and Rivers, Potential Dam Failures, Probable Maximum Surge and Seiche Flooding and Probable Maximum Tsunami Hazards, among others. The most significant flooding event is called the design basis flood and flooding protection requirements are correlated to this flood level in 2.4.10.

The Probable Maximum Tsunami (PMT) is defined as that tsunami for which the impact at the site is derived from the use of best available scientific information to arrive at a set of scenarios reasonably expected to affect the nuclear power plant site taking into account (a) appropriate consideration of the most severe of the natural phenomena that have been historically reported or determine from geological and physical data for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (b) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (c) the importance of the safety functions to be performed.

Site-specific tsunami data are collected from historical tsunami records, paleotsunami evidence, regional tsunami assessments, site-specific tsunami mechanisms, site-specific data, such as submarine survey of sea bed and approach channel geometry. Effects of tsunami on a nuclear power plant can be flooding due to water run up, hydro-dynamic pressure on exterior walls of structures, impact of floating debris, and foundation scouring. In addition, tsunami can draw down water from the intake source of plant cooling water.

The tsunami database is available for interactive search and downloads on the internet at http://www.ngdc.noaa.gov/hazard/tsu.shtml.

**Tsunami Safety Assessment**

The licensing bases for existing nuclear power plants are based on historical data at each site. This data is used to determine probable maximum tsunami and the tsunami effects are evaluated for each site with potential for tsunami flooding. The potential for tsunami hazard is determined on a hierarchical analysis process that can identify tsunami potential based primarily on distance from tsunami source and site elevation. The NRC also required existing plants to assess their potential vulnerability to external events, as part of the Individual Plant Examination of External Events Program. This process ensured that existing plants are not vulnerable to tsunami hazard, and they continue to provide adequate public health and safety.

Today, the NRC utilizes a risk-informed regulatory approach, including insights from probabilistic assessments and traditional deterministic engineering methods to make regulatory decisions about existing plants (e.g., licensing amendment decisions). Any new nuclear plant the NRC licenses will use a probabilistic, performance-based approach to establish the plant's seismic hazard and the seismic loads for the plant's design basis.

**Operating Plants**

The NRC is fully engaged in national international tsunami hazard mitigation programs, and is conducting active research to refine the tsunami sources in the Atlantic, Gulf Coast and Pacific Coast areas. Diablo Canyon (DC) and San Onofre (SONGS) are two nuclear plant sites that have potential for tsunami hazard. Both the DC (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at DC are designed for combination of tsunami-storm wave activity to 45 ft msl. SONGS has a reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action, designed to protect at approximately 27 ft msl. These reactors are adequately protected against tsunami effects. Distant tsunami sources for DC include the Aleutian area, Kuril-Kamchatka region, and the South American coast (for Songs the Aleutian area). Distant sources for SONGS is limited by the presence of a broad continental shelf. Local or near sources for DC include the Santa Lucia Bank and Santa Maria Basin Faults (for Songs the Santa Ana wind).

**Additional Information**

To read more about risk-related NRC policy, see the fact sheets on Probabilistic Risk Assessment (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/probabilistic-risk-asses.html) and Nuclear Reactor Risk (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/reactor-risk.html). Each provides more information on the use of probability in evaluating hazards (including earthquakes) and their potential impact on plant safety margins. Other regulatory framework includes General Design Criterion 2, 10 CFR Part 100.23, Regulatory Guide 1.102 "Flood Protection for Nuclear Power Plants", Rev. 1 1976, Regulatory Guide 1.59 "Design Basis for Nuclear Power Plants" Rev. 2 1977 (update in progress), and USNRC Standard Review Plan "Probable Maximum Tsunami Flooding" Section 2.4.6, Rev. 2.

March 2011

INFORMATION FROM RES STILL NEEDS TO BE ADDED

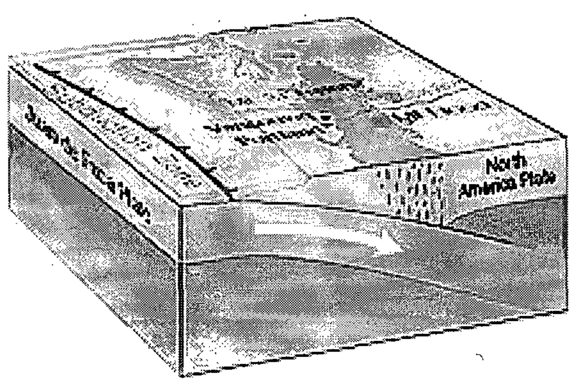
## Fact Sheet: Seismicity of the Central and Eastern US

**Key Points**:

- To date, very large earthquakes (Magnitudes greater than 8.25) have only occurred in specific geological settings, in particular the interfaces between tectonic plates in major **subduction zones**. The only subduction zone that potentially impacts the continental US is the Cascadia zone off the coast of northern California, Oregon and Washington.
- Recent analyses of the magnitudes of the largest earthquakes **not associated** with subduction zones indicates magnitudes are less than ~8.25.
- The size (magnitude) of earthquakes is proportional to the fault area that slips in a given earthquake. The prediction of earthquake magnitudes for a specific fault considers the dimensions of the fault. Extremely large earthquakes do not occur on small faults.
- Nuclear power plants are licensed based on vibratory ground shaking, not earthquake magnitude. The ground shaking (accelerations) are used to estimate forces which are used in the seismic design process. In many cases smaller magnitude earthquakes closer to a site produce more severe ground shaking than larger, more distant earthquakes. Hence it is important to consider all potential earthquake sources regardless of magnitude.

**Discussion:** Earthquakes with very large magnitudes such as the March 2011 earthquake off the northeast coast of the Japanese island of Honshu occur within subduction zones, which are locations where one of the earth's tectonic plates is subducting beneath (being thrust under) another. The fault that defines the Japan Trench plate boundary dips to the west, i.e., becomes deeper towards the coast of Honshu. Large offshore earthquakes have historically occurred in the same subduction zone (in 1611, 1896, and 1933) all of which produced significant tsunami waves. The magnitudes of these previous large earthquakes have been estimated to be between 7.6 and 8.6. Prior to March 2011, the Japan Trench subduction zone has produced nine earthquakes with magnitudes greater than 7 just since 1973.

The only subduction zone that is capable of directly impacting the continental US is the Cascadia subduction zone, which lies off of the coast of northern California, Oregon, and Washington. The fault surface defined by this interface dips to the east (becomes deeper) beneath the coast. The Cascadia subduction zone is capable of producing very large earthquakes if all or a large portion of the fault area ruptures in a single event. However, the rate of earthquake occurrence along the Cascadia subduction zone is much less than has been observed along the Japan Trench subduction zone. The only operating nuclear power plant in that area is Columbia, which is far from the coast (~220 miles/350 km) and the Cascadia subduction zone. *The occurrence of earthquakes on the Cascadia subduction zone has been considered in the evaluation of the Columbia NPP.*



Schematic Illustration of the Cascadia Subduction Zone

The size (magnitude) of earthquakes is proportional to the surface area of a fault that slips in a given earthquake. Large earthquakes are associated with large (long) faults. Hence, the prediction of earthquake magnitudes for a specific fault considers the dimensions of the fault. Identification of fault size is usually based on geologic mapping or the evaluation of spatial patterns of small earthquakes. To provide **a point of comparison**, the length of the fault that slipped during the March 11, 2011 magnitude 9 Japanese earthquake was >620 km, the length of the fault(s) that slipped during the magnitude 7.3 1992 Landers, CA earthquake was ~90 km and the estimated length of the Hosgi fault near Diablo Canyon NPP is 140 km and a magnitude of 7.5 is assigned to that fault. A number of major crustal faults or fault zones (not associated with the Cascadia subduction zone) have been identified that have produced earthquakes of magnitude 7.5 to 8 in the continental US (including California). ***These fault sources have been identified and characterized in seismic hazard assessments.***

Seismic designs at US nuclear power plants are developed in terms of seismic ground motion spectra, which are called the Safe Shutdown Earthquake ground motion response spectra (SSE). Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location. Currently operating nuclear power plants developed their SSEs based on a "deterministic" or "scenario earthquake" basis that account for the largest earthquake expected in the area around the plant. Seismic activity in the regions surrounding US plants is much lower than that for Japan since **most US plants are located in the interior of the stable continental US** The largest earthquakes within the continental US are the 1811-12 New Madrid sequence and the 1886 Charleston, SC, which were estimated to be between about magnitude 6.8 to 7.5. On the west coast of the US, the two nuclear power plants are designed to specific ground motions from earthquakes of about magnitude 7+ on faults located just offshore of the plants. The earthquakes on these faults are mainly strike-slip (horizontal motion on near vertical planes) type earthquakes, not subduction zone earthquakes. This fault geometry does not produce large tsunamigenic waves. Therefore, the likelihood of a significant tsunami from these faults is very remote.

## Fact Sheet: US Portable Array Information

NOTE: This is provided because IRIS participants let us know that here was a discussion about the NRC's involvement in this program during a meeting with congressional staffers. We have been involved in this for the last couple years.

the IRIS CONSORTIUM

The Incorporated Research Institutions for Seismology is the Consortium of Unites States Universities with Major Research Programs in Seismology and Related Fields.

**The Transportable Array: A Science Investment that Can Be Leveraged**

IRIS is installing the Transportable Array – a set of 400 broadband seismic instruments – in each of more than 1600 sites across the contiguous United States. The instruments operate at each site for two years and then are removed and redeployed further east. Roughly 1100 stations have been installed since 2003, and instruments have been removed from more than 600 of those sites in the western United States.

The National Science Foundation is funding the full cost to "roll" the Transportable Array across the US, more than $90,000,000 over ten years. Comparatively small incremental investments could add significant data that are relevant to the safety of nuclear power plants. These efforts would be uniquely cost effective, since NSF is already funding installation, and they would feed data into an existing, standardized and widely used data management system that already incorporates the vast majority of seismic data from US networks. But these opportunities are time constrained: the array will be fully installed in the contiguous 48 states by late 2013.

**More Value from Longer Term Regional Observations**

A dense, uniform seismic network is necessary for long-term, broad-area seismic monitoring of the central and eastern United States due to low event recurrence rates and the risk of significant earthquakes ($M$>5) anywhere in the region. Monitoring seismicity in the central and eastern US can be improved by turning selected sites into permanent seismic stations. A total of more than 35 Transportable Array stations have already been "adopted" by several organizations, creating a permanent legacy, but only in the western United States.

A strategic "1-in-4" plan would involve "adoption" of systematically selected stations in the central and eastern United States – every other station in both the east-west and north-south directions, creating a uniform grid of some 250 stations. Long-term regional operation could be combined with two optional enhancements to create a unique observatory for the study of seismicity, source characteristics, attenuation, and local ground acceleration.

**Enhancement 1: Acquire Higher Frequency Data**

Crustal rigidity in the central and eastern US makes it desirable to record high frequency characteristics of local and regional earthquakes. The existing instruments could be reconfigured to record high frequencies but doing so would nearly triple the data flow, necessitating improvements to the communications infrastructure.

**Enhancement 2: Add Strong Motion Sensors**

Acquiring strong motion sensors and reconfiguring field computers that record and telemeter the data would help to measure unique effects of severe shaking. The design anticipated this augmentation, and several stations in California and Washington were operated that way. Upgrade would be more efficient at sites that have not yet been installed.

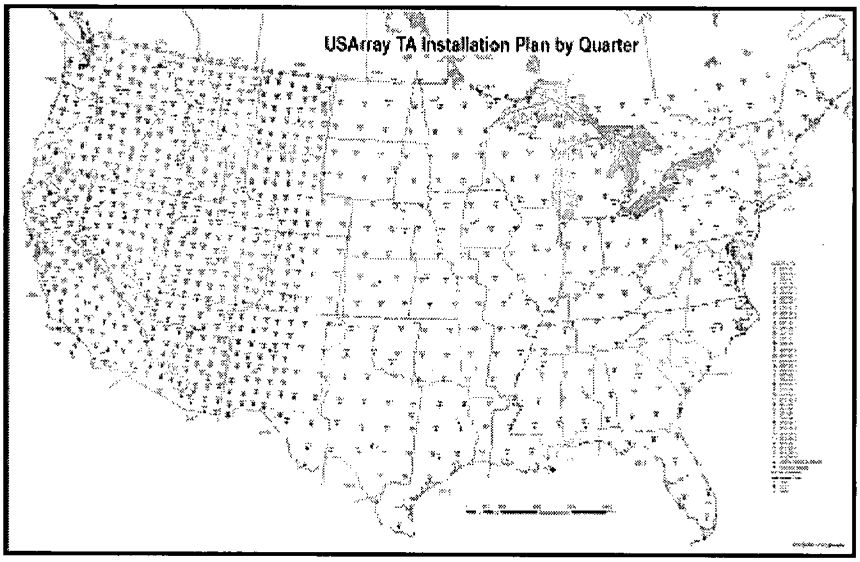
*Estimate of annual acquisition and O&M costs for the 1-in-4, 250-station network in central and eastern US.*

| Year | Stations | Acquisition[1] | O&M[2] | Total |
|---|---|---|---|---|
| 2011 | 50 | $1,800,000 | $ 400,000 | $2,200,000 |
| 2012 | 50 | $1,800,000 | $ 800,000 | $2,600,000 |
| 2013 | 50 | $1,800,000 | $1,200,000 | $3,000,000 |
| 2014 | 50 | $1,800,000 | $1,600,000 | $3,400,000 |
| 2015 | 50 | $1,800,000 | $2,000,000 | $3,800,000 |
| 2016 | – | – | $2,000,000 | $2,000,000 |

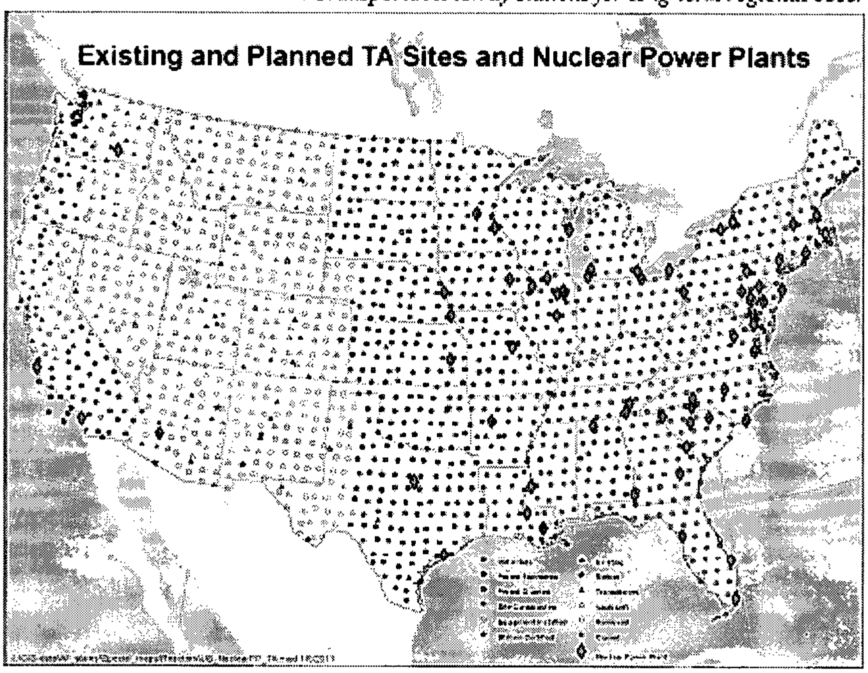
[1] Assumes upgrades to six channel data loggers with strong motion sensors.

[2] Assumes a conservative estimate of $8,000/station/year.

*The 1-in-4, 250-station network that could be created in the central and eastern US by "leaving behind" one out of every four Transportable Array stations during the years 2011 through 2015.*




*A large majority of nuclear power plants are located in the central and eastern parts of the US, where it is still possible to "leave behind" 1-in-4 Transportable Array stations for long-term regional observations.*



## Additional Information: Terms and Definitions

***Annual exceedance frequency (AEF)*** – Number of times per year that a site's ground motion is expected to exceed a specified acceleration.

***Active or seismogenic fault***- need to add definition of active fault from

***Capable Tectonic Source*** – A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation such as faulting or folding at or near the earth's surface in the present seismotectonic regime. It is described by at least one of the following: characteristics:

(1) presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years or at least once in the last approximately 50,000 years

(2) a reasonable association with one or more moderate to large earthquakes or sustained earthquake activity that are usually accompanied by significant surface deformation

(3) a structural association with a capable tectonic source that has characteristics of either item a or b (above), such that movement on one could be reasonably expected to be accompanied by movement on the other

In some cases, the geological evidence of past activity at or near the ground surface along a potential capable tectonic source may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the structure from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence is to be used in determining whether the structure is a capable tectonic source within this definition. Notwithstanding the foregoing paragraphs, the association of a structure with geological structures that are at least pre-Quaternary, such as many of those found in the central and eastern regions of the United States, in the absence of conflicting evidence, will demonstrate that the structure is not a capable tectonic source within this definition.

***Certified Seismic Design Response Spectra (CSDRS)*** – Site-independent seismic design response spectra that have been approved under Subpart B of 10 CFR Part 52 as the seismic design response spectra for an approved certified standard design nuclear power plant. The input or control location for the CSDRS is specified in the certified standard design.

***Combined License*** – A combined construction permit and operating license with conditions for a nuclear power facility issued pursuant to Subpart C of 10 CFR Part 52.

***Controlling Earthquakes*** – Earthquakes used to determine spectral shapes or to estimate ground motions at the site for some methods of dynamic site response. There may be several controlling earthquakes for a site. As a result of the probabilistic seismic hazard analysis (PSHA), controlling earthquakes are characterized as mean magnitudes and distances derived from a deaggregation analysis of the mean estimate of the PSHA.

***Core damage frequency (CDF)*** – **Expected number of core damage events per unit of time.** *Core damage* refers to the uncovery and heat-up of the reactor core, to the point that prolonged oxidation and severe fuel damage are not only anticipated but also involve enough of the core to result in off-site public health effects if released. *Seismic core damage frequency* refers to the component of total CDF that is due to seismic events.

***Cumulative Absolute Velocity (CAV)*** – For each component of the free-field ground motion, the CAV should be calculated as follows: (1) the absolute acceleration (g units) time-history is divided into 1-second intervals, (2) each 1-second interval that has at least 1 exceedance of 0.025g is integrated over time, and (3) all the integrated values are summed together to arrive at the CAV. The CAV is exceeded if the calculation is greater than 0.16 g-second. The application of the CAV in siting requires the development of a CAV model because the PSHA calculation does not use time histories directly.

***Deaggregation*** – The process for determining the fractional contribution of each magnitude-distance pair to the total seismic hazard. To accomplish this, a set of magnitude and distance bins are selected and the annual probability of exceeding selected ground acceleration parameters from each magnitude-distance pair is computed and divided by the total probability for earthquakes.

***Design basis earthquake* or *safe shutdown earthquake (SSE)*** – A *design basis earthquake* is a commonly employed term for the *safe shutdown earthquake* (*SSE)*; the SSE is the earthquake ground shaking for which certain structures, systems, and components are designed to remain functional. In the past, the SSE has been commonly characterized by a standardized spectral shape associated with a peak *ground acceleration* value.

***Design Factor*** – The ratio between the site-specific GMRS and the UHRS. The design factor is aimed at achieving the target annual probability of failure associated with the target performance goals.

***Early Site Permit*** – A Commission approval, issued pursuant to Subpart A of 10 CFR Part 52, for a site or sites for one or more nuclear power facilities.

***Earthquake Recurrence*** – The frequency of occurrence of earthquakes as a function of magnitude. Recurrence relationships or curves are developed for each seismic source, and they reflect the frequency of occurrence (usually expressed on an annual basis) of magnitudes up to the maximum, including measures of uncertainty.

***Frequency of Onset of Significant Inelastic Deformation (FOSID)*** – The annual probability of the onset of significant inelastic deformation (OSID). OSID is just beyond the occurrence of insignificant (or localized) inelastic deformation, and in this way corresponds to "essentially elastic behavior." As such, OSID of a structure, system, or component (SSC) can be expected to occur well before seismically induced core damage, resulting in much larger frequencies of OSID than seismic core damage frequency (SCDF) values. In fact, OSID occurs before SSC "failure," where the term failure refers to impaired functionality.

***Ground acceleration*** – Acceleration produced at the ground surface by seismic waves, typically expressed in units of *g*, the acceleration of gravity at the earth's surface.

***Ground Motion Response Spectra (GMRS)*** – A site-specific ground motion response spectra characterized by horizontal and vertical response spectra determined as free-field motions on the ground surface or as free-field outcrop motions on the uppermost in-situ competent material using performance-based procedures. When the GMRS are determined as free-field outcrop motions on the uppermost in-situ competent material, only the effects of the materials below this elevation are included in the site response analysis.

***Ground Motion Slope Ratio*** – Ratio of the spectral accelerations, frequency by frequency, from a seismic hazard curve corresponding to a 10-fold reduction in hazard exceedance frequency. (See Equation 3 in Regulatory Position 5.1.)

***High confidence of low probability of failure (HCLPF) capacity*** – A measure of *seismic margin*. In *seismic risk* assessment, *HCLPF capacity* is defined as the earthquake motion level, at which there is high confidence (95%) of a low probability (at most 5%) of failure of a structure, system, or component.

***In-column Motion*** – Motion that is within a soil column, as opposed to the motion at the surface or treated as if it is at the surface.

***Intensity*** – The intensity of an earthquake is a qualitative description of the effects of the earthquake at a particular location, as evidenced by observed effects on humans, on human-built structures, and on the earth's surface at a particular location. Commonly used scales to specify intensity are the Rossi-Forel, Mercalli, and Modified Mercalli. The Modified Mercalli Intensity (MMI) scale describes intensities with values ranging from I to XII in the order of severity. MMI of I indicates an earthquake that was not felt except by a very few, whereas MMI of XII indicates total damage of all works of construction, either partially or completely.

***Large early release frequency (LERF)*** – The expected number of large early releases per unit of time. A *large early release* is the rapid, unmitigated release of airborne fission products from the containment building to the environment, occurring before the effective implementation of off-site emergency response and protective actions, such that there is a potential for early health effects. *Seismic large early release frequency* refers to the component of total LERF that is due to seismic events.

***Magnitude*** – An earthquake's magnitude is a measure of the strength of the earthquake as determined from seismographic observations and is an objective, quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, Surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the most commonly used magnitude measurement is the Moment Magnitude, Mw, which is based on the seismic moment computed as the rupture force along the fault multiplied by the average amount of slip, and thus is a direct measure of the energy released during an earthquake.

***Maximum Magnitude*** – The maximum magnitude is the upper bound to earthquake recurrence curves.

***Mean Site Amplification Function*** – The mean amplification function is obtained for each controlling earthquake, by dividing the response spectrum from the computed surface motion by the response spectrum from the input hard rock motion, and computing the arithmetic mean of the individual response spectral ratios.

***Nontectonic Deformation*** – Nontectonic deformation is distortion of surface or near-surface soils or rocks that is not directly attributable to tectonic activity. Such deformation includes features associated with subsidence, karst terrain, glaciation or deglaciation, and growth faulting.

***Response Spectrum*** – A plot of the maximum responses (acceleration, velocity, or displacement) of idealized single-degree-of-freedom oscillators as a function of the natural frequencies of the oscillators for a given damping value. The response spectrum is calculated for a specified vibratory motion input at the oscillators' supports.

***Ring Area*** – Annular region bounded by radii associated with the distance rings used in hazard deaggregation (RG 1.208, Appendix D, Table D.1, "Recommended Magnitude and Distance Bins").

***Safe Shutdown Earthquake Ground Motion (SSE)*** – The vibratory ground motion for which certain structures, systems, and components are designed, pursuant to Appendix S to 10 CFR Part 50, to remain functional. The SSE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface.

***Seismic hazard*** – Any physical phenomenon, such as ground motion or ground failure, that is associated with an earthquake and may produce adverse effects on human activities (such as posing a risk to a nuclear facility).

***Seismic margin*** – The difference between a plant's capacity and its seismic design basis (*safe shutdown earthquake, or SSE*).

***Seismic risk*** – The risk (frequency of occurrence multiplied by its consequence) of severe earthquake-initiated accidents at a nuclear power plant. A severe accident is an accident that causes core damage, and, possibly, a subsequent release of radioactive materials into the environment. Several risk metrics may be used to express *seismic risk*, such as seismic *core damage frequency* and seismic *large early release frequency*.

***Seismic Wave Transmission (Site Amplification)*** – The amplification (increase or decrease) of earthquake ground motion by rock and soil near the earth's surface in the vicinity of the site of interest. Topographic effects, the effect of the water table, and basin edge wave-propagation effects are sometimes included under site response.

***Seismogenic Source*** – A portion of the earth that is assumed to have a uniform earthquake potential (same expected maximum earthquake and recurrence frequency), distinct from that of surrounding sources. A seismogenic source will generate vibratory ground motion but is assumed to not cause surface displacement. Seismogenic sources cover a wide range of seismotectonic conditions, from a well-defined tectonic structure to simply a large region of diffuse seismicity.

***Spectral Acceleration*** – Peak acceleration response of an oscillator as a function of period or frequency and damping ratio when subjected to an acceleration time history. It is equal to the peak relative displacement of a linear oscillator of frequency, f, attached to the ground, times the quantity $(2Bf)^2$. It is expressed in units of gravity (g) or cm/second$^2$.

***Stable Continental Region (SCR)*** – An SCR is composed of continental crust, including continental shelves, slopes, and attenuated continental crust, and excludes active plate boundaries and zones of currently active tectonics directly influenced by plate margin processes. It exhibits no significant deformation associated with the major Mesozoic-to-Cenozoic (last 240 million years) orogenic belts. It excludes major zones of Neogene (last 25 million years) rifting, volcanism, or suturing.

***Stationary Poisson Process*** – A probabilistic model of the occurrence of an event over time (or space) that has the following characteristics: (1) the occurrence of the event in small intervals is constant over time (or space), (2) the occurrence of two (or more) events in a small interval is negligible, and (3) the occurrence of the event in non-overlapping intervals is independent.

***Target Performance Goal (PF)*** – Target annual probability of exceeding the 1 E-05 frequency of onset of significant inelastic deformation (FOSID) limit state.

***Tectonic Structure*** – A large-scale dislocation or distortion, usually within the earth's crust. Its extent may be on the order of tens of meters (yards) to hundreds of kilometers (miles).

***Uniform Hazard Response Spectrum (UHRS)*** – A plot of a ground response parameter (for example, spectral acceleration or spectral velocity) that has an equal likelihood of exceedance at different frequencies.

***Within Motion*** – An earthquake record modified for use in a site response model. Within motions are developed through deconvolution of a surface recording to account for the properties of the overburden material at the level at which the record is to be applied. The within motion can also be called the "bedrock motion" if it occurs at a high-impedance boundary where rock is first encountered.

## What are the definitions of the SSE and OBE?

CLEAN UP BELOW information – and add above

From RG1.208 Safe Shutdown Earthquake Ground Motion (SSE). The vibratory ground motion for which certain structures, systems, and components are designed, pursuant to Appendix S to 10 CFR Part 50, to remain functional. The SSE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface

Appendix S to 10 CFR Part 50 (3) has the following information: Required Plant Shutdown. If vibratory ground motion exceeding that of the Operating Basis Earthquake Ground Motion or if significant plant damage occurs, the licensee must shut down the nuclear power plant. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after the occurrence of the Operating Basis Earthquake Ground Motion, the licensee must consult with the Commission and must propose a plan for the timely, safe shutdown of the nuclear power plant. Prior to resuming operations, the licensee must demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public and the licensing basis is maintained.

The ratio is provided in guidance as the ratio that the licensees can chose without additional analysis. The OBE mostly used to be half for existing plants, but now it's a 1/3 unless you do analyses to show why it should be ½.

| | |
|---|---|
| **Definition of Safe Shutdown Earthquake** | The safe-shutdown earthquake (SSE) for the site is the ground motion response spectra (GMRS), which also satisfies the minimum requirement of paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Code of Federal Regulations (10 CFR Part 50). |
| **Definition of Operating Basis Earthquake:** | To satisfy the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE) ground motion is defined as follows:<br>(iv) For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.<br>(v) For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in design control document (DCD).<br>(vi) The spectrum ordinate criterion to be used in conjunction with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," issued March 1997, is the lowest of (i) and (ii). |

## List of Questions

**From:** Burnell, Scott
**To:** Kammerer, Annie; Hiland, Patrick; Skeen, David; Case, Michael; RST01 Hoc; LIA06 Hoc
**Cc:** Uhle, Jennifer
**Subject:** FW: Seismic Q&As March 19th 8am update
**Date:** Saturday, March 19, 2011 9:44:08 AM
**Attachments:** Seismic Questions for Incident Response 3-19-11 8am.pdf

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All;

OPA thinks these are great. We're working with the LT to provide them to DOE Sec. Chu and to get the PDF posted to the NRC Web site. Thanks.

Scott

TT\25

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Scott

# Compiled Seismic Questions for NRC Response to the March 11, 2011 Japanese Earthquake and Tsunami

**This is current as of 3-20-11 at 8pm.**

***The keeper of this file is Annie Kammerer. Please provide comments, additions and updates to Annie with CC to Clifford Munson and Jon Ake.***

***A SharePoint site has been set up so that anyone can download the latest Q&As. The site is found at NRC>NRR>NRR TA or at http://portal.nrc.gov/edo/nrr/NRR%20TA/FAQ%20Related%20to%20Events%20Occuring%20in%20Japan/Forms/AllItems.aspx***

***A list of topics is shown in the Table of Contents at the front of this document.***

***A list of all questions is provided at the end of the document.***

***A list of terms and definitions is included at the end of the document.***

*We greatly appreciate the assistance of the many people who have contributed to this document. Please do not distribute beyond the NRC.*



TT\27

## CONTENTS

## Natural Hazards and Ground Shaking Design Levels

### 1) Does the NRC consider earthquakes of magnitude 9?

**Public response:** This earthquake was caused by a "subduction zone" event, which is the type of earthquake that can produce the largest magnitudes. A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington. As a result, magnitude 9 events would only be considered for this particular seismic source. The NRC requires all credible earthquakes that may impact a site to be considered.

**Additional, technical, non-public information:** None.

### 2) Did the Japanese underestimate the size of the maximum credible earthquake that could affect the plants?

**Public response:** The magnitude of the earthquake was somewhat greater than was expected for that part of the subduction zone. However, the Japanese nuclear plants were recently reassessed using ground motion levels similar to those that are believed to have occurred at the sites. The ground motions against which the Japanese nuclear plants were reviewed were expected to result from earthquakes that were smaller, but were much closer to the sites. The NRC does not currently have information on the maximum tsunami height that was expected at the sites.

**Additional, technical, non-public information:** A PDF file provided by John Anderson (prepared by Japanese colleagues) indicates that the majority of the recorded ground motions during the main shock were below the attenuation curve by Si & Midorikawa (1999). Most of the recorded motions fit well to median minus 1 sigma of their GMPE. There are also about a dozen stations with the recorded ground motions above 1g. The highest recorded PGA (~3g) is at the K-Net station MYG004. We can use this information to try to estimate motions at the plants as soon as someone catches a breath.

### 3) Can an earthquake and tsunami as large as happened in Japan also happen here?

**Public response:** See below.

### 4) What if an earthquake like the Sendai earthquake occurred near a US plant?

**Public response:** This earthquake occurred on a "subduction zone", which is the type of tectonic region that produces earthquakes of the largest magnitude. A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate. Subduction zone earthquakes are also required to produce the kind of massive tsunami seen in Japan. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington. So, a continental earthquake and tsunami as large as in Japan could only happen there. The only nuclear plant near the Cascadia subduction zone is the Columbia Generating Station. This plant is located a large distance from the coast (approximately 225 miles) and the subduction zone (approximately 300 miles), so the ground motions estimated at the plant are far lower than those seen at the Fukushima plants. This distance also precludes the possibility of a tsunami affecting the plant. Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximately 8. Magnitude is measured on a log scale and so a magnitude 9 earthquake produces about ten times stronger shaking and releases about 31 times more energy than a magnitude 8 earthquake.

**Additional, technical, non-public information:** None.

## 5) What magnitude earthquake are US plants designed to?

**Public Answer:** Ground motion is a function of both the magnitude of an earthquake and the distance from the fault to the site. Nuclear plants, and in fact all engineered structures, are actually designed based on ground motion levels, not earthquake magnitudes. The existing nuclear plants were designed based on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquakes expected in the area around the plant. A margin is further added to the predicted ground motions to provide added robustness.

**Additional, technical non-public information:** In the past, "deterministic" or "scenario based" analyses were used to determine ground shaking (seismic hazard) levels. Now a probabilistic method is used that accounts for possible earthquakes of various magnitudes that come from potential sources (including background seismicity) and the likelihood that each particular hypothetical earthquake occurs. The ground motions that are used as seismic design bases at US nuclear power plants are called the Safe Shutdown Earthquake ground motion (SSE) and are described mathematically through use of a response spectrum. On the west coast of the US, the two nuclear power plants are designed to specific ground motions that are determined from earthquakes of about magnitude 7 (SONGS) and 7.5 (Diablo) on faults located just offshore of the plants. Because the faults are well characterized, the magnitude and distances are known. However the design and licensing bases are still the ground motions...not the earthquakes. The earthquakes on these faults are mainly strike-slip (horizontal motion) type earthquakes, not subduction zone earthquakes. Therefore, the likelihood of a tsunami from these faults is remote.

## 6) How many US reactors are located in active earthquake zones?

**Public Answer:** Although we often think of the US as having "active" and "non-active" earthquake zones, earthquakes can actually happen almost anywhere. Seismologists typically separate the US into low, moderate, and high seismicity zones. The NRC requires that every nuclear plant be designed for site-specific ground motions that are appropriate for their locations. In addition, the NRC has specified a minimum ground motion level to which nuclear plants must be designed.

**Additional, technical non-public information:** This does not have a simple answer and NRC seismic staff are developing a fact sheet to respond to this question. There are also two plants that are in highly seismicity areas of California. Unfortunately, the extent of the moderate seismicity zones in the US are open to interpretation and are a matter of scientific debate. The preliminary consensus opinion by NRC staff is that there are approximately 9 plants in the moderate seismicity zones in the CEUS: 4 or 5 in the Charleston SZ (depending on whose interpretation you use, it varies widely), 1 in the Wabash valley SZ, 2 in the East Tennessee SZ, 1 in the Central Virginia SZ. But some of these are open to interpretation and debate.

Please note that although the earthquakes in the CEUS are rare, they can be big. The most widely felt earthquakes within the continental US were the 1811-12 New Madrid sequence and the 1886 Charleston, SC, which were estimated to be between about magnitude 7.0 to 7.75.

## 7) Has this changed our perception of earthquake risk to the plants in the US?

**Public Answer:** The NRC continues to determine that US nuclear plants are safe. This does not change the NRC's perception of earthquake hazard (i.e., ground motion levels) at US nuclear plants. It is too early to tell what the lessons from this earthquake are. The NRC will look closely at all aspects of response of the plants to the earthquake and tsunami to determine if any actions need to be taken in US nuclear plants and if any changes are necessary to NRC regulations.

**Additional, technical, non-public information:** We expect that there would be lessons learned and we may need to seriously relook at common cause failures, including dam failure and tsunami.

### 8) Can significant damage to a nuclear plant like we see in Japan happen in the US due to an earthquake? Are the Japanese nuclear plants similar to US nuclear plants?

**Public Answer:** All US nuclear plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those nuclear plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events. In addition to the design of the plants, significant effort goes into emergency response planning and accident management. This approach is called defense-in-depth.

The Japanese facilities are similar in design to some US facilities. However, the NRC has required modifications to the plants since they were built, including design changes to control hydrogen and pressure in the containment. The NRC has also required plants to have additional equipment and measures to mitigate damage stemming from large fires and explosions from a beyond-design-basis event. The measures include providing core and spent fuel pool cooling and an additional means to power other equipment on site.

**Additional technical, non-public information:** Currently operating reactors were designed using a "deterministic" or "maximum credible earthquake" approach. Seismic hazard for the new plants is determined using a probabilistic seismic hazard assessment approach that explicitly addresses uncertainty and the potential for beyond-design-basis earthquakes, as described in Regulatory Guide 1.208. The NRC requires that adequate margin beyond the design basis ground shaking levels is assured. The NRC further enhances seismic safety for beyond-design-basis events through the use of a defense-in-depth approach.

In addition, the NRC reviews the seismic risk at operating reactors as needed when information may have changed. Over the last few years the NRC has undertaken a program called Generic Issue 199, which is focused on assessing hazard for plants in the central and eastern US using the latest techniques and data and determining the possible risk implications of any increase in the anticipated ground shaking levels. This program will help us assure that the plants are safe under exceptionally rare and extreme ground motions that represent beyond-design-basis events.

### 9) If the earthquake in Japan was a larger magnitude than considered by plant design, why can't the same thing happen in the US?

**Public response:** *Discuss in terms of, IPEEE, Seismic PRA to be provided by Nilesh*

**Additional, technical, non-public information:** ADD

### 10) What level of earthquake hazard are the US reactors designed for?

**Public Answer:** Each reactor is designed for a different ground motion that is determined on a site-specific basis. The existing nuclear plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquakes expected in the area around the plant, without consideration of the likelihood of the earthquakes considered. New reactors are designed using probabilistic techniques that characterize both the ground motion levels and uncertainty at the proposed site. These probabilistic techniques account for the ground motions that may result from all potential seismic sources in the region around the site. Technically speaking, this is the ground motion with an annual frequency of occurrence of $1 \times 10^{-4}$/year, but this can be thought of as the ground motion that occurs every 10,000 years on average. One important aspect is that probabilistic hazard and risk-assessment techniques account for beyond-design basis events. NRC's Generic Issue 199 (GI-199) project is using the latest probabilistic techniques used for new nuclear plants to review the safety of the existing plants. [see questions in the section about GI-199 for more information]

**Additional technical, non-public information:** Note to OPA: This may perhaps seem like an oddly worded general question because the word "hazard" has several meanings, but in fact it is a specific technical question. If you see "earthquake hazard levels" or similar language, check with the seismic staff.

### 11) What is the likelihood of the design basis or "SSE" ground motions being exceeded over the life of a nuclear plant?

**Public response:** The ground motions that are used as seismic design bases at US nuclear plants are called the Safe Shutdown Earthquake ground motion (SSE). In the mid to late 1990s, the NRC staff reviewed the potential for ground motions beyond the design basis as part of the Individual Plant Examination of External Events (IPEEE). From this review, the staff determined that seismic designs of operating nuclear plants in the US have adequate safety margins for withstanding earthquakes. Currently, the NRC is in the process of conducting GI-199 to again assess the resistance of US nuclear plants to earthquakes. Based on NRC's analyses to date, the probability of ground motions exceeding the SSE for the plants in the Central and Eastern United States is less than 2%, with values ranging from a low of 0.1% to a high of 6%.

It is important to remember that structures, systems and components are required to have "adequate margin," meaning that they must continue be able withstand shaking levels that are above the plant's design basis.

**Additional technical, non-public information:** There is a section of this document focused on questions related to GI-199.

### 12) What is magnitude anyway? What is the Richter Scale? What is intensity?

**Public Answer:** An earthquake's magnitude is a measure of the strength of the earthquake as determined from seismographic observations. Magnitude is essentially an objective, quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, Surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the most commonly used magnitude measurement is the Moment Magnitude, Mw, which is based on the strength of the rock that ruptured, the area of the fault that ruptured, and the average amount of slip. Moment magnitude is, therefore, a direct measure of the energy released during an earthquake. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology and was based on the behavior of a specific seismograph that was manufactured at that time. The instruments are no longer in use and the magnitude scale is, therefore, no longer used in the technical community. However, the Richter Scale is a term that is so commonly used by the public that scientists generally just answer questions about "Richter" magnitude by substituting moment magnitude without correcting the misunderstanding.

The intensity of an earthquake is a qualitative assessment of effects of the earthquake at a particular location. The intensity assigned is based on observed effects on humans, on human-built structures, and on the earth's surface at a particular location. The most commonly used scale in the US is the Modified Mercalli Intensity (MMI) scale, which has values ranging from I to XII in the order of severity. MMI of I indicates an earthquake that was not felt except by a very few, whereas MMI of XII indicates total damage of all works of construction, either partially or completely. While an earthquake has only one magnitude, intensity depends on the effects at each particular location.

**Additional, technical non-public information:** None.

### 13) How do magnitude and ground motion relate to each other?

**Public Answer:** The ground motion experienced at a particular location is a function of the magnitude of the earthquake, the distance from the fault to the location of interest, and other elements such as the geologic materials through which the waves pass.

**Additional, technical non-public information:** None.

### 14) Which reactors are along coastal areas that could be affected by a tsunami?

**Public Answer:** Many nuclear plants are located in coastal areas that could potentially be affected by a tsunami. Two nuclear plants, Diablo Canyon and San Onofre, are on the Pacific Coast, which is known to have a tsunami hazard. Two nuclear plants on the Gulf Coast, South Texas and Crystal River, could also be affected by tsunami. There are many nuclear plants on the Atlantic Coast or on rivers that may be affected by a tidal bore resulting from a tsunami. These include St. Lucie, Turkey Point, Brunswick, Oyster Creek, Millstone, Pilgrim, Seabrook, Calvert Cliffs, Salem/Hope Creek, and Surry. Tsunami on the Gulf and Atlantic Coasts occur, but are very rare. Generally the flooding anticipated from hurricane storm surge exceeds the flooding expected from a tsunami for nuclear plants on the Atlantic and Gulf Coast. Regardless, all nuclear plants are designed to withstand a tsunami.

**Additional, technical non-public information:** A table with information on tsunami design levels is provided in the "Additional Information" section of this document.

### 15) What would be the results of a tsunami generated off the coast of a US plant? (Or why are we confident that large tsunamis will not occur relatively close to US shores?)

**Public response:** Like seismic hazard, the level of tsunami that each plant is designed for is site-specific and is appropriate for what may occur at each location. Many plants are located in coastal areas that could potentially be affected by tsunami. Two plants, Diablo Canyon and San Onofre, are on the Pacific Coast, which is known to have tsunami hazard. There are also two plants on the Gulf Coast, South Texas and Crystal River. There are many plants on the Atlantic Coast or on rivers that may be affected by a tidal bore resulting from a tsunami. These include St. Lucie, Turkey Point, Brunswick, Oyster Creek, Millstone, Pilgrim, Seabrook, Calvert Cliffs, Salem/Hope Creek, and Surry. Tsunami on the Gulf and Atlantic Coasts occur, but are very rare. Generally the flooding anticipated from hurricane storm surge exceeds the flooding expected from a tsunami for plants on the Atlantic and Gulf Coast.

**Additional, technical, non-public information:** A table with information on tsunami design levels is provided in the "Additional Information" section of this document.

**16) How are combined seismic and tsunami events treated in risk space? Are they considered together?**

The PRA Standard (ASME/ANS-Ra-Sa2009) does address the technical requirements for both seismic events and tsunamis (tsunami hazard under the technical requirements for external flooding analysis). But together? The standard does note that uncertainties associated with probabilistic analysis of tsunami hazard frequency are large and that an engineering analysis can usually be used to screen out tsunamis.

**17) How are aftershocks treated in terms of risk assessment?**

Seismic PRAs do not consider the affect of aftershocks since there are not methods to predict equipment fragility after the first main shock.

## Design Against Natural Hazards & Plant Safety in the US

### 19) Are nuclear power plants designed for tsunamis?

**Public Answer:** Yes. Plants are built to withstand a variety of environmental hazards and those plants that might face a threat from tsunami are required to withstand large waves and the maximum wave height at the intake structure (which varies by plant.)

**Additional, technical, non-public information:** Tsunami are considered in the design of US nuclear plants. Nuclear plants are designed to withstand flooding from not only tsunami, but also hurricane and storm surge; therefore there is often significant margin against tsunami flooding. However, it should be noted that Japanese experience has shown that drawdown can be a significant problem.

Currently the US NRC has a tsunami research program that is focused on developing modern hazard assessment techniques and additional guidance through cooperation with the National Oceanic and Atmospheric Administration and the United States Geological Survey. This has already lead to several technical reports and an update to NUREG 0-800. The NOAA and USGS contractors are also assisting with NRO reviews of tsunami hazard. A new regulatory guide on tsunami hazard assessment is currently planned in the office of research, although it is not expected to be available in draft form until 2012.

### 20) What level of tsunami are use nuclear plants designed for?

**Public Answer:** Like seismic hazard, the level of tsunami that each plant is designed for is site-specific and is appropriate for what may occur at each location.

**Additional, technical, non-public information:** None.

### 21) Is there a minimum earthquake shaking that nuclear plants designed for?

**Public Answer:** Yes. According to Appendix S to 10 CFR Part 50, the foundation level ground motion must be represented by an appropriate response spectrum with a peak ground acceleration of at least 0.1g.

**Additional, technical, non-public information:** NOTE TO OPA: this comes straight from RG1.208 and it, therefore, approved for public release. If you get this question, we can help make it more user friendly.

### 22) Which plants are close to known active faults? What are the faults and how far away are they from the plants?

**Public Answer:** Jon to develop answer with Dogan's help. I created a placeholder table for your use "Table of Plants Near Known Active Faults" to be populated in the additional information section. The plots that Dogan made are in the additional information section under "Plot of Mapped Active Quaternary Faults and Nuclear Plants in the US". This is really high priority after the congressional hearings.

**Additional, technical, non-public information:** ADD

### 23) How was the seismic design basis for an existing nuclear power plant established?

**Public Answer:** The seismic ground motion used for the design basis was determined from the evaluation of the maximum historic earthquake within 200 miles of the site, without explicitly considering the time spans between such earthquakes; safety margin was then added beyond this maximum historic earthquake to form a hypothetical *design basis earthquake*. The relevant regulation for currently operating plants is 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for

Nuclear Power Plants" (http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-appa.html).

**Additional, technical, non-public information:** See discussion at end of GI-199 section for discussion of safety margin and design basis.

### 24) Is there margin above the design basis?

**Public Answer:** Yes, there is margin beyond the design basis. In the mid to late 1990s, NRC staff reviewed the plants' assessments of potential consequences of severe earthquakes (earthquakes beyond the safety margin included in each plant's design basis), which licensees performed as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs.

**Additional, technical, non-public information:** None.

### 25) Are US plants safe? Would a plant in the U.S. be able to withstand a large earthquake?

**Public Answer:** US plants are designed for appropriate earthquake shaking levels that are based on historical data for the site plus additional margin to account for uncertainties. Currently, the NRC is conducting a program called Generic Issue 199, which is reviewing the adequacy of the earthquake design of US NPPs in central and eastern North America based on the latest data and analysis techniques. The NRC will look closely at all aspects of the response of the plants in Japan to the earthquake and tsunami to determine if any actions need to be taken in US plants and if any changes are necessary to NRC regulations.

**Additional, technical, non-public information:** None.

### 26) Was the Japanese plant designed for this type of accident? Are US nuclear plants?

**Public Answer:** See below.

**Additional, technical, non-public information:** None.

### 27) Why do we have confidence that US nuclear power plants are adequately designed for earthquakes and tsunamis?

**Public Answer:** Nuclear plants in both the US and Japan are designed for earthquake shaking. In addition to the design of the plants, in the US significant effort goes into emergency response planning and accident mitigation. This approach is called defense-in-depth.

**Additional, technical, non-public information:** None.

### 28) Can this happen here (i.e., an earthquake that significantly damages a nuclear power plant)? Are the Japanese plants similar to US plants?

**Public Answer:** All US nuclear power plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events Nuclear power plants are designed to be safe based on the most severe natural phenomena historically reported for the site and surrounding area. The Japanese facilities are similar in design to several US facilities. However, the US has required many changes that

**Additional technical, non-public information:** Currently operating reactors were designed using a "deterministic" or "maximum credible earthquake" approach. Seismic hazard for the new plants is determined using a probabilistic seismic hazard assessment approach that explicitly addresses uncertainty, as described in Regulatory Guide 1.208. The NRC requires that adequate margin beyond the design basis ground shaking levels is assured. The NRC further enhances seismic safety for beyond-design-basis events through the use of a defense-in-depth approach.

In addition, the NRC reviews the seismic risk at operating reactors as needed when information may have changed. Over the last few years the NRC has undertaken a program called Generic Issue 199, which is focused on assessing hazard for plants in the central and eastern US using the latest techniques and data and is determining the possible risk implications of any increase in the anticipated ground shaking levels. This program will help us assure that the plants are safe under exceptionally rare and extreme ground motions that represent beyond-design-basis events.

The reactor design is a Boiling Water Reactor that is similar to some US designs, including Oyster Creek, Nine Mile Point and Dresden Units 2 and 3.

### 29) Could an accident sequence like the one at Japan's Fukushima Daiichi nuclear plants happen in the US?

**Public response:** It is difficult to answer this question until we have a better understanding of the precise problems and conditions that faced the operators at Fukushima Daiichi. We do know, however, that Fukushima Daiichi Units 1-3 lost all offsite power and emergency diesel generators. This situation is called "station blackout." US nuclear power plants are designed to cope with a station blackout event that involves a loss of offsite power and onsite emergency power. The Nuclear Regulatory Commission's detailed regulations address this scenario. US nuclear plants are required to conduct a "coping" assessment and develop a strategy to demonstrate to the NRC that they could maintain the plant in a safe condition during a station blackout scenario. These assessments, proposed modifications to the plant, and operating procedures were reviewed and approved by the NRC. Several plants added additional AC power sources to comply with this regulation.

In addition, US nuclear plant designs and operating practices since the terrorist events of September 11, 2001, are designed to mitigate severe accident scenarios such as aircraft impact, which include the complete loss of offsite power and all on-site emergency power sources.

US nuclear plant designs include consideration of seismic events and tsunamis'. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations.

**Additional technical, non-public information:** None

### 30) Should US nuclear facilities be required to withstand earthquakes and tsunamis of the kind just experienced in Japan? If not, why not?

**Public response:** US nuclear reactors are designed to withstand an earthquake equal to the most significant historical event or the maximum projected seismic event and associated tsunami without any breach of safety systems.

The lessons learned from this experience must be reviewed carefully to see whether they apply to US nuclear power plants. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards, however. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations.

The United States Geological Survey (USGS) conducts continuous research of earthquake history and geology, and publishes updated seismic hazard curves for various regions in the continental US. These curves are updated approximately every six years. NRC identified a generic issue (GI-199) that is currently undergoing an evaluation to assess implications of this new information to nuclear plant sites located in the central and eastern United States. The industry is working with the NRC to address this issue.

**Additional technical, non-public information:** None

### 31) Can you summarize the plant seismic design basis for the US plants? Are there any special issues associated with seismic design?

**Public response:** Please see one of the several tables provided in the "Additional information" section of this document.

**Additional, technical, non-public information:** None

### 32) How do we know that the equipment in plants is safe in earthquakes?

**Public response:** All equipment important to safety (required to safely shutdown a nuclear power plant) is qualified to withstand earthquakes in accordance with plants' licensing basis and NRC regulations.

**Additional, technical, non-public information:** 10 CFR 50, Appendix A, General Design Criterion 2 and 4, 10 Part 100, and Appendix S. Guidance: Regulatory Guides 1.100, IEEE 344 and ASME QME-1

### 33) How do we know equipment will work if the magnitude is bigger than expected, like in Japan?

**Public response:** Nuclear plant systems are designed to mitigate a design basis earthquake which includes margin above the postulated site specific earthquake. (reviewers comment: this needs to be expanded)

**Additional, technical, non-public information:** See part 100 Reactor Site Criteria

### 34) Are US plants susceptible to the same kind of loss of power as happened in Japan?

**Public response:** NRC recognized that there is the possibility of a total loss of AC power at a site, called a 'Station Blackout', or SBO. Existing Regulations require the sites to be prepared for the possibility of an SBO. In addition to battery powered back-up system to immediately provide power for emergency systems, NRC regulations require the sites to have a detailed plan of action to address the loss of AC power while maintaining control of the reactor.

There has also been an understanding that sites can lose offsite power as well. Of course, this can be caused by earthquake. However, hurricane- or tornado-related high winds may potentially damage the transmission network in the vicinity of a nuclear plant as well. Flood waters can also affect transformers used to power station auxiliary system. These types of weather related events have the potential to degrade the offsite power source to a plant.

The onsite Emergency Diesel Generators need fuel oil stored in tanks that are normally buried underground. These tanks and associated pumps and piping require protection from the elements. Above ground tanks have tornado and missile protection.

In case both offsite and onsite power supplies fail, NRC has required all licensee to evaluate for a loss of all AC power (station blackout) scenario and implement coping measures to safely shutdown the plant law 10 CFR 50.63.

**Additional, technical, non-public information:** Some plants have safeguards equipment below sea level and rely on watertight doors or Bilge pumps to remove water from equipment required to support safe shutdown. Overflowing rivers can result in insurmountable volume of water flooding the vulnerable areas. SBO definition in 10CFR50.2, SBO plan requirements in 10CFR50.63

**35) How do we know that the emergency diesel generators in Diablo Canyon and SONGS will not fail to operate like in Japan?**

**Public response:** Emergency Diesel Generators are installed in a seismically qualified structure. Even if these EDGs fail, plants can safely shutdown using station blackout power source law 10 CFR 50.63.

**Additional, technical, non-public information:** None.

**36) Is all equipment at the plant vulnerable to tsunami?**

**Public response:** Nuclear plants are designed to withstand protection against natural phenomena such as tsunami, earthquakes. (reviewers comment: this needs to be expanded. I need assistance with this)

**Additional, technical, non-public information:** ADD

**37) What protection measures do plants have against tsunami?**

**Public response:** Plants are designed to withstand protection against natural phenomena such as tsunami, earthquakes. (note from reviewer: add information on breakwater from songs and Diablo example. I need assistance with this)

**Additional, technical, non-public information:** ADD

**38) Is there a risk of loss of water during tsunami drawdown? Is it considered in design?**

**Public response:** *Goutam, Henry and Rich, can you guys answer this?*

**Additional, technical, non-public information:** ADD

**39) Are nuclear buildings built to withstand earthquakes? What about tsunami?**

**Public response:** *There is language elsewhere in this document that answers that...copy here.*

**Additional, technical, non-public information:** ADD

**40) Are aftershocks considered in the design of equipment at the plants? Are aftershocks considered in design of the structure?**

**Public response:** ADD

**Additional, technical, non-public information:** ADD

**41) Are there any special issues associated with seismic design at the plants? For example, Diablo Canyon has special requirements. Are there any others?**

**Public response:** Both SONGS and Diablo canyon are licensed with an automatic trip for seismic events. *(can this be expanded? any others?) Mike Markley, can your group assist with this?*

**Additional, technical, non-public information:** ADD

42) **Is the NRC planning to require seismic isolators for the next generation of nuclear power plants? How does that differ from current requirements and/or precautions at existing US nuclear power plants?**

**Public response:** The NRC would not require isolators for the next generation of plants. However, it is recognized that a properly designed isolation system can be very effective in mitigating the effect of earthquake. Currently the NRC is preparing guidance for plant designers considering the use of seismic isolation devices.

**Additional, technical, non-public information:** A NUREG is in the works in the office of research. It is expected to be available for comment in 2011.

43) **Are there any US nuclear power plants that incorporate seismic isolators? What precautions are taken in earthquake-prone areas?**

**Public response:** No currently constructed nuclear power plants in the US use seismic isolators. However seismic isolation is being considered for a number of reactor designs under development. Currently seismic design of plants is focused on assuring that design of structures, systems, and components are designed and qualified to assure that there is sufficient margin beyond the design basis ground motion.

**Additional, technical, non-public information:** None.

44) **Do you think that the recent Japan disaster will cause any rethinking of the planned seismic isolation guidelines, particularly as it regards earthquakes and secondary effects such as tsunamis?**

**Public response:** Whenever an event like this happens, the NRC thoroughly reviews the experience and tries to identify any lessons learned. The NRC further considers the need to change guidance or regulations. In this case, the event will be studied and any necessary changes will be made to the guidance under development. However, it should be noted that Japan does not have seismically isolated nuclear plants.

**Additional, technical, non-public information:** None.

## Seismically Induced Fire & Spent Fuel Pool Fires

### 45) How does the NRC address seismic-induced fire?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The NRC's rules for fire protection are independent of the event that caused the fire. The power plant operators are required to evaluate all the fire hazards in the plant and make sure a fire will not prevent a safe plant shutdown. The NRC's guidance says that power plant operators should assume that a fire can happen at any time. The rules do not require specific consideration of a fire that starts as a result of an earthquake. In addition, we do not require analysis of more than one fire at a time at one reactor.

### 46) Does the NRC require the fire protection water supply system be designed to withstand an earthquake?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The NRC recommends the licensee follow the applicable National Fire Protection Association (NFPA) codes and standards for the fire protection systems or provide an acceptable alternative. This would include local building code earthquake requirements. Since 1976, the NRC has recommended that, "At a minimum, the fire suppression system should be capable of delivering water to manual hose stations located within hose reach of areas containing equipment required for safe plant shutdown following the safe shutdown earthquake (SSE)." For plants located, "in areas of high seismic activity, the staff will consider on a case-by-case basis the need to design the fire detection and suppression system to be functional following the SSE." This is the guidance provided to plants that were licensed to operate, or had construction permits prior to July 1, 1976. For plants with applications docketed but construction permit not received as of July 1, 1976, they were required, " in the event of the most severe earthquake, i.e., the SSE, the fire suppression system should be capable of delivering water to manual hose stations located within hose reach of areas containing equipment required for safe plant shutdown." How are safe shutdown equipment protected from an oil spill which can cause potential fire?

The NRC's guidance since 1976 also recommends that fire detection, alarm, and suppression systems function as designed after less severe earthquakes that are expected to occur once every 10 years. The guidance further recommends plant operators in areas of high seismic activity consider the need to design those fire protection systems to function after a severe earthquake.

### 47) How are safe shutdown equipment protected from an oil spill which can cause potential fire?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** In general, the NRC recommends that curbing and dikes be located around all equipment that presents an oil fire hazard. In one special case, the Reactor Cooling Pumps (RCPs) located inside the containment of Pressurized Water Reactors (PWRs) the NRC requires that plants have a seismically qualified oil collection system. The purpose of this requirement is that in the event of a severe earthquake the lubrication oil is not spread out inside containment.

## 48) How are safe shutdown equipment protected from a hydrogen fire?

**Public Response:** The below is from an internal document. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** Hydrogen can be normally found in a couple areas of the plant. For example, most all large electric generating stations (Nuclear, Coal, Oil, Gas and Hydro) use hydrogen as a blanket in the electric generator. This hydrogen storage is typically well separated from safe shutdown equipment. Hydrogen may also be generated in Battery Rooms during charging and discharging of the stations emergency batteries. The battery rooms are typically equipped with hydrogen detectors set to alarm at about 2% (Hydrogen's lower flammable limit is 4.1%). The ventilation system is typically run to prevent any hydrogen build up. In PWR's hydrogen is used as a cover gas in the Volume Control Tank (VCT). This gas is kept at a normally lower pressure (15-20 psig) to allow oxygen scavenging in the tank. Systems like this typically have devices such as excess flow check valves that automatically isolate the system if excess flow occurs. The NRC recommends that pipes that contain hydrogen are designed to withstand a severe earthquake. This design includes a separate pipe wrapped around the hydrogen pipe that vents any leaked hydrogen to the outside.

*[Also please note that this is general information. Mark Salley noted that if the question relates to H2 generated as a part of fuel failure there is a whole other conversation that needs to happen. Please contact him with questions.]*

## 49) What do we know about the potential for and consequences of a zirconium fire in the spent fuel pool?

**Public Response:** The below is from an internal document. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** Spent fuel pools contain large amounts of water to keep the fuel cooled, and no fire can result as long as the water covers the fuel. Should the pool not be cooled for a substantial amount of time (on the order of days), the water in the pool may boil off. Should that continue and the fuel be exposed, the fuel could overheat. In the worst case, the zirconium cladding could oxidize and burn. The result of such a fire would be significant damage to the fuel, also the fire has the potential to propagate to the other assemblies, as well as release of hydrogen gas and volatile radioactive materials.

## 50) Can a zirconium fuel fire be prevented by wide spacing of spent fuel assemblies in the spent fuel pool?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** Wider spacing would help in preventing a fire. Preventing a fire requires coolability in absence of water submersion. This depends on the heat and the assembly arrangement in the pool. A disbursed arrangement of assemblies based on their decay heat is coolable in significantly less time than that needed for a uniformly loaded pool. Other arrangements can also mitigate the potential of the onset of zirconium fires.

## Seismically Induced Internal Flooding

### 51) How does the NRC consider seismically induced equipment failures leading to internal flooding?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** 10 CFR Part 50 Appendix A General Design Criterion (GDC) 2 requires, in part, that structures, systems, and components (SSCs) important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. 10 CFR Part 50 Appendix A, GDC 4 requires the SSCs important to safety being designed to accommodate the effects of the flooding associated with seismic events. NUREG-0800, Standard Review Plan, Section 3.4.1, "Internal Flood Protection for Onsite Equipment Failures," provide guidance for the NRC staff to consider seismically induced equipment failures (pipe breaks, tank failures) that could affect safety-related SSCs to perform their safety functions.

The specific areas of review include the following :

- Identify all safety-related SSCs that must be protected against flooding;
- The location of the safety-related SSCs relative to the **internal flood level** (from internal flood analysis) in various buildings, rooms, and enclosures that house safety-related SSCs;
- Possible flow paths from interconnected non-safety-related areas to rooms that house safety-related SSCs;
- The adequacy of the isolation, if applicable, from sources causing the flood (e.g., tank of water )
- Provisions for protection against possible in-leakage sources (from outside to inside of the structures)
- All SSCs that could be a potential source of internal flooding (e.g. pipe breaks and cracks, tank and vessel failures, backflow through drains), **which includes seismically induced equipment failures,** are included for the internal flood analysis – see Q&A (2);
- Design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.);
- Safety-related structures that are protected from below-grade groundwater seepage by means of a permanent dewatering system.

### 52) How is the potential source of internal flooding from the seismically induced equipment failures postulated in the internal flood analysis?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** All of the non-safety-related systems in the room are assumed to fail. However, the analysis systematically considers the flooding condition/level caused by only one system at a time. By considering the pipe size, volume of the source tank, and the isolation valves, the limiting case, which is the one that releases the largest volume of water, is used to determine the internal flood level. All of the safety-related SSCs are designed to be located above the calculated flood level caused by the limiting case.

### 53) Are the non-safety-related equipment failures assumed to occur at the same time?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** No. As stated earlier, for design basis flood analysis, it is assumed that a system (containing water source) fails one at a time. Then, the most limiting case, a system breach that causes highest level of flooding, is applied in the design of the location of the safety-related systems.

## About Japanese Hazard, Design and Earthquake Impact

### 54) Was the damage to the Japanese nuclear plants mostly from the earthquake or the tsunami?

**Public response:** Because this event happened in Japan, it is hard for NRC staff to make the assessment necessary to understand exactly what happened at this time. In the nuclear plants there may have been some damage from the shaking, and the earthquake caused the loss of offsite power. However, the tsunami appears to have played a key role in the loss of other power sources at the site producing station blackout, which is a critical factor in the ongoing problems.

**Additional, technical, non-public information:** None

### 55) What was the disposition of the plant during the time after the earthquake struck and before the tsunami arrived? Was there indication of damage to the plant solely from the earthquake (if so, what systems) and did emergency procedures function during this time.

**Public response:** Given that the Fukushima plant is not in the US, the NRC does not yet have enough information to answer this question.

**Additional, technical, non-public information:** Typically there would be the opportunity to get this data, but given the situation it is not clear.

### 56) What magnitude earthquake was the plant designed to withstand? For example, what magnitude earthquake was the plant expected to sustain with damage but continued operation? And with an expected shutdown but no release of radioactive material?

**Public response:** There are two shaking levels relevant to the Fukushima plant, the original design level ground motion and a newer review level ground motion. As a result of a significant change in seismic regulations in 2006, NISA, the Japanese regulator initiated a program to reassess seismic hazard and seismic risk for all nuclear plants in Japan. This resulted in new assessments of higher ground shaking levels (i.e. seismic hazard) and a review of seismic safety for all Japanese plants. The program is still on-going, but has already resulted in retrofit in some plants. Therefore, it is useful to discuss both the design level and a review level ground motion for the plants. A relevant table is found a few questions down, and also in the "Additional Information: Useful Tables" section.

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Fukushima | Magnitude 7.1 Earthquake near the site | 600 gal (0.62g) | 370 gal (0.37g) |

**Additional, technical, non-public information:** Add

### 57) Did this reactor sustain damage in the July 16, 2007 earthquake, as the Kashiwazaki power plant did? What damage and how serious was it?

**Public response:** Neither Fukushima power plant was affected by the 2007 earthquake.

**Additional, technical, non-public information:** None.

### 58) Was the Fukushima power plant designed to withstand a tsunami of any size? What sort of modeling was done to design the plant to withstand either seismic events or tsunamis? What specific design criteria were applied in both cases?

**Public response:** Japanese plants are designed to withstand both earthquake and tsunami. An English explanation of how Tsunami hazard assessments are undertaken for Japanese plants is found in Annex II to IAEA Guidance on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations Assessment of Tsunami Hazard: Current Practice in Some States in Japan. The design ground motions are as shown above. We do not have information on the design basis tsunami.

**Additional, technical, non-public information:** Annie has a copy of the draft annex and will put them into ADAMS

### 59) What is the design level of the Japanese plants? Was it exceeded?

**Public response:** As a result of a significant change in seismic regulations in 2006, the Japanese regulator initiated a program to reassess seismic hazard and seismic risk for all nuclear plants in Japan. This resulted in new assessments of higher ground shaking levels (i.e. seismic hazard) and a review of seismic safety for all Japanese plants. The program is still on-going, but has already resulted in retrofit in some plants. Therefore, it is useful to discuss both the design level and a review level ground motion for the plants, as shown below.

Currently we do not have official information. However, it appears that the ground motions (in terms of peak ground acceleration) are similar to the $S_s$ shaking levels, although the causative earthquakes are different. Thus the design basis was exceeded, but the review level may not have been.

**Table: Original Design Basis Ground Motions ($S_2$) and New Review Level Ground Motions ($S_s$) Used for Review of Japanese Plants**

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 gal (0.59g) | 375 gal (0.38g) |
| Fukushima | Earthquake near the site (M7.1) | 600 gal (0.62g) | 370 gal (0.37g) |
| Tokai | Earthquakes specifically undefined | 600 gal (0.62g) | 380 gal (0.39g) |
| Hamaoka | Assumed Tokai (M8.0), etc. | 800 gal (0.82g) | 600 gal (0.62g) |

**Additional, technical, non-public information:** None

### 60) What are the Japanese $S_1$ and $S_s$ ground motions and how are they determined?

**Public response:** Japanese nuclear power plants are designed to withstand specified earthquake ground motions, previously specified as $S_1$ and $S_2$, but now simply $S_S$. The design basis earthquake ground motion $S_1$ was defined as the largest earthquake that can reasonably be expected to occur at the site of a nuclear power plant, based on the known seismicity of the area and local faults that have shown activity during the past 10,000 years. A power reactor could continue to operate safely during an $S_1$ level earthquake, though in practice they are set to trip at lower levels. The $S_2$ level ground motion was based on a larger earthquake from faults that have shown activity during the past 50,000 years and assumed to be closer to the site. The revised seismic regulations in May 2007 replaced $S_1$ and $S_2$ with $S_S$. The $S_S$ design basis earthquake is based on evaluating potential earthquakes from faults that have shown activity during the past 130,000 years. The ground motion from these potential earthquakes are simulated for each of the sites and used to determine the revised $S_S$ design basis ground motion level. Along with the change in definition, came a requirement to consider "residual risk", which is a consideration of the beyond-design-basis event.

**Additional, technical, non-public information:** None

### 61) Did this earthquake affect the Kashiwazaki-Kariwa nuclear power plant?

**Public response:** No, this earthquake did not affect Kashiwazaki-Kariwa nuclear power plant and all reactors remained in the state of operation prior to the March 11, 2011, Japan earthquake. It also did not trip during an earthquake of magnitude XX that occurred on the western side subsequent to the 8.9 earthquake. This is very important for the stability of Japan's energy supply due to the loss of production at TEPCO's Fukushima nuclear power plants.

**Additional, technical, non-public information:** None

### 62) How high was the tsunami at the Fukushima nuclear power plants?

**Public response:** The tsunami modeling team at the National Oceanic and Atmospheric Administration's Pacific Marine Environmental Lab have estimated the wave height just offshore to be approximately 8 meters in height at Fukushima Daiichi and approximately 7 meters in Fukushima Daini. This is based on recordings from NOAA's Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys and a high resolution numerical model developed for the tsunami warning system. If plant recordings exist they were not yet provided to the NRC.

**Additional, technical, non-public information:** NOAA's PMEL center has provided us their best numbers for all the plants on the NW coast of Japan. These can be found in the Additional Information section in the back of this document.

### 63) Wikileaks has a story that quotes US embassy correspondence and some un-named IAEA expert stating that the Japanese were warned about this ... Does the NRC want to comment?

http://www.dailymail.co.uk/news/article-1366721/Japan-tsunami-Government-warned-nuclear-plants-withstand-earthquake.html

**Public response:** TBD Annie to explain the history of their recent retrofit program.

**Additional, technical, non-public information:** The article talks about that the plants and that they were checked for a magnitude 7, but the earthquake was a 9. The reality is that they assumed the magnitude 7 close in had similar ground motions to a 9 farther away. They did check (and retrofit) the plant to the ground motions that they probably saw (or nearly). The problem was the tsunami. We probably need a small write up so that staff understands, even if we keep it internal.

## Impact at US Nuclear Power Plants During the March 11, 2011 Earthquake and Tsunami?

### 64) Was there any damage to US reactors from either the earthquake or the resulting tsunami?

**Public Answer:** No

**Additional, technical non-public information**: Two US plants on the Pacific Ocean (Diablo Canyon and San Onofre) experienced higher than normal sea level due to tsunami. However, the wave heights were consistent with previously predicted levels and this had no negative impact to the plants. In response, Diablo Canyon Units 1 and 2 declared an "unusual event" based on tsunami warning following the Japanese earthquake. They have since exited the "unusual event" declaration, based on a downgrade to a tsunami advisory.

### 65) Have any lessons for US plants been identified?

**Public Answer:** The NRC is in the process of following and reviewing the event in real time. This will undoubtedly lead to the identification of issues that warrant further study. However, a complete understanding of lessons learned will require more information than is currently available to NRC staff.

**Additional, technical non-public information:** We need to take a closer look at common cause failures, such as earthquake and tsunami, and earthquake and dam failure.

## NRC Response and Future Licensing Actions

### 66) What is the NRC doing about the emergencies at the nuclear power plants in Japan? Are you sending staff over there?

**Public Answer:** We are closely following events in Japan, working with other agencies of the federal government and with our counterparts in that country. In addition, we currently have a team of experts in boiling water reactors working in Japan.

**Additional technical, non-public information:** NOTE TO OPA: please check the current staffing in Japan to provide more accurate information. This is changing on an ongoing basis. We are taking the knowledge that the staff has about the design of the US nuclear plants and we are applying this knowledge to the Japan situation. For example, this includes calculations of severe accident mitigation that have been performed.

### 67) With NRC moving to design certification, at what point is seismic capability tested - during design or modified to be site-specific? If in design, what strength seismic event must these be built to withstand?

**Public Answer:** During design certification, vendors propose a seismic design in terms of a ground motion spectrum for their nuclear facility. This spectrum is called a standard design response spectrum and is developed so that the proposed nuclear facility can be sited at most locations in the central and eastern United States. The vendors show that this design ground motion is suitable for a variety of different subsurface conditions such as hard rock, deep soil, or shallow soil over rock. Combined License and Early Site Permits applicants are required to develop a site specific ground motion response spectrum that takes into account all of the earthquakes in the region surrounding their site as well as the local site geologic conditions. Applicants estimate the ground motion from these postulated earthquakes to develop seismic hazard curves. These seismic hazard curves are then used to determine a site specific ground motion response spectrum that has a maximum annual likelihood of $1x10^{-4}$ of being exceeded. This can be thought of as a ground motion with a 10,000 year return period. This site specific ground motion response spectrum is then compared to the standard design response spectrum for the proposed design. If the standard design ground motion spectrum envelopes the site specific ground motion spectrum then the site is considered to be suitable for the proposed design. If the standard design spectrum does not completely envelope the site specific ground motion spectrum, then the COL applicant must do further detailed structural analysis to show that the design capacity is adequate. Margin beyond the standard design and site specific ground motions must also be demonstrated before fuel loading can begin.

**Additional technical, non-public information:** None.

### 68) What are the near term actions that U.S. plants are taking in consideration of the events in Japan?

**Public Answer**: The U.S. nuclear energy industry has already started an assessment of the events in Japan and is taking steps to ensure that U.S. reactors could respond to events that may challenge safe operation of the facilities. These actions include:

- Verify each plant's capability to manage major challenges, such as aircraft impacts and losses of large areas of the plant due to natural events, fires or explosions.
  Verify each plant's capability to manage a total loss of off-site power.

- Verify the capability to mitigate flooding and the impact of floods on systems inside and outside the plant.
- Perform walk-downs and inspection of important equipment needed to respond successfully to extreme events like fires and floods.

**Additional technical, non-public information:** Note to OPA: This was a Q&A from the 3/21 briefing. please check that this is OK to provide to the public before doing so.

### *69)* What are the immediate steps NRC is taking?

**Public Answer**: To date (march 20, 2011) the NRC has taken the following steps:

- The Nuclear Regulatory Commission has issued an Information Notice to all currently operating U.S. nuclear power plants, describing the effects of the March 11 earthquake and tsunami on Japanese nuclear power plants.
- The notice provides a brief overview of how the earthquake and tsunami are understood to have disabled several key cooling systems at the Fukushima Daiichi nuclear power station, and also hampered efforts to return those systems to service. The notice is based on the NRC's current understanding of the damage to the reactors and associated spent fuel pools as of Friday, March 18.
- The notice reflects the current belief that the combined effects of the March 11 earthquake and tsunami exceeded the Fukushima Daiichi plant's design limits. The notice also recounts the NRC's efforts, post-9/11, to enhance U.S. plants' abilities to cope with severe events, such as the loss of large areas of a site, including safety systems and power supplies.

The NRC expects U.S. nuclear power plants will review the entire notice to determine how it applies to their facilities and consider actions, as appropriate.

**Additional technical, non-public information:** Note to OPA: This was a Q&A from the 3/21 briefing. please check that this is OK to provide to the public before doing so.

### 70) Should U.S. residents be using Potassium iodide?

**Public Response**: It is the responsibility of the individual States to decide on the use of KI. It is EPAs responsibility to inform states of projected doses. Due to the extremely low levels of radioactivity expected on the U.S. West coast and Pacific States/territories, the NRC staff does not recommend use of KI.

**Additional technical, non-public information:** None.

# Reassessment of US Plants and Generic Issue 199 (GI-199)

### 71) Can we get the rankings of the plants in terms of safety? (Actually this answer should be considered any time GI-199 data is used to "rank" plants)

**Public Response:** The NRC does not rank nuclear plants by seismic risk. The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The results of the GI-199 safety risk assessment should not be interpreted as definitive estimates of plant-specific seismic risk because some analyses were very conservative making the calculated risk higher than in reality. The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool.

**Additional, technical, non-public information:** NOTE TO OPA: This The following answer to "What are the current findings of GI-199", to create a longer answer if it is appropriate.

### 72) What are the current findings of GI-199?

Currently operating nuclear plants in the US remain safe, with no need for immediate action. This determination is based on NRC staff reviews of updated seismic hazard information and the conclusions of the first stage of GI-199. Existing nuclear plants were designed with considerable margin to be able to withstand the ground motions from the "deterministic" or "scenario earthquake" that accounted for the largest earthquakes expected in the area around the plant. The results of the GI-199 assessment demonstrate that the probability of exceeding the design basis ground motion may have increased at some sites, but only by a relatively small amount. In addition, the probabilities of seismic core damage are lower than the guidelines for taking immediate action. Although there is not an immediate safety concern, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** None.

### 73) If the plants are designed to withstand the ground shaking why is there so much risk from the design level earthquake

Much of the risk in the total risk levels provided in the report comes from earthquakes stronger than the safe shutdown ground motion. The anything indicated in the geologic record used to determine the design requirements at these sites. The numbers are based on an evaluation of all of the potential seismic sources in the CEUS and are used to produce seismic hazard estimates (curves) for each site. The GI-199 effort to date has performed a screening assessment to determine if further, more detailed studies are warranted. This study has utilized information from plant-specific evaluation of external hazards, including earthquakes. That information was gathered to identify potential seismic vulnerabilities, not to produce robust risk estimates. Therefore, the GI-199 results should be viewed as preliminary and not definitive.

### 74) Does the NRC have a position on the MSNBC article that ranked the safety of US plants?

**Public Response:** A recent article by MSNBC (add reference) cites results of a US Nuclear Regulatory Commission study released in September, 2010. The study investigated the implications of updated seismic hazard estimates in the central and eastern United States. The study was prepared as a screening assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The report clearly states that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." Accordingly, the results were not used to rank or compare plants. The study produced plant-specific results of the estimated change in risk from seismic hazards. The study did not rely on the absolute value of the seismic risk except to assure that all operating plants are safe. The plant-specific results were used in aggregate to determine the need for continued evaluation and were included in the report for openness and transparency. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

The report reached three main conclusions: 1) Seismic hazard estimates have increased at some operating plants in the central and eastern US; 2) there is no immediate safety concern, plants have significant safety margin and overall seismic risk estimates remain small; and 3) assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** This was the draft press release. Were any changes made?

### 75) Overall, how would the NRC characterize the CDF numbers? A quirk of numbers? A serious concern?

**Public Response:** The study is still underway and it is too early to predict the final outcome. However, staff has determined that there is no immediate safety concern and that overall seismic risk estimates remain small. If at any time the NRC determines that an immediate safety concern exists, action to address the issue will be taken. However, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** None.

### 76) Describe the study and what it factored in – plant design, soils, previous quakes, etc.

**Public Response:** The study considers the factors that impact estimates of both the seismic hazard (i.e. ground shaking levels) at the site and the plants resistance to earthquakes (mathematically represented by the plant level fragility curve). Previous quakes, the tectonic environment, and the soils that underlie the site are all used in the development of the ground shaking estimates used in the analyses. Plant design and the seismic resistance of the important structures, systems, and components are all used in the development of plant level fragility curves.

**Additional, technical, non-public information:** None.

### 77) Explain "seismic curve" and "plant level fragility curve".

**Public Response:** A seismic curve is a graphical representation of seismic hazard. Seismic hazard in this context is the highest level of ground motion expected to occur (on average) at a site over different periods of time. Plant level fragility is the probability of damage to plant structures, systems and components as a function of ground shaking levels.

**Additional, technical, non-public information:** None.

### 78) Explain the "weakest link model".

**Public Response:** The weakest link model is a method for evaluating the importance of different frequencies of ground vibration to the overall plant performance. The model and its details are not integral to understanding the fundamental conclusions of the study.

**Additional, technical, non-public information:** None.

### 79) What would constitute fragility at a plant?

**Public Response:** Fragility is a term that relates the probability of failure of an individual structure, system or component to the level of seismic shaking it experiences. Plant level fragility is the probability of damage to sets of plant structures, systems and components as a function of ground shaking levels.

**Additional, technical, non-public information:** None.

### 80) The 1-in-18,868 risk for Limerick: What is the risk for? A jostling? A crack? Significant core damage leading to a meltdown?

**Public Response:** The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted consistent with NRC directives. The results of the GI-199 SRA should not be interpreted as definitive estimates of plant-specific seismic risk. The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

**Additional, technical, non-public information:** None.

### 81) Can someone put that risk factor into perspective, using something other than MSNBC's chances of winning the lottery?

**Public Response:** As noted above, the risk factors determined in GI-199 were conservative estimates of risk intended for use as a screening tool. Use of these factors beyond this intended purpose is inappropriate.

**Additional, technical, non-public information:** None.

### 82) What, if anything, can be done at a site experiencing such a risk? (Or at Limerick in particular.)

**Public Response:** The probabilistic seismic risk analyses (SPRA) that are performed to determine the core damage frequency (CDF) numbers also provides a significant amount of information on what the plant vulnerabilities are. This allows the analyst to determine what can be done to the plant to address the risk.

**Additional, technical, non-public information:** None.

### 83) Has anyone determined that anything SHOULD be done at Limerick or any of the other PA plants?

**Public Response:** The fundamental conclusion of the report is that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." The NRC is planning to issue a Generic Communication to operating reactor licensees in the CEUS requesting additional information. This includes the plants in PA.

**Additional, technical, non-public information:** None.

**84) I noted the language on Page 20 of the report: This result confirms NRR's conclusion that currently operating plants are adequately protected against the change in seismic hazard estimates because the guidelines in NRR Office Instruction LIC-504 "Integrated Risk-Informed Decision Making Process for Emergent Issues" are not exceeded. Can someone please explain?**

**Public response:** Can someone help with this?

**Additional, technical, non-public information:** None.

**85) Is the earthquake safety of US plants reviewed once the plants are constructed?**

**Public response:** Yes, earthquake safety is reviewed during focused design inspections, under the Generic Issues Program (GI-199) and as part of the Individual Plant Evaluation of External Events program (IPEEE) that was conducted in response to Generic Letter 88-20 Supplement 4.

**Additional, technical, non-public information:** None.

**86) Does the NRC ever review tsunami risk for existing plants?**

**Public Answer:** The NRC has not conducted a generic issue program on tsunami risk to date. However, some plants have been reviewed as a result of the application for a license for a new reactor. In the ASME/ANS 2009 seismic probabilistic risk assessment standard, all external hazards are included.

**Additional, technical, non-public information:** None.

**87) Does GI-199 consider tsunami?**

**Public response:** GI-199 stems from the increased in perceived seismic hazard focused on understanding the impact of increased ground motion on the risk at a plant. GI-199 does not consider tsunami

**Additional, technical, non-public information:** In the past there has been discussion about a GI program on tsunami, but the NRC's research and guidance was not yet at the point it would be effective. We are just getting to this stage and the topic should be revisited.

**88) What is Generic Issue 199 about?**

**Public Answer:** Generic Issue 199 investigates the safety and risk implications of updated earthquake-related data and models. These data and models suggest that the probability for earthquake ground motion above the seismic design basis for some nuclear plants in the Central and Eastern United States, although is still low, is larger than previous estimates.

**Additional, technical, non-public information:** See additional summary/discussion of GI-199 and terms below.

**89) Where can I get current information about Generic Issue 199?**

**Public Answer:** The public NRC Generic Issues Program (GIP) website (http://www.nrc.gov/about-nrc/regulatory/gen-issues.html) contains program information and documents, background and historical information, generic issue status information, and links to related programs. The latest Generic Issue Management Control System quarterly report, which has regularly updated GI-199 information, is publicly available at http://www.nrc.gov/reading-rm/doc-collections/generic-issues/quarterly/index.html. Additionally, the US Geological Survey provides data and results that are publicly available at http://earthquake.usgs.gov/hazards/products/conterminous/2008/.

**Additional, technical, non-public information:** The GI-199 section of the NRC internal GIP website (http://www.internal.nrc.gov/RES/projects/GIP/Individual%20GIs/GI-0199.html) contains additional information about Generic Issue 199 (GI-199) and is available to NRC staff.

### 90) How was the seismic design basis for an existing nuclear power plant established?

**Public Answer:** The seismic ground motion used for the design basis was determined from the evaluation of the maximum historic earthquake within 200 miles of the site, without explicitly considering the time spans between such earthquakes; safety margin was then added beyond this maximum historic earthquake to form a hypothetical *design basis earthquake*. The relevant regulation for currently operating plants is 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-appa.html).

**Additional, technical, non-public information: See** discussion at end of GI-199 section for discussion of safety margin and design basis.

### 91) Is there margin above the design basis?

**Public Answer**: Yes, there is margin beyond the design basis. In the mid to late 1990s, NRC staff reviewed the plants' assessments of potential ground motion beyond the safety margin included in each plant's design basis, which licensees performed as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs.,

**Additional, technical, non-public information:** The goal of seismic engineering is to design structures, systems and components that explicitly do not fail at the design level. The application of specific codes, standards, and analysis techniques results in margin beyond the design level. The assessments carried out as part of the IPEEE program demonstrated that margin exists in the operating reactors against seismic demand.

### 92) Are all US plants being evaluated as a part of Generic Issue 199?

**Public Answer:** The scope of the Generic Issue 199 (GI-199) Safety/Risk Assessment is limited to all plants in the Central and Eastern United States. Although plants at the Columbia, Diablo Canyon, Palo Verde, and San Onofre sites are not included in the GI-199 Safety/Risk Assessment, the Information Notice on GI-199 is addressed to all operating power plants in the US (as well as all independent spent fuel storage installation licensees). The staff will also consider inclusion of operating reactors in the Western US in its future generic communication information requests.

**Additional, technical, non-public information:** The staff is currently developing specific information needs to be included in a Generic Letter to licensees in the CEUS.

### 93) Are the plants safe? If you are not sure they are safe, why are they not being shut down? If you are sure they are safe, why are you continuing evaluations related to this generic issue?

**Public Answer:** Yes, currently operating nuclear plants in the United States remain safe, with no need for immediate action. This determination is based on NRC staff reviews associated with Early Site Permits (ESP) and updated seismic hazard information, the conclusions of the Generic Issue 199 Screening Panel (comprised of technical experts), and the conclusions of the Safety/Risk Assessment Panel (also comprised of technical experts).

No immediate action is needed because: (1) existing plants were designed to withstand anticipated earthquakes with substantial design margins, as confirmed by the results of the Individual Plant Examination of External Events program; (2) the probability of exceeding the *safe shutdown earthquake* ground motion may have increased at some sites, but only by a relatively small amount; and (3) the Safety/Risk Assessment Stage results indicate that the probabilities of seismic core damage are lower than the guidelines for taking immediate action.

Even though the staff has determined that existing plants remain safe, the Generic Issues Program criteria (Management Directive 6.4) direct staff to continue their analysis to determine whether any cost-justified plant improvements can be identified to make plants enhance plant safety.

**Additional, technical, non-public information :** The Safety/Risk Assessment results confirm that plants are safe. The relevant risk criterion for GI-199 is total *core damage frequency* (CDF). The threshold for taking immediate regulatory action (found in NRR Office Instruction LIC-504, see below) is a total CDF greater than or on the order of $10^{-3}$ (0.001) per year. For GI-199, the staff calculated seismic CDFs of $10^{-4}$ (0.0001) per year and below for nuclear power plants operating in the Central and Eastern US (CEUS) (based on the new US Geological Survey seismic hazard curves). The CDF from internal events (estimated using the staff-developed Standardized Plant Analysis of Risk models) and fires (as reported by licensees during the IPEEE process and documented in NUREG-1742), when added to the seismic CDF estimates results in the total risk for each plant to be, at most, $4 \times 10^{-4}$ (0.0004) per year or below. This is well below the threshold (a CDF of $10^{-3}$ [0.001] per year) for taking immediate action. Based on the determination that there is no need for immediate action, and that this issue has not changed the licensing basis for any operating plant, the CEUS operating nuclear power plants are considered safe. In addition, as detailed in the GI-199 Safety/Risk Assessment there are additional, qualitative considerations that provide further support to the conclusion that plants are safe.

Note: The NRC has an integrated, risk-informed decision-making process for emergent reactor issues (NRR Office Instruction LIC-504, ADAMS Accession No. ML100541776 [not publically available]). In addition to deterministic criteria, LIC-504 contains risk criteria for determining when an emergent issue requires regulatory action to place or maintain a plant in a safe condition.

### 94) What do you mean by "increased estimates of seismic hazards" at nuclear power plant sites?

**Public Answer:** *Seismic hazard* (earthquake hazard) represents the chance (or probability) that a specific level of ground motion could be observed or exceeded at a given location. Our estimates of seismic hazard at some Central and Eastern United States locations have changed based on results from recent research, indicating that earthquakes occurred more often in some locations than previously estimated. Our estimates of seismic hazard have also changed because the models used to predict the level of ground motion, as caused by a specific magnitude earthquake at a certain distance from a site, changed. The increased estimates of seismic hazard at some locations in the Central and Eastern United States were discussed in a memorandum to the Commission, dated July 26, 2006. (The memorandum is available in the NRC Agencywide Documents Access and Management System [ADAMS] under Accession No. ML052360044).

**Additional, technical, non-public information:** See additional discussion of terms at the end of the document.

### 95) Does the SCDF represent a measurement of the risk of radiation RELEASE or only the risk of core damage (not accounting for secondary containment, etc.)?

**Public Response:** Seismic core damage frequency is the probability of damage to the core resulting from a seismic initiating event. It does not imply either a meltdown or the loss of containment, which would be required for radiological release to occur. The likelihood of radiation release is far lower.

**96) Did an NRC spokesperson tell MSNBC's Bill Dedman that the weighted risk average was invalid and useless? He contends to us that this is the case.**

**Public Response:** No. See Answers below.

**97) 3. If it was "invalid" as he claims, why would the USGS include that metric?**

**Public Response:** The weighted average is not invalid (see Answer 5 below). All of the values in Appendix D were developed by NRC staff. Table D-1 in Appendix D uses the (2008) US Geological Survey (USGS) seismic source model, but the Seismic Core Damage Frequency results were developed by US NRC staff. The USGS seismic source model is the same one used to develop the USGS National Seismic Hazard Maps.

**98) Can you explain the weighted average and how it compares to the weakest link average?**

**Public Response:** Tables D-1 through D-3 in Appendix D of the US NRC study show the "simple" average of the four spectral frequencies (1, Hz, 5 Hz, 10 Hz, peak ground acceleration (PGA)), the "IPEEE weighted" average and the "weakest link" model. These different averaging approaches are explained in Appendix A.3 (simple average and IPEEE weighted average) and Appendix A.4 (weakest link model). The weighted average uses a combination of the three spectral frequencies (1, 5, and 10 Hz) at which most important structures, systems, and components of nuclear power plants will resonate. The weakest link is the largest SCDF value from among the four spectral frequencies noted above.

**99) Ultimately would you suggest using one of the models (average, weighted, weakest link) or to combine the information from all three?**

**Public Response:** Most nuclear power plant structures, systems, and components resonate at frequencies between 1 and 10 Hz, so there are different approaches to averaging the Seismic Core Damage Frequency (SCDF) values. By using multiple approaches, the NRC staff gains a better understanding of the uncertainties involved in the assessments.

**100) Were there any other factual inaccuracies or flaws in Mr. Dedman's piece you would like clarify/point out.**

**Public Response:** The US Nuclear Regulatory Commission study, released in September, 2010, was prepared as a screening assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The report clearly states that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." Accordingly, the results were not used to rank or compare plants. The study produced plant-specific results of the estimated change in risk from seismic hazards. The study did not rely on the absolute value of the seismic risk except to assure that all operating plants are safe. The plant-specific results were used in aggregate to determine the need for continued evaluation and were included in the report for openness and transparency. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

**101) Mr. Dedman infers that the plant quake risk has grown (between the 1989 and 2008 estimates) to the threshold of danger and may cross it in the next study. Is this the NRC's position?**

**Public Response:** The US NRC evaluation is still underway and it is too early to predict the final outcome. However, staff has determined that there is no immediate safety concern and that overall seismic risk estimates remain small. If at any time the NRC determines that an immediate safety concern exists, action to address the issue will be taken. However, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue

**102) Let's say there's an estimate expressed as "2.5E-06." (I'm looking at Table D-2 of the safety/risk assessment of August 2010.) I believe that this expression means the same as 2.5 x 10^-06, or 0.0000025, or 2.5 divided by one million. In layman's terms, that means an expectation, on average, of 2.5 events every million years, or once every 400,000 years. Similarly, "2.5E-05" would be 2.5 divided by 100,000, or 2.5 events every 100,000 years, on average, or once every 40,000 years. Is this correct?**

**Public Response:** Yes, at least partly. In the subject documents the frequencies for core damage or ground motion exceedance have been expressed in the form "2.5E-06". As you noted this is equivalent to 2.5x10-6, or 0.000025 per year. If, for example, the core damage frequency was estimated as 2.5E-06, this would be equivalent to an expectation of 2.5 divided by a million per year. It is not really correct to think of these values as "once every 400,000 years," the two numbers are mathematically equivalent but do not convey the same statistical meaning within this context. Rather, you could characterize it as 1 in 400,000 per year of something occurring.

**Additional, technical, non-public information:** None

**103) The GI-199 documents give updated probabilistic seismic hazard estimates for existing nuclear power plants in the central and eastern US What document has the latest seismic hazard estimates (probabilistic or not) for existing nuclear power plants in the western US?**

**Public Response:** At this time the staff has not formally developed updated probabilistic seismic hazard estimates for the existing nuclear power plants in the Western US However, NRC staff during the mid- to late-1990's reviewed the plants' assessments of potential consequences of severe ground motion from earthquakes beyond the plant design basis as part of the Individual Plant Examination of External Events (IPEEE) program. From this review, the NRC staff determined that the seismic designs of operating plants in the US have adequate safety margin. NRC staff has continued to stay abreast of the latest research on seismic hazards in the Western US and interface with colleagues at the US Geological Survey. The focus of Generic Issue 199 has been on the CEUS. However, the Information Notice that summarized the results of the Safety/Risk Assessment was sent to all existing power reactor licensees. The documents that summarize existing hazard estimates are contained in the Final Safety Analysis Reports (FSARS) and in the IPEEE submittals. It must be noted that following 9/11 the IPEEE documents are no longer publicly available.

**Additional, technical, non-public information:** None

**104) The GI-199 documents refer to newer data on the way. Have NRC, USGS et al. released those? I'm referring to this: "New consensus seismic-hazard estimates will become available in late 2010 or early 2011 (these are a product of a joint NRC, US Department of Energy, US Geological Survey (USGS) and Electric Power Research Institute (EPRI) project). These consensus seismic hazard estimates will supersede the existing EPRI, Lawrence Livermore National Laboratory, and USGS hazard estimates used in the GI-199 Safety/Risk Assessment."**

**Public Response:** The new consensus hazard curves are being developed in a cooperative project that has NRC, US Department of Energy, US Geological Survey (USGS) and Electric Power Research Institute (EPRI) participation. The title is: The Central and Eastern US Seismic Source Characterization (CEUS-SSC) project. The project is being conducted following comprehensive standards to ensure quality and regulatory defensibility. It is in its final phase and is expected to be publicly released in the fall of 2011. The project manager is Larry Salamone (Lawrence.salamone@srs.gov, 803-645-9195) and the technical lead on the project is Dr. Kevin Coppersmith (925-974-3335, kcoppersmith@earthlink.net). Additional information on this project can be found at: http://mydocs.epri.com/docs/ANT/2008-04.pdf, and http://my.epri.com/portal/server.pt?open=512&objID=319&&PageID=218833&mode=2&in_hi_userid=2&cached=true.

**Additional, technical, non-public information:** None

**105) What is the timetable now for consideration of any regulatory changes from the GI-199 research?**

**Public Response:** The NRC is working on developing a Generic Letter (GL) to request information from affected licensees. The GL will likely be issued in a draft form within the next 2 months to stimulate discussions with industry in a public meeting. After that it has to be approved by the Committee to Review Generic Requirements, presented to the Advisory Committee on Reactor Safeguards and issued as a draft for formal public comments (60 days). After evaluation of the public comments it can then be finalized for issuance. We expect to issue the GL by the end of this calendar year, as the new consensus seismic hazard estimates become available. The information from licensees will likely require 3 to 6 months to complete. Staff's review will commence after receiving licensees' responses. Based on staff's review, a determination can be made regarding cost beneficial backfits where it can be justified.

**Additional, technical, non-public information:** None

1. Please explain in plain language how the NRC determined plants are safe with regard to the results of our GI199 assessment report..

2. The GI199 Safety/Risk Assessment states 24 plants "lie in the continue zone" (pg 23) These plants "need more assessment." What are these 24 plants? Why are these plants that require further evaluation safe? (pg 23 and Figure 8)

3. Why is the list of plants identified by the NRC for further evaluation under GI199 different than those identified by MSNBC as the "top 10" likely to fail due to seismic event?

4. Why are plants safe when MSNBC calculations indicate several hundred percent increases in the risk of a seismic event that damages the core?

5. Why do Indian Point 2 and Indian Point 3 plants have different probabilities of failing due to a seismic event when the plants are located next to each other? Is IP3 calculated to be the most

likely to fail due to a seismic event? Why? Why is IP2 different? Aren't these plant at the same location and very similar design?

6. Why is Pilgrim not in the NRC "continue to evaluate zone" but second on the MSNBC list as moist likely to fail due to a seismic event?

## Seismic Probabilistic Risk Assessment (SPRA)

**106) The NRC increasingly uses risk-information in regulatory decisions. Are risk-informed PRAs useful in assessing an event such as this?**

**Public response:** Nilesh Chokshi to provide Q&As on SPRA

**Additional, technical, non-public information:** None

## Defense-in-Depth and Severe Accident Management

This is not exactly related to seismic questions. I read these with great interest. I believe there are many staff who would like to be more informed about this topic. So, I have included it.

### 107) Although there undoubtedly will be many lessons learned about severe accidents from the tragic events at Fukushima, have you identified any early lessons?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** There will undoubtedly be many lessons learned in the months and years to come as we learn more about the tragic events at the Fukushima Daiichi plant in Japan. However, one of the early lessons is this: You can't anticipate — either in the deterministic design basis of the plant or through probabilistic risk assessment models — everything that could happen. That is why the NRC's defense-in-depth philosophy is fundamental to ensuring that safety is achieved, even under extreme circumstances, such as those experienced at the Fukushima Daiichi plant. This NRC focus on defense-in-depth has led to a number of improvements in the design and operation of U.S. Nuclear Power Plants:

- Studies of severe accident prevention and mitigation in the 1980s led to a number of improvements at plants, such as installation of hardened vents at BWRs with Mark I containments. (See "fact sheet" for more detail.)
- Also, in the 1980s (specifically in 1988) the NRC concluded that additional regulatory requirements were justified in order to provide further assurance that a loss of both offsite and onsite emergency ac power systems would not adversely affect public health and safety and the station blackout rule was enacted. Studies conducted by the NRC since this rule has been in effect confirms that the hardware and procedures that have been implemented to meet the station blackout requirements have resulted in significant risk reduction and have further enhanced defense-in-depth. However, we plan to carefully evaluate the lessons learned from the events in Japan to determine if enhancements to the station blackout rule are warranted. (See "fact sheet" on station black-out.)
- Operator procedures that are symptom-based and ensure that operators primary focus is maintaining the critical safety functions such as ensuring the core is cooled and covered.
- Addition procedures for operators to use in the event of a severe accident (Severe Accident Mitigation Guidelines (SAMG)).
- Provisions in 10 CFR 50.54hh that require licensees to develop and implement guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities in situations involving loss of large areas of the plant due to explosions or fire.

### 108) What procedures do U.S. plants have for responding to an unexpected event like the events in Japan.

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** One of the most significant lessons learned from the Three Mile Island Accident in 1979 was that operating procedures need to be symptom based and less prescriptive. Procedures that previously directed operators to take a series of actions based on a preestablished accident were replaced with procedures that directed operators to maintain the critical safety functions, such as keeping the core covered and cooled. Operators routinely practice these procedures on a plant specific simulator to ensure that they can be implemented for a wide range of accident scenarios, including a station blackout scenario, or other events caused by an earthquake or a flood.

### 109) What are Severe Accident Management Guidelines

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** SAMGs are the set of guidelines employed to manage the in-plant response following a severe accident (i.e., Beyond design basis events that are expected to have resulted in significant core damage).

The *ultimate objective* of SAMGs is to protect the health and safety of the public from the hazards associated with the uncontrolled release of radioactive materials

The *operational objective* of SAMGs is to protect or restore, if possible, the integrity of the three physical barriers (fuel, reactor coolant system, and containment) to contain fission products.

Some important aspects of the guidelines are as follows:

- SAMGs go beyond the Emergency Operating Procedures (EOPs)
- SAMGs identify all possible means of achieving the operational objective, including the use of non-safety-related equipment and capabilities on site (including capabilities from other units)
- plant-specific SAMGs identify the various safety functions and list the capabilities to achieve that function, with some high-level procedure-like guidance.

## Station Blackout

This is not exactly related to seismic questions. But, similar to the above topics, I read these with great interest. I believe there are many staff who would like to be more informed about this topic and this is an excellent summary. So, I have included it here.

### 110) What is the definition of station blackout?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Station blackout (SBO) means the complete loss of alternating current (ac) electric power to the essential and nonessential switchgear buses in a nuclear power plant (i.e., loss of offsite electric power system concurrent with turbine trip and unavailability of the onsite emergency ac power system). Station blackout does not include the loss of available ac power to buses fed by station batteries through inverters or by alternate ac sources as defined in this section, nor does it assume a concurrent single failure or design basis accident. At single unit sites, any emergency ac power source(s) in excess of the number required to meet minimum redundancy requirements (i.e., single failure) for safe shutdown (non-DBA) is assumed to be available and may be designated as an alternate power source(s) provided the applicable requirements are met. At multi-unit sites, where the combination of emergency ac power sources exceeds the minimum redundancy requirements for safe shutdown (non-DBA) of all units, the remaining emergency ac power sources may be used as alternate ac power sources provided they meet the applicable requirements. If these criteria are not met, station blackout must be assumed on all the units.

### 111) What is the existing regulatory requirement regarding SBO?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Each light-water-cooled nuclear power plant licensed to operate must be able to withstand for a specified duration and recover from a station blackout as defined in Sec. 50.2.

### 112) How many plants have an alternate ac (AAC) source with the existing EDGs

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** 60 plants

### 113) How many plants cope with existing class 1E batteries?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** 44 plants

### 114) What are the coping duration determined for the plants based on the SBO Rule

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** 4-16 hours (4 hours only with batteries; 4-16 with AAC)

### 115) How is coping duration determined?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The specified station blackout duration shall be based on the following factors:

(i) The redundancy of the onsite emergency ac power sources;

(ii) The reliability of the onsite emergency ac power sources;

(iii) The expected frequency of loss of offsite power; and

(iv) The probable time needed to restore offsite power.

### 116) When does the SBO event start?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The onset of a loss of offsite power and onsite power as verified by the control room indications

### 117) When does the SBO event end?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Either onsite or offsite power is recovered.

### 118) Did the NRC review the licensee's actions to meet the SBO rule?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes. The NRC staff reviewed the responses from each licensee and issued a SER accepting the proposed coping methods. All plants have (1) established SBO coping and recovery procedures; (2) completed training for these procedures; (3) implemented modifications as necessary to cope with an SBO; and (4) ensured a 4-16 hour coping capability. In addition, the staff performed pilot inspections at 8 sites to verify the implementation of the SBO rule implementation. No issues were identified during initial implementation.

### 119) Are all plants designed to mitigate a station blackout event?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes. All plants have the capability to withstand and recover from a SBO event. In 1988, the NRC concluded that additional regulatory requirements were justified in order to provide further assurance that a loss of both offsite and onsite emergency ac power systems—a station blackout condition--would not adversely affect public health and safety. Studies conducted by the NRC have shown that the hardware and procedures that have been implemented to meet the station blackout requirements have resulted in significant risk reduction and have further enhanced defense in depth.

# Emergency Preparedness (Emphasis on B.5.b)

Although this is not strictly seismic, it is often the case that design for mitigation actions taken for one issue have impact on others. It seems apparent that the actions taken for B.5.b are going to have an impact on the assessment of seismic risk at the plants.

### 120) Is the emergency preparedness planning basis for nuclear power plants is valid?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes- NRC continues to conduct studies to determine the vulnerability of nuclear power plants and the adequacy of licensee programs to protect public health and safety. Whether the initiating event is a severe earthquake, a terrorist based event, or a nuclear accident, the EP planning basis provides reasonable assurance that the public health and safety will be protected. EP plans have always been based on a range of postulated events that would result in a radiological release, including the most severe.

### 121) What is B.5.b?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** After the terrorist attacks of 9/11, the NRC issued an Interim Compensatory Measures (ICM)Order on February 25, 2002, requiring power reactor licensees to take certain actions to prevent or mitigate terrorist attacks. Section B.5.b of the ICM Order required licensees to "Develop specific guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities using existing or readily available resources (equipment and personnel) that can be effectively implemented under the circumstances associated with loss of large areas of the plant due to explosions or fire."

### 122) What were Phases 1, 2, and 3 of the B.5.b?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information: Phase 1:** Phase 1 was part of a larger NRC effort to enhance the safety and security of the nation's nuclear power plants. The Phase 1 effort was initiated as part of the February 2002 ICM Order. The Order, among other things, required licensees to look at what might happen if a nuclear power plant lost large areas due to explosions or fire. The licensees then were required to identify – and later implement – strategies that would maintain or restore cooling for the reactor core, containment building, and spent fuel pool. The requirements listed in Section B.5.b of the ICM Order directed licensees to identify "mitigative strategies" (meaning the measures licensees could take to reduce the potential consequences of a large fire or explosion) that could be implemented with resources already existing or "readily available."

**Phase 2:** In Phase 2, the NRC independently looked at additional ways to protect the spent fuel pools at nuclear power plants. The NRC's plant-specific assessments identified both "readily available" and other resources that could be used to mitigate damage to spent fuel pools and the surrounding areas. The assessments considered damage that could have been caused by land, water, or air attacks.

**Phase 3:** In Phase 3, each nuclear power plant licensee identified ways to improve its ability to protect the reactor core and containment from a terrorist attack. This was done by identifying both "readily available" and other resources that could be used to mitigate loss of large areas of the plant due to fires and explosions. In addition, the NRC independently assessed the plant and audited the licensee's effort to identify additional mitigation strategies.

### 123) Has the NRC inspected full implementation of the mitigating strategies?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** All phases of the B.5.b mitigating strategies were complete and inspected by December 2008.

### 124) What additional action has been taken?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** On March 27, 2009, the NRC amended 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," which added 10 CFR 50.54(hh)(2) in order to impose the same mitigating strategies requirements on new reactor applicants and licensees as those imposed by the ICM Order and associated license conditions. The Statement of Considerations for this rulemaking specifically noted that the requirements described in Section 50.54(hh) are for addressing certain events that are the cause of large fires and explosions an in addition, the rule contemplates that the initiating event for such large fires and explosions could be any number of beyond-design basis events, including natural phenomena such as earthquakes, tornadoes, floods, and tsunami.

### 125) Is more information available about the mitigating strategies and inspections and reviews conducted?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** In general, the B.5.b mitigating strategies are plans, procedures, and pre-staged equipment whose intent is to minimize the effects of adverse events or accidents due to terrorist attacks. The NRC does not publicly release information that could assist terrorists to make nuclear power plants less safe. Since the NRC cannot share the details of the mitigating strategies with the public, we have given briefings to elected officials such as state governors and members of Congress to share sensitive unclassified or classified information, as appropriate. In addition, the NRC

## Other External Hazards

### 126) How many plants are in hurricane zones?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The plants near Gulf of Mexico and East coast as far north as Pilgrim have experienced Hurricane force winds in the past. Approximately 30 plants fall in this category.

### 127) How many plants are susceptible to flooding?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Most nuclear plants are close to large bodies of water and are situated on flat lands. Approximately 80% of the plants fall in this category. There are a few plants that may NOT be vulnerable to flooding such as Palo Verde.

### 128) How many plants are susceptible to blizzard?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The plants in California, Arizona, South Texas, Louisiana and Florida are not expected to fall in this category. Approximately 80% of the plants are likely to experience blizzard conditions or adverse wintry weather conditions.

### 129) How many plants are susceptible to tornadoes?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Majority of the plants in the Midwest and the South have had tornado activity in the area. Approximately 50% of the operating plants

# Plant-Specific Questions

## San Onofre Nuclear Generating Station (SONGS) Questions

### 130) SONGS received a white finding in 2008 for 125VDC battery issue related to the EDGs that went undetected for 4 years. NRC issued the white finding as there was increased risk that one EDG may not have started due to a low voltage condition on the battery on one Unit (Unit 2). Aren't all plants susceptible to the unknown? Is there any assurance the emergency cooling systems will function as desired in a Japan-like emergency?

**Public response:** The low voltage condition was caused by a failure to properly tighten bolts on a electrical breaker that connected the battery to the electrical bus that would be relied on to start the EDG in case of a loss of off-site power. This was corrected immediately on identification and actions taken to prevent its reoccurrence. The 3 other EDGs at SONGS were not affected.

**Additional, technical, non-public information:** None

### 131) Has the earthquake hazard at SONGS been reviewed like Diablo Canyon nuclear power plant (DCNPP) is doing? Are they planning on doing an update before relicensing?

**Public Answer:** Relicensing does not evaluate the potential change to seismic siting of a plant. If there is a seismic design concern, it would be addressed for the plant as it is currently operating.

The closest active fault is approximately five miles offshore from San Onofre, a system of folds and faults exist called the OZD need to write out full name. The Cristianitos fault is ½ mile southeast, but is an inactive fault. Other faults such as the San Andreas and San Jacinto, which can generate a larger magnitude earthquake, are far enough away that they would produce ground motions much less severe than the OZD for San Onofre.

Past history relative to nearby major quakes have been of no consequences to San Onofre. In fact, three major earthquakes from 1992 to 1994 (Big Bear, Landers and Northridge), ranging in distance from 70-90 miles away and registering approximately 6.5 to 7.3 magnitude, did not disrupt power production at San Onofre. The plant is expected to safely shutdown if a major earthquake occurs nearby. Safety related structures, systems and components have been designed and qualified to remain functional and not fail during and after an earthquake.

**Additional, technical, non-public information:** None

### 132) Is possible to have a tsunami at songs that is capable of damaging the plant?

**Public Information**: The San Onofre Units 2 and 3 plant grade is elevation +30.0 feet MLLW. The controlling tsunami for San Onofre occurring during simultaneous high tide and storm surge produces a maximum runup to elevation +15.6 feet MLLW at the Unit 2 and 3 seawall. When storm waves are superimposed, the predicted maximum runup is to elevation +27 MLLW. Tsunami protection for the SONGS site is provided by a reinforced concrete seawall constructed to elevation +30.0 MLLW. A tsunami greater than this height is extremely unlikely.

**Additional, technical, non-public information:** None

### 133) Does SONGS have an emergency plan for tsunami?

**Public Response**: The SONGS emergency plan does initiate the emergency response organization and results in declaration of emergency conditions via their EALs. The facility would then make protective action recommendations to the Governor, who would then decide on what protective actions would be ordered for the residents around SONGS.

**Additional, technical, non-public information:** None

### 134) Has evacuation planning at SONGS considered tsunami?

**Public Response:** These considerations would be contained in the State and local (City, County) emergency plans, which are reviewed by FEMA. FEMA then certifies to the NRC that they have "reasonable assurance" that the off-site facilities can support operation of SONGS in an emergency.

**Additional, technical, non-public information:** None

### 135) Is SONGS designed against tsunami and earthquake?

**Public Response:** Yes. SONGS is designed against both tsunami and earthquake.

**Additional, technical, non-public information:** None

### 136) What is the height of water that SONGS is designed to withstand?

**Public Response:** 30 feet (9.1 meters). Information for all plants can be found in the "Additional Information' section of this document.

**Additional, technical, non-public information:** None

### 137) What about drawdown and debris?

**Public Response:** *Good question...can HQ answer? Goutam, Henry, or Rich...can you help with this one?*

**Additional, technical, non-public information:** None

### 138) Will this be reviewed in light of the Japan earthquake.

**Public Response:** The NRC will do a thorough assessment of the lessons learned from this event and will review all potential issues at US nuclear plants as a result.

**Additional, technical, non-public information:** None

### 139) Could all onsite and offsite power be disrupted from SONGS in the event of a tsunami, and if that happened, could the plant be safely cooled down if power wasn't restored for days after?

**Public Response:** Seismic Category I equipment is equipment that is essential to the safe shutdown and isolation of the reactor or whose failure or damage could result in significant release of radioactive material. All Seismic Category I equipment at SONGS is designed to function following a DBE with ground acceleration of 0.67g.

The operating basis earthquake (1/2 of the DBE) is characterized by maximum ground shaking of 0.33g. Historically, even this level of ground shaking has not been observed at the site. Based on expert analysis, the average recurrence interval for 0.33g ground shaking at the San Onofre site would be in excess of 1000 years and, thus, the probability of occurrence in the 40-year design life of the plant would be less than 1 in 25. The frequency of the DBE would be much more infrequent, and very unlikely to occur during the life of the plant. Even if an earthquake resulted in greater than the DBE movement/acceleration at SONGS, the containment structure would ultimately protect the public from harmful radiation release, in the event significant damage occurred to Seismic category 1 equipment.

**Additional, technical, non-public information:** None

### 140) Are there any faults nearby SONGS that could generate a significant tsunami?

**Public Response:** Current expert evaluations estimate a magnitude 7 earthquake about 4 miles (6.4 km) from SONGS. This is significantly less than the Japan earthquake, and SONGS has been designed to withstand this size earthquake without incident. Should discuss the different tectonic nature (not a subduction zone like Japan)?

**Additional, technical, non-public information:** None

### 141) What magnitude or shaking level is SONGS designed to withstand? How likely is an earthquake of that magnitude for the SONGS site?

**Public Response:** The design basis earthquake (DBE) is defined as that earthquake producing the maximum vibratory ground motion that the nuclear power generating station is designed to withstand without functional impairment of those features necessary to shut down the reactor, maintain the station in a safe condition, and prevent undue risk to the health and safety of the public. The DBE for SONGS was assessed during the construction permit phase of the project. The DBE is postulated to occur near the site (5 miles (8km)), and the ground accelerations are postulated to be quite high (0.67g), when compared to other nuclear plant sites in the U.S (0.25g or less is typical for plants in the eastern US). Based on the unique seismic characteristics of the SONGS site, the site tends to amplify long-period motions, and to attenuate short-period motions. These site-specific characteristics were accounted for in the SONGS site-specific seismic analyses.

**Additional, technical, non-public information:** None

### 142) Could SONGS withstand an earthquake of the magnitude of the Japanese earthquake?

**Public Response:** We do not have current information on the ground motion at the Japanese reactors. SONGS was designed for approximately a 7.0 magnitude earthquake 4 miles (6.4 km) away. The Japanese earthquake was much larger (8.9), but was also almost 9 miles (14.5 km) away. The local ground motion at a particular plant is significantly affected by the local soil and bedrock conditions. SONGS was designed (0.67g) to withstand more than 2 times the design motion at average US plants.

**Additional, technical, non-public information:** None

### 143) What about the evacuation routes at SONGS? How do we know they are reasonable?

**Public Response:** FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at SONGS. The next such exercise is planned for April 12, 2011.

**Additional, technical, non-public information:** None

**144) Regarding tsunami at DCNPP and SONGS, is the tsunami considered separately from flooding in licensing? And from the design perspective, is the flood still the controlling event for those plants rather than the tsunami?**

Public response: See below

**145) What is the design level flooding for DNCPP and SONGS? Can a tsunami be larger?**

**Public response:** Both the Diablo Canyon (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at Diablo canyon are designed for combination of tsunami-storm wave activity. SONGS has reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action

**Additional, technical, non-public information:** None

**146) Is there potential linkage between the South Coast Offshore fault near SONGS and the Newport-Inglewood Fault system and/or the Rose Canyon fault? Does this potential linkage impact the maximum magnitude that would be assigned to the South Coast Offshore fault and ultimately to the design basis ground motions for this facility?**

**Public response:** Stephanie and Jon to answer (you may want to change the question) based on the discussions in the articles sent by Lara U.

**Additional, technical, non-public information:** Proposed action is to check the FSAR for San Onofre and read the discussion on characterization of the offshore fault. A quick look at discussion of the Newport Ingelwood from other sources suggest this is part of the "system". It would be helpful to check the basis for segmenting the fault in the FSAR. Probably have to dig on this a bit, may need to look at the USGS/SCEC/ model for this area.

## Diablo Canyon Nuclear Power Plant (DCNPP) Questions

**147) Now after the Japan tragedy, will the NRC finally hear us (A4NR) and postpone DC license renewal until seismic studies are complete? How can you be sure that what happened there is not going to happen at Diablo with a worse cast earthquake and tsunami?**

**Public response:** ADD

**Additional, technical, non-public information:** ADD

**148) The evacuation routes at DCNPP see are not realistic. Highway 101 is small...and can you imagine what it will be like with 40K people on it? Has the evacuation plan been updated w/ all the population growth?**

**Public Response:** FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at DCNPP.

**Additional, technical, non-public information:** None

**149) Are there local offshore fault sources capable of producing a tsunami with very short warning times?**

**Public Response:** ADD- question forwarded to region

**Additional, technical, non-public information:** ADD

**150) Are there other seismically induced failure modes (other than tsunami) that would yield LTSBO? Flooding due to dam failure or widespread liquefaction are examples.**

**Public Response:** ADD question forwarded to region

**Additional, technical, non-public information:** ADD

**151) Ramifications of beyond design basis events (seismic and tsunami) and potential LTSBO on spent fuel storage facilities?**

**Public Response:** ADD question forwarded to region

**Additional, technical, non-public information:** ADD

**152) Why did the Emergency Warning go out for a 'tsunami' that was only 6 ft (1.8 m) high? Do these guys really know what they're doing? Would they know it if a big one was really coming? Crying wolf all the time doesn't instill a lot of confidence.**

**Public Response:** The warning system performed well. The 6 foot (1.8 meters) wave was predicted many hours before and arrived at the time it was predicted. Federal officials to accurately predicted the tsunami arrival time and size; allowing local official to take appropriate measures as they saw necessary to warn and protect the public. It should be understood that even a 6 foot tsunami is very dangerous. Tsunamis have far more energy and power than wind-driven waves.

**Additional, technical, non-public information:** ADD

**153) How big did the Japanese think an earthquake and tsunami could be before March 11, 2011? Why were they so wrong (assuming this earthquake/tsunami was bigger than what they had designed the plant for)?**

**Public Response:** ADD can HQ answer?

**Additional, technical, non-public information:** ADD

**The Japanese were supposed to have one of the best tsunami warning systems around. What went wrong last week (both with the reactors and getting the people out...see #1, evacuation plan above)?**

**Public Response:** ADD can HQ answer?

**Additional, technical, non-public information:** ADD

**154) Regarding the tsunami at DCNPP and SONGS, is the tsunami considered separately from flooding in licensing? And from the design perspective, is the flood still the controlling event for those plants rather than the tsunami?**

**Public Response:** Both the Diablo Canyon (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at Diablo canyon are designed for combination of tsunami-storm wave activity. SONGS has reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action

**Additional, technical, non-public information:** ADD

*NOTE: need to add to SONGS and DCNPP... Canyon and San Onofre IPEEEs - based on the Technical Evaluation Reports, Diablo did consider a locally induced tsunami in a limited way (the aux service water pumps were assumed to become flooded following a seismic event) while SONGS did not consider a coupled seismic/tsunami event.*

**155) Shouldn't the NRC make licensees consider a Tsunami coincident with a seismic event that triggers the Tsunami?**

ADD

**156) Given that SSCs get fatigued over time, shouldn't the NRC consider after-shocks in seismic hazard analyses?**

ADD

**157) Did the Japanese also consider an 8.9 magnitude earthquake and resulting tsunami "way too low a probability for consideration"?**

ADD

**158) GI-199 shows that the scientific community doesn't know everything about the seismicity of CEUS. And isn't there a prediction that the West coast is likely to get hit with some huge earthquake in the next 30 years or so? Why does the NRC continue to license plants on the west coast?**

Work the following into Q&As as time permits.

After an earthquake, in order to restart, In practice a licensee needs to determine from engineering analysis that the stresses on the plant did not exceed their licensed limits. That would be a very tall order for a plant that experienced a beyond design basis earthquake, and probably is why it had taken Japan so long to restore the KK plants following the earlier earthquake.

**159) Has industry done anything on tsunami hazards? Also, has anyone done work to look at the effect of numerous cycles of low amplitude acceleration following a larger event. I would expect we would have some information because how do we know a plant would be fit to start back up after an event? We cannot possibly do NDE on everything to determine if flaws have propagated to the point where they need to be replaced.**

### 160) Aren't the California plants right on the San Andreas fault?

No.. Both plants are approximately 50 miles from the San Andreas Fault. However, both are closer to other active fault zones. Diablo Canyon is closer to the Hosgri fault zone and has been retrofit to be safe in ground motions from a magnitude 7.5 earthquake on the Hosgri, which is 3 miles away. Recently there was a new fault, called the Shoreline fault discovered, about a 1/2 mile from the plant. But it is smaller and only capable of about a 6.5 earthquake at the most. The ground motions from the Hosgri's 7.5 earthquake would be larger than an 6.5 on the Shoreline fault. San Onofre is closes to the Newport-Inglewood fault which is about 5 miles away and capable of a magnitude 7. San Onofre was built to withstand the ground motions from that earthquake.

## Indian Point Questions

### 161) Why is Indian Point safe if there is a fault line so close to it?

**Public Response**: The Ramapo fault system, located near the Indian Point Nuclear Power Plant, is an example of an old fault system that, based on geologic field evidence, has not been active in the last 65.5 million years. The Ramapo fault system extends primarily from southeastern New York to northern New Jersey and is made up of a series of northeast- oriented faults. Even though there is minor earthquake activity in the vicinity of the Ramapo faults, this earthquake activity cannot be directly correlated with any individual fault within the Ramapo fault system.

US nuclear power plants are designed and built to withstand the largest expected earthquake in the site region, based on observed historical seismicity and field evidence for prehistoric earthquakes, and are also designed to incorporate seismic safety margins. A potential earthquake in and around the vicinity of the Ramapo fault system was taken into account during the NRC licensing process for the Indian Point plants, and the plant design incorporated the largest expected earthquake in the site region. In summary, the Ramapo fault system exhibits no definitive evidence for recent fault displacement (i.e., no evidence for fault activity in the last 65.5 million years) and the Indian Point nuclear power plant was designed and built to safely shutdown in the event of an earthquake having the highest magnitude observed in the site region. Therefore, the NRC concluded that the risk of significant damage to the Indian Point reactors due to a potential earthquake is acceptable.

**Additional, technical, non-public information:** The information above and following is consistent with the literature and the UFSAR for IP related to the Ramapo fault. The Ramapo fault system, which passes through the Indian Point area, is a group of Mesozoic age faults, extending from southeastern New York to northern New Jersey, as well as further southwest. The fault system is composed of a series of southeast-dipping, northeast-striking faults. Various faults of the system contain evidence of repeated slip in various directions since Proterozoic time, including Mesozoic extensional reactivation. However, the USGS staff, who reviewed 31 geologic features in the Appalachian Mountains and Coastal Plain and compiled a National Database on Quaternary Faulting (Crone and Wheeler, 2000), listed the Ramapo fault system as low risk because the fault system lacks evidence for Quaternary slip. They further pointed out that the Ramapo fault system, and 17 other geologic features, "have little or no published geologic evidence of Quaternary tectonic faulting that could indicate the likely occurrence of earthquakes larger than those observed historically" (Wheeler and Crone, 2004). Among these faults, the Ramapo fault system is one of the three that underwent a paleoseismological study. In two trenches excavated across the Ramapo fault, no evidence of Quaternary tectonic faulting was found (Wheeler and Crone, 2000). Because the Ramapo fault system is relatively inactive, , and because the plants are designed to safely shutdown in the event of an earthquake of the highest intensity ever recorded in that area, the NRC has concluded that the risk of significant damage to the reactors due to a probable earthquake in the area is extremely small.

The letter that was sent to the NRC from Rep Lowey refers to the Ramapo seismic zone (RSZ) and the Dobbs Ferry fault. The letter incorrectly states that the Dobbs Ferry fault is located within the Ramapo seismic zone. Based on the literature, it is not. It is close, but it is considered to be in the Manhattan Prong more to the east (more like 10-15 miles away) while the Ramapo fault system is considered to be in the Reading Prong (a couple of miles away from IP). Also for clarification, the seismicity is considered to be within the Precambrian/Paleozoic basement at depths greater than the Mesozoic Newark Basin where the RSZ is situated.

# Pending and Unanswered Questions from Members of Congress

The below questions are gleaned from the congressional letters coming into the NRC. Because they generally cover different topics, they are being kept together as sets to assist the office assigned with response. Once a formal response is developed and sent, the questions will be moved to the appropriate sections.

## 162) Received 3/16/11 from Congresswoman Lowey

The key elements of the congresswoman's letter are as follows:

The Ramapo Seismic Zone is a particular threat because the zone passes within two miles of Indian Point. The Ramapo Seismic zone includes the Dobbs Ferry fault in Westchester, which generated a 4.1 magnitude earthquake in 19S5. The Columbia University study suggests that this pattern of subtle but active faults increases the risk to the New York City area and that an earthquake with a magnitude of 7.0 on the Richter scale is within reach. Disturbingly, Entergy measures the risk of an earthquake near Indian Point to be between 1.0 and 3.0 on the Richter scale, despite evidence to the contrary.

The NRC should study Indian Point's risk of, and ability to sustain a disaster, including the impact of earthquakes and hurricanes, as well as collateral impacts such as loss of power, inability to cool reactors and emergency evacuation routes. The NRC should evaluate how a similar incident in the New York metropolitan area could be further complicated due to a dramatically higher population and the effectiveness of the proposed evacuation routes.

**Public Response:** Please see technical elements in the above question. NRR has the lead for developing the formal response

**Additional, technical, non-public information:** please see the significant amount of information above

## 163) From 3/16/11 Press Release from Senators Boxer and Feinstein

Plant Design and Operations

1. What changes to the design or operation of the Diablo Canyon and SONGS facilities have improved safety at the plants since they began operating in the mid-1980s?

   **Public Response:** NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

2. What emergency notification systems have been installed at California nuclear power plants? Has there ever been a lapse of these systems during previous earthquakes or emergencies?

   **Public Response:** NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

3. What safety measures are in place to ensure continued power to California reactors in the event of an extended power failure?

   **Public Response:** NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

Type of Reactor

4. What are the differences and similarities between the reactors being used in California (pressurized water reactors) and those in Japan (boiling water reactors), as well as the facilities used to house the reactors, including the standards to which they were built and their ability to withstand natural and manmade disasters?

**Public Response**: NRR/DORL developing response

**Additional, technical, non-public information:** ADD

Earthquakes and Tsunamis

5. We have been told that both Diablo Canyon and San Onofre Nuclear Generating Station are designed to withstand the maximum credible threat at both plants, which we understand to be much less than the 9.0 earthquake that hit Japan. What assumptions have you made about the ability of both plants to withstand an earthquake or tsunami? Given the disaster in Japan, what are our options to provide these plants with a greater margin for safety?

**Public Response**: Annie and Kamal developing response

**Additional, technical, non-public information:** ADD

6. Have new faults been discovered near Diablo Canyon or San Onofre Nuclear Generating Station since those plants began operations? If so, how have the plants been modified to account for the increased risk of an earthquake? How will the NRC consider information on ways to address risks posed by faults near these plants that is produced pursuant to state law or recommendations by state agencies during the NRC relicensing process?

**Public Response**: Annie and Kamal developing response

**Additional, technical, non-public information:** ADD

7. What are the evacuation plans for both plants in the event of an emergency? We understand that Highway 1 is the main route out of San Luis Obispo, what is the plan for evacuation of the nearby population if an earthquake takes out portions of the highway and a nuclear emergency occurs simultaneously?

**Public Response**: NRR/DORL developing response

**Additional, technical, non-public information:** ADD

8. What is the NRC's role in monitoring radiation in the event of a nuclear accident both here and abroad? What is the role of EPA and other federal agencies?

**Public Response**: NRR/DORL developing response

**Additional, technical, non-public information:** ADD

9. What monitoring systems currently are in place to track potential impacts on the US, including California, associated with the events in Japan?

**Public Response**: NRR/DORL developing response

**Additional, technical, non-public information:** ADD

10. 6. Which federal agency is leading the monitoring effort and which agencies have responsibility for assessing human health impacts? What impacts have occurred to date on the health or environment of the US or are currently projected or modeled in connection with the events in Japan?

**Public Response**: NRR/DORL developing response

**Additional, technical, non-public information:** ADD

11. What contingency plans are in place to ensure that the American public is notified in the event that hazardous materials associated with the events in Japan pose an imminent threat to the US?

**Public Response**: NRR/DORL developing response

**Additional, technical, non-public information:** ADD

## 164) From 3/15/11 Press Release from Congresspeople Markey and Capps

Note that these are only the seismic questions. There are other questions that are structural

1. Provide the Richter or moment magnitude scale rating for each operating nuclear reactor in the United States. If no such information exists, on what basis can such an assertion be made regarding the design of any single nuclear power plant?

**Public Response**: US nuclear power plants are designed for different ground motions determined on a site-specific basis, which are called the Safe Shutdown Earthquake ground motions (SSE). Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location. Ground motion, or shaking, is a function of both earthquake magnitude and distance from the fault to the site. The magnitude alone cannot be used to predict ground motions. Currently operating nuclear power plants developed their SSEs based on a "deterministic" or "scenario earthquake" basis that account for the largest earthquake expected in the area around the plant.

Please see the available table of Design Basis Ground Motions for US Plants in the Additional Information: Useful Tables.

**Additional, technical, non-public information:** ADD

2. The San Onofre reactor is reportedly designed to withstand a 7.0 earthquake, and the Diablo Canyon reactor is designed to withstand a 7.5 magnitude. According to the Southern California Earthquake Center (SCEC), there is an 82% probability of an earthquake 7.0 magnitude in the next 30 years, and a 37 percent probability that an earthquake of 7.5 magnitude will occur. Shouldn't these reactors be retrofitted to ensure that they can withstand a stronger earthquake than a 7.5? If not, why not?

**Public Response**: This needs to be edited and enhanced. The noted SCEC magnitudes and probabilities are sourced from Uniform California Earthquake Rupture Forecast (UCERF) Figure 2 (http://www.scec.org/core/public/sceccontext.php/3935/13662). The value quoted describes the probability that an earthquake of that magnitude will occur somewhere in Southern California. The probability that earthquakes of those magnitudes occur near the plants is far smaller. Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location.

**Additional, technical, non-public information:** The colors in UCERF Figure 2 represent the probabilities of having a nearby earthquake rupture (within 3 or 4 miles) of magnitude 6.7 or larger in the next 30 years. Therefore, reading the colors off of Figure 2, the San Onofre and Diablo Canyon NPPs have a ≤10% probability of having a ≥M6.7 earthquake rupture within 3 to 4 miles in the next 30 years. Therefore, retrofitting these reactors to withstand earthquakes of M7.5 or stronger based on the UCERF study would put an unnecessary burden on the licensees.

3. Provide specific information regarding the differences in safety-significant structures between a nuclear power plant that is located in a seismically active area and one that is not. Provide, for each operating nuclear reactor in a seismically active area, a full list and description of the safety-significant design features that are included that are not included in similar models that are not located in seismically active areas.

**Public Response**: This is a rough draft. We need to get some reviews of this. Assumed NRR will have ultimate responsibility for the response.

There are no differences in safety requirements for nuclear power plants located in seismically active areas and ones that are not. Regardless of site seismicity, Appendix S to 10 CFR Part 50 requires for site-specific SSE ground motions, structures, systems, and components will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motions. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation elevation of structures must be an appropriate response spectrum with peak ground acceleration (PGA) of at least 0.10g. Design basis loads for nuclear power plant structures, important to safety, include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Institute of Concrete (ACI-349) and the American Institute of Steel Construction (AISC N690), are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads. In addition to the nominal seismic design, all new generation reactors have to demonstrate a seismic margin of 1.67 relative to the site-specific seismic demands.

For the current operating fleet of nuclear power reactors, site-to-site differences in structural design can result from differences in external site hazards such as seismic, wind, tornado, and tsunami. For a low-seismicity region, wind or tornado loads may control the design. Conversely, for a high-seismicity region, seismic loads will likely control. Structures in high-seismicity regions have robust designs with typically higher capacity shear walls, as an example. Systems and components will also be more robust and are designed and tested to higher levels of acceleration.

**Additional, technical, non-public information:** ADD

4. In your opinion, can any operating nuclear reactors in the United States withstand an earthquake of the magnitude experience in Japan?

**Public Response**: The March 11, 2011, magnitude 9 earthquake that recently affected Japan is different than earthquakes that could affect US nuclear plants. Each US nuclear plant is designed to a ground-shaking level that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. The Japan earthquake was caused by a "subduction zone" event, which is the type of mechanism that produces the largest possible magnitude earthquakes. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington, so an earthquake this large could only happen in that region. The only plant in that area is Columbia Generating Station, which is approximately 225 miles (363 km) from the coast and the subduction zone. Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximate 8, which is 10 times smaller than a magnitude 9.

**Additional, technical, non-public information:** ADD

## Questions for the Japanese

**NOTE: These were all collected from what we produced after the KKNPP earthquake. These need to be gone through and revised for this event. We should separate into high, medium and low priorities:**

**The below is pulled from an KKNPP summary...to be reviewed...**

What seismic monitoring equipment exists at the plants? Can we get the recordings from the
Are there recordings of the tsunami at the plant location?
What is the geology and soil profile at the plants?
NOAA has a prediction of very large tsunami waves at Onagawa. Are these accurate?

**The below is pulled from an KKNPP summary...to be reviewed...**

DESIGN BASES: Exactly what is the design basis ground motion for each of the plants? Did it change through time (i.e. from the first plant to the seventh)? Where was the design basis motion defined, at the top of rock, at the ground surface, at the floor level or somewhere else? Were the site-specific geotechnical properties used in the development of the design basis ground motions for each plant?

SEISMIC HAZARDS: What assumptions were used in the seismic hazard evaluation to arrive at the design basis ground motions? What faults were considered, what magnitudes and geometries were assumed? What activity rates were assumed for both fault sources and "background" earthquakes?

OBSERVATIONS-GROUND MOTIONS: What ground motions were recorded and where were they recorded? Specifically, what free-field, in-structure and down-hole recordings were obtained? What are the locations of the instruments that obtained records? Did all the instruments respond as planned, or are there lessons to be learned? Can the digital data be shared with the NRC? Is there any way of evaluating how well the existing analysis methods predicted the observed motions at different points within the plant?

OBSERVATIONS-DAMAGE: What damage was observed at the plants? How well did equipment such as cranes perform? Were there observations of displacements of equipment from anchorages, were cracks observed in any of the buildings? How well did non-nuclear safety type of buildings and equipment perform? What types of geotechnical phenomena were observed, was there ground deformation/slope failures, lateral spreading or liquefaction near the facility? Did the ABWRs perform better or similar to the older designs?

**And another set from the KKNPP earthquake...to be reviewed...**

Please provide the following information in the time frame indicated:

Highest Priority Questions – as soon as possible

- A timeline describing the order of events and the individual plant responses to the earthquake
- Confirmation that all operating and shut down units achieved or maintained safe-shutdown conditions without manual operator intervention or complications. Did all safety-related systems respond to the seismic scram as designed? Please note if there were any unexpected plant responses to the event, including any spurious signals.
- A more detailed description of the impacts of the earthquake on the plant (e.g., what systems were involved, which pipes were damaged, where did the leakage occur (pipe wall, joints, fittings,,etc).
- A description of seismic instrumentation at the site and at each of the 7 units, soil/rock shear wave properties through depth, instrument location and mounting condition, all the recorded

data on the basis of unified starting time, such that the coherency of motion through the surface or the foundations and at depth can be determined

- Full spectrum seismic design basis for the plant.
- What actually caused the Unit 3B house transformer fire?

Additional Questions – please provide answers as more information is developed

- Damage to buildings, slope failures, intake structure failure, if any
- Behavior of cranes, cables and conduits
- Failures of any large pumps and valves, pipe mounted control or valve failure
- Instances of any relay or vibration sensitive components malfunctioning
- Nature of damage to service water and fire-suppression piping - their diameter, material they are made of including their elastic properties, design standards used for the piping design, nature of failure (at support, anchor motion, failure of anchors, subsidence differential movement etc)
- Were there any systems that changed state?
- Impact on physical security, and any vulnerabilities identified
- Were there any impacts on the grid because of the event?
- Please describe the switchyard performance?
- What emergency preparedness concerns have been identified as a result of the event?

3B Transformer Specific Questions – please respond when there is time and other issues have been addressed

- What are the primary and secondary voltages of the transformer?
- What type of transformer - liquid or dry-type (air-cooled)?
- Who was the manufacturer of the transformer?
- What are the physical dimensions of the transformer?
- How are the transformer coils restrained within the cabinet?
- What is the clearance between transformer energized component and cabinet?
- What is the relative displacement for connection between the high voltage leads and the first anchor point (adequate slack?) in the transformer?
- What was the natural frequency of the burned transformer, if known?
- What was the acceleration level (or the response spectrum, if available) at the support location of the burned transformer?
- What seismic requirements exist for the burned transformer? Was the transformer tested or analyzed to a specific acceleration or response spectra, and if so, what are they?
- Are there any of the same type of transformer installed at other locations in the plant?

## Additional Information: Useful Tables

### Table of Design Basis Ground Motions for US Plants

| Design Basis Earthquake Information | | | | | |
|---|---|---|---|---|---|
| **Nuclear Plant By State/Location** | **Maximum Observed Or Inferred Intensity (MMI Scale)** | **Relative Distance Of Seismic Source** | **Design SSE Peak Acceleration, *g*** | **OBE Peak Acceleration, *g*** | **Soil Condition** |
| **New York** | | | | | |
| Fitzpatrick | VI | Near | 0.15 | 0.08 | Soil |
| Ginna 1 | VIII/IX | >60 miles | 0.2 | 0.08 | Rock |
| Indian Point 2, 3 | VII | Near | 0.15 | 0.1 | Rock |
| Nine Mile Point 1 | IX-X | >60 miles | 0.11 | 0.06 | Rock |
| Nine Mile Point 2 | VI | Near | 0.15 | 0.075 | Rock |
| **New Jersey** | | | | | |
| Salem 1,2 | VII-VIII | Near | 0.2 | 0.1 | Deep Soil |
| **Connecticut** | | | | | |
| Millstone 1, 2, 3 | VII | Near | 0.17 | 0.07 | Rock |
| **Vermont** | | | | | |
| Vermont Yankee | VI | Near | 0.14 | 0.07 | Rock |
| **Ohio** | | | | | |
| Davis Besse 1 | VII | Near | 0.15 | 0.08 | Rock |
| Perry 1 | VII | Near | 0.15 | 0.08 | Rock |
| **Georgia** | | | | | |
| Hatch 1, 2 | VII | Near | 0.15 | 0.08 | Deep Soil |
| Vogtle 1, 2 | VII-VIII | Near | 0.2 | 0.12 | Deep Soil |
| **Tennessee** | | | | | |
| Seqouyah 1, 2 | VIII | Near | 0.18 | 0.09 | Rock |
| Watts Bar 1 | VIII | Near | 0.18 | 0.09 | Rock |
| **California** | | | | | |
| San Onofre 2, 3 | IX-X | Near | 0.67 | 0.34 | Soil |
| Diablo Canyon 1, 2 | X-XI | Near | 0.75 | 0.20 | Rock |
| **Florida** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Crystal River 3 | V | Near | 0.10 | 0.05 | Rock |
| St. Lucie 1, 2 | VI | Near | 0.10 | 0.05 | Soil |
| Turkey Point 3, 4 | VII | Near | 0.15 | 0.05 | Rock |

**NOTES:**

MMI=Modified Mercalli Intensity, a measure of observed/reported damage and severity of shaking.
Relative distance measure used in FSAR to develop SSE acceleration, "Near" indicates distance less than 10 miles.
SSE=Safe Shutdown Earthquake ground motion, for horizontal acceleration, in units of earth's gravity, *g*.
OBE=Operating Basis Earthquake ground motion, level of horizontal acceleration, which if exceeded requires plant shutdown.

## Table of SSE, OBE and Tsunami Water Levels

| Nuclear Plant Name<br>By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration<br>(g) | Operating Basis Earthquake (OBE) Peak Acceleration,<br>(g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Alabama | | | |
| Browns Ferry | 0.200 | 0.100 | N/A (Non-Coastal) |
| Farley | 0.100 | 0.050 | N/A (Non-Coastal) |
| Arkansas | | | |
| Arkansas Nuclear | 0.200 | | N/A (Non-Coastal) |
| Arizona | | | |
| Palo Verde | 0.200 | 0.100 | N/A (Non-Coastal) |
| California | | | |
| Diablo Canyon | 0.400 | 0.200 | The design basis maximum combined wave runup is the greater of that determined for near-shore or distantly-generated tsunamis, and results from near-shore tsunamis. For distantly-generated tsunamis, the combined runup is 30 feet. For near-shore tsunamis, the combined wave runup is 34.6 feet, as determined by hydraulic model testing. The safety-related equipment is installed in watertight compartments to protect it from adverse sea wave events to elevation +48 feet above mean lower low water line (MLLWL). |
| San Onofre | 0.670 | 0.340 | The controlling tsunami occurs during simultaneous high tide and storm surge produces a maximum runup to elevation +15.6 feet mean lower low water line (MLLWL) at the Unit 2 and 3 seawall. When storm waves are superimposed, the predicted maximum runup is to elevation +27 MLLWL. Tsunami protection for the SONGS site is provided by a reinforced concrete seawall constructed to elevation +30.0 MLLWL. |
| Connecticut | | | |
| Millstone | 0.170 | 0.090 | 18 ft SWL |
| Florida | | | |
| Crystal River | 0.050 | 0.025 | N/A (Non-Coastal) |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| St. Lucie | 0.100 | 0.050 | No maximum tsunami level, bounded by PMH surge of +18 MLW wave runup, with plant openings at +19.5 MLW |
| Turkey Point | 0.150 | 0.050 | No maximum tsunami level, bounded by PMH surge of +18.3 MLW water level, site protected to +20 MLW with vital equipment protected to +22 MLW |
| Georgia | | | |
| Hatch | 0.150 | 0.080 | N/A (Non-Coastal) |
| Vogtle | 0.200 | 0.120 | N/A (Non-Coastal) |
| Illinois | | | |
| Braidwood | 0.200 | 0.090 | N/A (Non-Coastal) |
| Byron | 0.200 | 0.090 | N/A (Non-Coastal) |
| Clinton | 0.250 | 0.100 | N/A (Non-Coastal) |
| Dresden | 0.200 | 0.100 | N/A (Non-Coastal) |
| LaSalle | 0.200 | 0.100 | N/A (Non-Coastal) |
| Quad Cities | 0.240 | 0.120 | N/A (Non-Coastal) |
| Iowa | | | |
| Duane Arnold | 0.120 | 0.060 | N/A (Non-Coastal) |
| Kansas | | | |
| Wolf Creek | 0.120 | 0.060 | N/A (Non-Coastal) |
| Louisiana | | | |
| River Bend | 0.100 | 0.050 | |
| Waterford | 0.100 | | Floods – 30 feet MSL |
| Maryland | | | |
| Calvert Cliffs | 0.150 | 0.080 | 14 ft design wave |
| Massachusetts | | | |
| Pilgrim | 0.150 | 0.080 | *Storm flooding design basis - 18.3ft |
| Michigan | | | |
| D.C. Cook | 0.200 | 0.100 | N/A |
| Fermi | 0.150 | 0.080 | N/A |
| Palisades | 0.200 | 0.100 | N/A |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Missouri | | | |
| Callaway | 0.200 | | N/A (Non-Coastal) |
| Mississippi | | | |
| Grand Gulf | 0.150 | 0.075 | N/A |
| Minnesota | | | |
| Monticello | 0.120 | 0.060 | N/A (Non-Coastal) |
| Prarie Island | 0:120 | 0.060 | N/A (Non-Coastal) |
| Nebraska | | | |
| Cooper | 0.200 | 0.100 | N/A (Non-Coastal) |
| Fort Calhoun | 0.170 | 0.080 | N/A (Non-Coastal) |
| New York | | | |
| Fitzpatrick | 0.150 | 0.080 | N/A (Non-Coastal) |
| Ginna | 0.200 | 0.080 | N/A |
| Indian Point | 0.150 | 0.100 | 15 ft msl |
| Nine Mile Point, Unit 1 | 0.110 | 0.060 | N/A |
| Nine Mile Point, Unit 2 | 0.150 | 0.075 | N/A |
| New Hampshire | | | |
| Seabrook | 0.250 | 0.125 | (+) 15.6' MSL Still Water Level (Tsunami Flooding -Such activity is extremely rare on the US Atlantic coast and would result in only minor wave action inside the harbor.) |
| New Jersey | | | |
| Hope Creek | 0.200 | 0.100 | 35.4 MSL The maximum probable tsunami produces relatively minor water level changes at the site. The maximum runup height reaches an elevation of 18.1 feet MSL with coincident 10 percent exceedance high tide) |
| Oyster Creek | 0.184 | 0.092 | (+) 23.5' MSL Still Water Level (Probable Maximum Tsunami - Tsunami events are not typical of the eastern coast of the United States and have not, therefore, been addressed.) |

| Nuclear Plant Name<br>By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration<br>(g) | Operating Basis Earthquake (OBE) Peak Acceleration,<br>(g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Salem | 0.200 | 0.100 | 21.9 MSL (There is no evidence of surface rupture in East Coast earthquakes and no history of significant tsunami activity in the region) |
| North Carolina | | | |
| Brunswick | 0.160 | 0.030 | N/A |
| McGuire | 0.150 | 0.080 | N/A (Non-Coastal) |
| Shearon Harris | 0.150 | | N/A (Non-Coastal) |
| Ohio | | | |
| Davis-Besse | 0.150 | 0.080 | N/A |
| Perry | 0.150 | 0.080 | N/A |
| Pennsylvania | | | |
| Beaver Valley | 0.130 | 0.060 | N/A (Non-Coastal) |
| Limerick | 0.150 | 0.075 | N/A (Non-Coastal) |
| Peach Bottom | 0.120 | 0.050 | N/A (Non-Coastal) |
| Three Mile Island | 0.120 | 0.060 | N/A (Non-Coastal) |
| Susquehanna | 0.150 | 0.080 | N/A (Non-Coastal) |
| South Carolina | | | |
| Catawba | 0.150 | 0.080 | N/A (Non-Coastal) |
| Oconee | 0.150 | 0.050 | N/A (Non-Coastal) |
| Robinson | 0.200 | 0.100 | N/A (Non-Coastal) |
| V.C. Summer | 0.250 | 0.150 | N/A (Non-Coastal) |
| Tennessee | | | |
| Sequoyah | 0.180 | 0.090 | N/A (Non-Coastal) |
| Watts Bar, Unit 1 | 0.180 | 0.090 | N/A (Non-Coastal) |
| Texas | | | |
| Comanche Peak | 0.120 | 0.060 | N/A |
| South Texas Project | 0.100 | 0.050 | N/A |
| Vermont | | | |

| Nuclear Plant Name<br>By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration<br>(g) | Operating Basis Earthquake (OBE) Peak Acceleration,<br>(g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Vermont Yankee | 0.140 | 0.070 | N/A |
| Virginia | | | |
| North Anna | 0.180 | | N/A |
| Surry | 0.150 | 0.080 | N/A |
| Washington | | | |
| Columbia | 0.250 | | N/A (Non-Coastal) |
| Wisconsin | | | |
| Kawaunee | 0.120 | 0.060 | N/A |
| Point Beach | 0.120 | | N/A |
| **Definition of Safe Shutdown Earthquake** | The safe-shutdown earthquake (SSE) for the site is the ground motion response spectra (GMRS), which also satisfies the minimum requirement of paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Code of Federal Regulations (10 CFR Part 50). | | |
| **Definition of Operating Basis Earthquake:** | To satisfy the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE) ground motion is defined as follows:<br>(i) For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.<br>(ii) For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in design control document (DCD).<br>(iii) The spectrum ordinate criterion to be used in conjunction with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," issued March 1997, is the lowest of (i) and (ii). | | |

## Table of Plants Near Known Active Faults or in High or Moderate Seismicity Zones

It should be noted that in much of the Central and Eastern US, the seismicity comes from "background" seismicity. Background seismicity is earthquake activity, where the earthquakes cannot be tied to known faults.

| Plant (state) | Nearest Active Fault or Seismic Zone | Distance to Fault or Range of Distances to Zones | Type of Faulting Mechanism | Range of Maximum Magnitude ($M_w$) | OBE (g) | SSE (g) |
|---|---|---|---|---|---|---|
| Diablo Canyon (CA) | Hosgri Fault | 5 miles | Predominantly Strike Slip | 7.5 | | |
| | Shoreline Fault | 0.5 miles | Strike Slip | 6.25 to 6.75 best estimate by NRC staff in RIL 09-001. Final report on the fault in review by NRC staff | | |
| San Onofre (CA) | | | | | | |
| Comanche Peak | | | | | | |

## Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes, and Seismic Core Damage Frequencies

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Arkansas 1 | 05000313 | 0.2 | 2.8E-04 | 0.3 | 4.1E-06 | 0.3g full-scope EPRI SMA | GI-199 |
| Arkansas 2 | 05000368 | 0.2 | 9.7E-05 | 0.3 | 4.1E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Beaver Valley 1 | 05000334 | 0.12 | 3.3E-04 | n/a | 4.8E-05 | seismic PRA | GI-199 |
| Beaver Valley 2 | 05000412 | 0.12 | 2.7E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Braidwood 1 | 05000456 | 0.2 | 6.7E-05 | 0.3 | 7.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Braidwood 2 | 05000457 | 0.2 | 6.7E-05 | 0.3 | 7.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 1 | 05000259 | 0.2 | 2.5E-04 | 0.3 | 3.7E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 2 | 05000260 | 0.2 | 2.5E-04 | 0.26 | 5.4E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 3 | 05000296 | 0.2 | 2.5E-04 | 0.26 | 5.4E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Brunswick 1 | 05000325 | 0.16 | 7.3E-04 | 0.3 | 1.5E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Brunswick 2 | 05000324 | 0.16 | 7.3E-04 | 0.3 | 1.5E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Byron 1 | 05000454 | 0.2 | 5.2E-05 | 0.3 | 5.8E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Byron 2 | 05000455 | 0.2 | 5.2E-05 | 0.3 | 5.8E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Callaway | 05000483 | 0.2 | 3.8E-05 | 0.3 | 2.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Calvert Cliffs 1 | 05000317 | 0.15 | 1.9E-04 | n/a | 1.0E-05 | seismic PRA | GI-199 |
| Calvert Cliffs 2 | 05000318 | 0.15 | 1.9E-04 | n/a | 1.2E-05 | seismic PRA | GI-199 |
| Catawba 1 | 05000413 | 0.15 | 1.4E-04 | n/a | 3.7E-05 | seismic PRA | GI-199 |
| Catawba 2 | 05000414 | 0.15 | 1.4E-04 | n/a | 3.7E-05 | seismic PRA | GI-199 |
| Clinton | 05000461 | 0.25 | 5.8E-05 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Columbia | 05000397 | 0.25 | 1.7E-04 | n/a | 2.1E-05 | seismic PRA | IPEEE |
| Comanche Peak 1 | 05000445 | 0.12 | 1.6E-05 | 0.12 | 4.0E-06 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |
| Comanche | 05000446 | 0.12 | 1.6E-05 | 0.12 | 4.0E-06 | reduced-scope EPRI SMA; SSE = | GI-199 |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Peak 2 | | | | | | 0.12g | |
| Cooper | 05000298 | 0.2 | 1.5E-04 | 0.3 | 7.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Crystal River 3 | 05000302 | 0.1 | 8.9E-05 | 0.1 | 2.2E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| D.C. Cook 1 | 05000315 | 0.2 | 2.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| D.C. Cook 2 | 05000316 | 0.2 | 2.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Davis Besse | 05000346 | 0.15 | 6.3E-05 | 0.26 | 6.7E-06 | reduced-scope EPRI SMA | GI-199 |
| Diablo Canyon 1 | 05000275 | 0.75 | 2.0E-04 | n/a | 4.1E-05 | seismic PRA | IPEEE |
| Diablo Canyon 2 | 05000323 | 0.75 | 2.0E-04 | n/a | 4.1E-05 | seismic PRA | IPEEE |
| Dresden 2 | 05000237 | 0.2 | 9.7E-05 | 0.26 | 1.9E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Dresden 3 | 05000249 | 0.2 | 9.7E-05 | 0.26 | 1.9E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Duane Arnold | 05000331 | 0.12 | 2.3E-04 | 0.12 | 3.2E-05 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |
| Farley 1 | 05000348 | 0.1 | 1.0E-04 | 0.1 | 2.8E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Farley 2 | 05000364 | 0.1 | 1.0E-04 | 0.1 | 2.8E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Fermi 2 | 05000341 | 0.15 | 1.0E-04 | 0.3 | 4.2E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Fitzpatrick | 05000333 | 0.15 | 3.2E-04 | 0.22 | 6.1E-06 | 0.3g focused-scope NRC SMA | GI-199 |
| Fort Calhoun 1 | 05000285 | 0.17 | 3.7E-04 | 0.25 | 5.4E-06 | 0.3g focused-scope NRC SMA | GI-199 |
| Ginna | 05000244 | 0.2 | 1.0E-04 | 0.2 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Grand Gulf | 05000416 | 0.15 | 1.0E-04 | 0.15 | 1.2E-05 | reduced-scope EPRI SMA; SSE = 0.15g | GI-199 |
| Hatch 1 | 05000400 | 0.148 | 3.9E-04 | 0.29 | 2.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Hatch 2 | 05000321 | 0.15 | 2.7E-04 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Hope Creek | 05000366 | 0.2 | 9.7E-05 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Indian Point 2 | 05000354 | 0.15 | 4.9E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Indian Point 3 | 05000247 | 0.15 | 4.9E-04 | n/a | 3.3E-05 | seismic PRA | GI-199 |
| Kewaunee | 05000286 | 0.12 | 2.8E-04 | n/a | 1.0E-04 | seismic PRA | GI-199 |
| LaSalle 1 | 05000305 | 0.2 | 1.7E-04 | n/a | 5.1E-06 | seismic PRA | GI-199 |
| LaSalle 2 | 05000373 | 0.2 | 1.7E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Limerick 1 | 05000374 | 0.15 | 1.8E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Limerick 2 | 05000352 | 0.15 | 1.8E-04 | 0.15 | 5.3E-05 | reduced-scope EPRI SMA | GI-199 |
| McGuire 1 | 05000353 | 0.15 | 9.5E-05 | 0.15 | 5.3E-05 | reduced-scope EPRI SMA | GI-199 |
| McGuire 2 | 05000369 | 0.15 | 9.5E-05 | n/a | 3.1E-05 | seismic PRA | GI-199 |
| Millstone 1 | 05000370 | 0.254 | 9.3E-05 | n/a | 3.1E-05 | seismic PRA | GI-199 |
| Millstone 2 | 05000336 | 0.17 | 8.3E-05 | 0.25 | 1.1E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Millstone 3 | 05000423 | 0.17 | 8.3E-05 | n/a | 1.5E-05 | seismic PRA | GI-199 |
| Monticello | 05000263 | 0.12 | 9.3E-05 | 0.12 | 1.9E-05 | modified focused/expended reduced-scope EPRI SMA | GI-199 |
| Nine Mile Point 1 | 05000220 | 0.11 | 1.5E-04 | 0.27 | 4.2E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Nine Mile Point 2 | 05000410 | 0.15 | 4.8E-05 | 0.23 | 5.6E-06 | SPRA and focused-scope EPRI SMA | GI-199 |
| North Anna 1 | 05000338 | 0.12 | 2.1E-04 | 0.16 | 4.4E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| North Anna 2 | 05000339 | 0.12 | 2.1E-04 | 0.16 | 4.4E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Oconee 1 | 05000269 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oconee 2 | 05000270 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oconee 3 | 05000287 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oyster Creek | 05000219 | 0.17 | 1.5E-04 | n/a | 1.4E-05 | seismic PRA | GI-199 |
| Palisades | 05000255 | 0.2 | 1.4E-04 | n/a | 6.4E-06 | seismic PRA | GI-199 |
| Palo Verde 1 | 05000528 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Palo Verde 2 | 05000529 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| Palo Verde 3 | 05000530 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Peach Bottom 2 | 05000277 | 0.12 | 2.0E-04 | 0.2 | 2.4E-05 | modified focused-scope EPRI SMA | GI-199 |
| Peach Bottom 3 | 05000278 | 0.12 | 2.0E-04 | 0.2 | 2.4E-05 | modified focused-scope EPRI SMA | GI-199 |
| Perry | 05000440 | 0.15 | 2.2E-04 | 0.3 | 2.1E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Pilgrim 1 | 05000293 | 0.15 | 8.1E-04 | n/a | 6.9E-05 | seismic PRA | GI-199 |
| Point Beach 1 | 05000266 | 0.12 | 2.0E-04 | n/a | 1.1E-05 | seismic PRA | GI-199 |
| Point Beach 2 | 05000301 | 0.12 | 2.0E-04 | n/a | 1.1E-05 | seismic PRA | GI-199 |
| Prairie Island 1 | 05000282 | 0.12 | 2.0E-04 | 0.28 | 3.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Prairie Island 2 | 05000306 | 0.12 | 2.0E-04 | 0.28 | 3.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Quad Cities 1 | 05000254 | 0.24 | 8.2E-04 | 0.09 | 2.7E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Quad Cities 2 | 05000265 | 0.24 | 8.2E-04 | 0.09 | 2.7E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| River Bend | 05000458 | 0.1 | 2.4E-04 | 0.1 | 2.5E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Robinson (HR) | 05000261 | 0.2 | 1.1E-03 | 0.28 | 1.5E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| Saint Lucie | 05000335 | 0.1 | 1.4E-04 | 0.1 | 4.6E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Salem 1 | 05000389 | 0.2 | 2.6E-04 | 0.1 | 4.6E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Salem 2 | 05000272 | 0.2 | 2.6E-04 | n/a | 9.3E-06 | seismic PRA | GI-199 |
| San Onofre 2 | 05000361 | 0.67 | 1.2E-04 | n/a | 1.7E-05 | seismic PRA | IPEEE |
| San Onofre 3 | 05000362 | 0.67 | 1.2E-04 | n/a | 1.7E-05 | seismic PRA | IPEEE |
| Seabrook | 05000311 | 0.25 | 1.3E-04 | n/a | 9.3E-06 | seismic PRA | GI-199 |
| Sequoyah 1 | 05000443 | 0.18 | 7.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Sequoyah 2 | 05000327 | 0.18 | 7.1E-04 | 0.27 | 5.1E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| Shearon Harris 1 | 05000328 | 0.15 | 4.6E-05 | 0.27 | 5.1E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| South Texas 1 | 05000498 | 0.1 | 3.0E-05 | n/a | 6.2E-06 | seismic PRA | GI-199 |

| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
|---|---|---|---|---|---|---|---|
| South Texas 2 | 05000499 | 0.1 | 3.0E-05 | n/a | 6.2E-06 | seismic PRA | GI-199 |
| Summer | 05000395 | 0.15 | 3.9E-04 | 0.22 | 3.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Surry 1 | 05000280 | 0.15 | 2.2E-04 | n/a | 5.7E-06 | seismic PRA | GI-199 |
| Surry 2 | 05000281 | 0.15 | 2.2E-04 | n/a | 5.7E-06 | seismic PRA | GI-199 |
| Susquehanna 1 | 05000387 | 0.1 | 1.9E-04 | 0.21 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Susquehanna 2 | 05000388 | 0.1 | 1.9E-04 | 0.21 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Three Mile Island 1 | 05000289 | 0.12 | 1.0E-04 | n/a | 4.0E-05 | seismic PRA | GI-199 |
| Turkey Point 3 | 05000250 | 0.15 | 3.8E-05 | 0.15 | 1.0E-05 | site-specific approach; SSE=0.15g | GI-199 |
| Turkey Point 4 | 05000251 | 0.15 | 3.8E-05 | 0.15 | 1.0E-05 | site-specific approach; SSE=0.15g | GI-199 |
| Vermont Yankee | 05000271 | 0.14 | 1.2E-04 | 0.25 | 8.1E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Vogtle 1 | 05000424 | 0.2 | 1.5E-04 | 0.3 | 1.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Vogtle 2 | 05000425 | 0.2 | 1.5E-04 | 0.3 | 1.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Waterford 3 | 05000382 | 0.1 | 1.1E-04 | 0.1 | 2.0E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Watts Bar | 05000390 | 0.18 | 2.9E-04 | 0.3 | 3.6E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Wolf Creek | 05000482 | 0.12 | 3.7E-05 | 0.2 | 1.8E-05 | reduced-scope EPRI SMA | GI-199 |
| | | 25th percentile | 9.6E-05 | | 6.0E-06 | | |
| | | min | 1.6E-05 | | 2.0E-06 | | |
| | | median | 1.7E-04 | | 1.5E-05 | | |
| | | mean | 3.1E-04 | | 2.1E-05 | | |
| | | max | 3.9E-03 | | 1.0E-04 | | |
| | | 75th percentile | 2.6E-04 | | 3.2E-05 | | |

## Design Basis Ground Motions and New Review Level Ground Motions Used for Review of Japanese Plants

| Plant sites | Contributing earthquakes | New DBGM $S_s$ | Original DBGM $S_2$ |
|---|---|---|---|
| Tomari | Earthquakes undefined specifically | 550 Gal | 370 Gal |
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 | 375 |
| Higashidoori | Earthquakes undefined specifically | 450 | 375 |
| Fukushima | Earthquake near the site (M7.1) | 600 | 370 |
| Tokai | Earthquakes undefined specifically | 600 | 380 |
| Hamaoka | Assumed Tokai (M8.0), etc. | 800 | 600 |
| Shika | Sasanami-oki Fault (M7.6) | 600 | 490 |
| Tsuruga | Urazoko-Uchiikemi Fault (M6.9), etc. →Mera-Kareizaki - Kaburagi(M7.8), Shelf edge+B+Nosaka (M7.7) | 800 | 532 |
| Mihama | C, Fo-A Fault (M6.9)→ Shelf edge+B+Nosaka(M7.7) | 750 | 405 |
| Ohi | C, Fo-A Fault (M6.9)→Fo-A+Fo-B （M7.4) | 700 | 405 |
| Takahama | Fo-A Fault (M6.9) →Fo-A+Fo-B(M7.4) | 550 | 370 |
| Shimane | Shinji Fault (M7.1) | 600 | 456 |
| Ikata | Central Tectonic Structure (M7.6) | 570 | 473 |
| Genkai | Takekoba F. （M6.9) → Enhanced uncertainty consideration | 540 | 370 |
| Sendai | Gotandagawa F.(M6.9), F-A(M6.9) | 540 | 372 |
| Kashiwazaki-Kariwa | F-B Fault (M7.0), Nagaoka-plain-west Fault (M8.1) | 2300 (R1 side)<br>1209 (R5 side) | 450 |
| Monjyu (Proto Type FBR) | Shiraki-Niu F.(M6.9) , C F.(M6.9)→Shelf edge+B+Nosaka(M7.7), Small Damping | 760 | 408 |
| Shimokita Reprocessing F. | Deto-Seiho F.(M6.8), Yokohama F.(M6.8) | 450 | 320 |

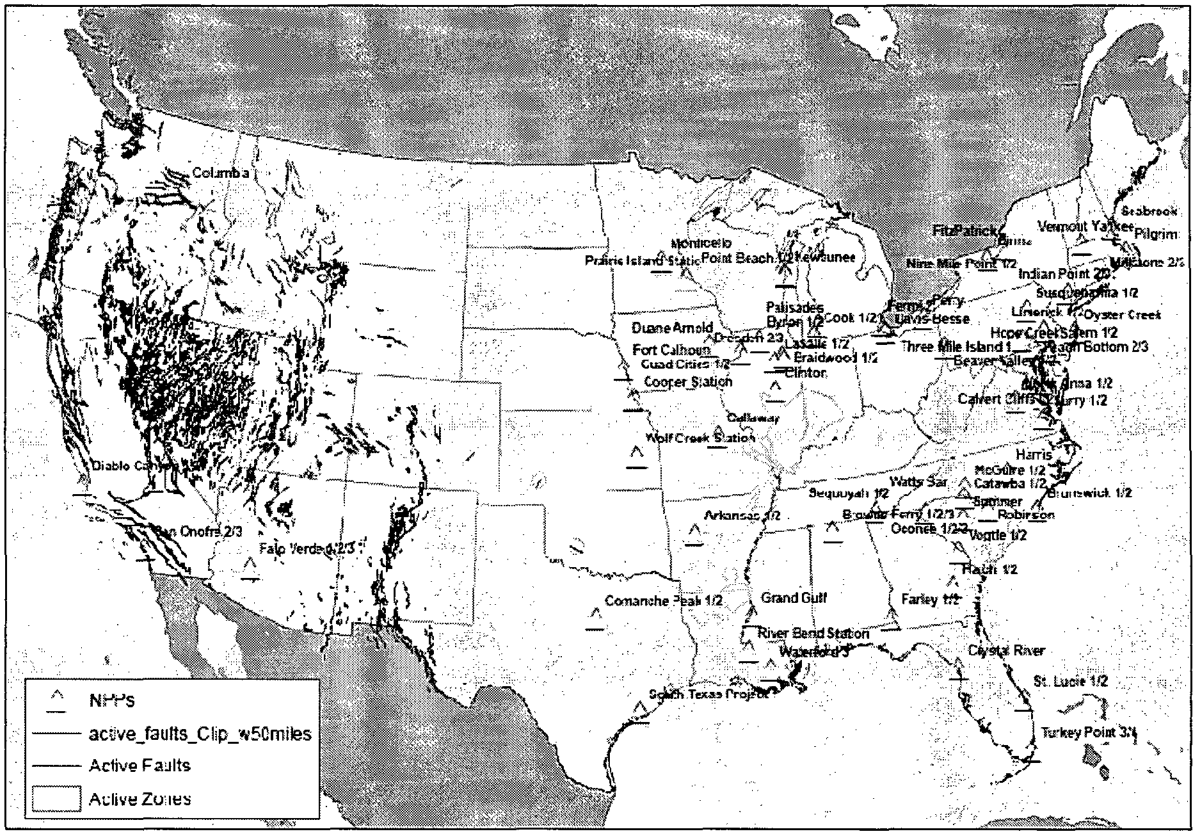
## Status of Review of Japanese NPPs to New Earthquake Levels Based on 2006 Guidance

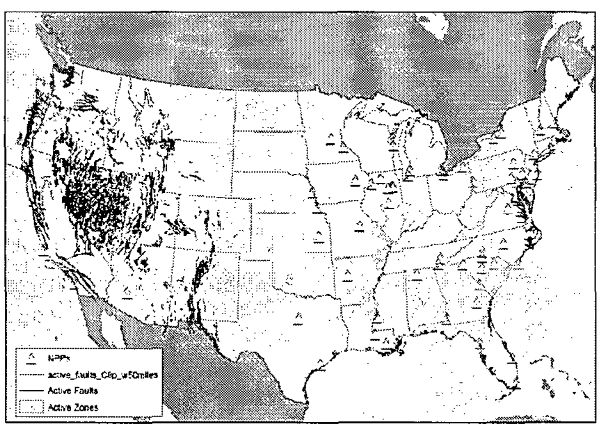
| Utility | Site (Unit) | Type | Dec.2010 |
|---|---|---|---|
| Hokkaido | Tomari | PWR | △ |
| Tohoku | Onagawa (Unit1) | BWR | ◎ |
| | Higashi-dori | BWR | △ |
| Tokyo | Kashiwazaki-Kariwa | BWR | Unit 1,5,6,7 ◎ |
| | Fukushima-No1 | BWR | Unit 3 ◇, 5 ◎ |
| | Fukushima-No2 | BWR | Unit 4,5 ◎ |
| Chubu | Hamaoka | BWR | △ |
| Hokuriku | Shika (Unit 2) | BWR | ◎ |
| Kansai | Mihama(Unit 1) | PWR | ◎ |
| | Ohi(Unit 3,4) | PWR | ◎ |
| | Takahama （Unit 3,4) | PWR | ◎ |
| Chugoku | Shimane (Unit 1, 2) | BWR | ◎ |
| Shikoku | Ikata (Unit 3) | PWR | ◎ |
| Kyushu | Genkai (Unit 3 ) | PWR | ◎ |
| | Sendai (Unit 1) | PWR | ◎ |
| Japan Atomic Power | Tokai-Daini | BWR | ○ |
| | Tsuruga | BWR/PWR | △ |
| JAEA | Monjyu | Proto Type FBR | ◎ |
| Japan Nuc. Fuel | Rokkasyo | Reprocessing | ◎ |
| ◎: NSC review finished, ○: NISA review finished and in NSC review, △: Under review by NISA | | | |

## Additional Information: Useful Plots

### Plot of Mapped Active Quaternary Faults and Nuclear Plants in the US

It is important to note that this plot somewhat misleading as faults in the central and eastern US are not well characterized. For example, the faults responsible for very large historic events, such as the 1811 and 1812 New Madrid Earthquakes, and the 1886 Charleston Earthquakes have not been conclusively located.



## Nuclear Plants in the US Compared to the USGS National Seismic Hazard Maps

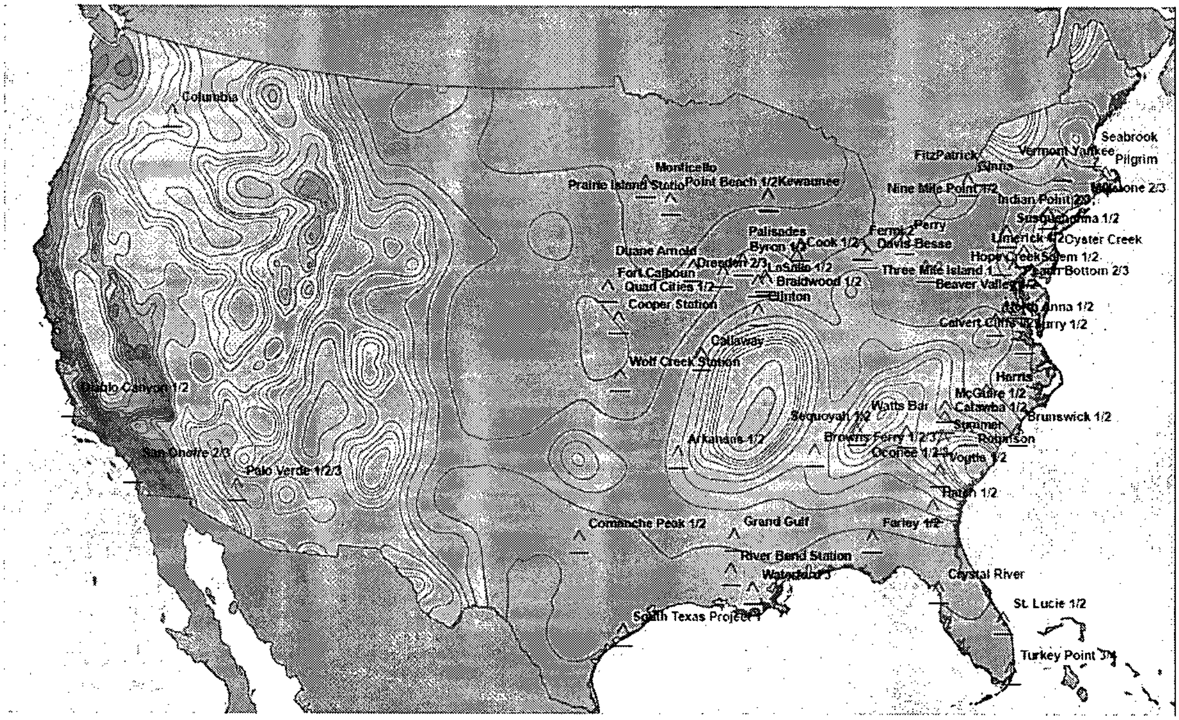
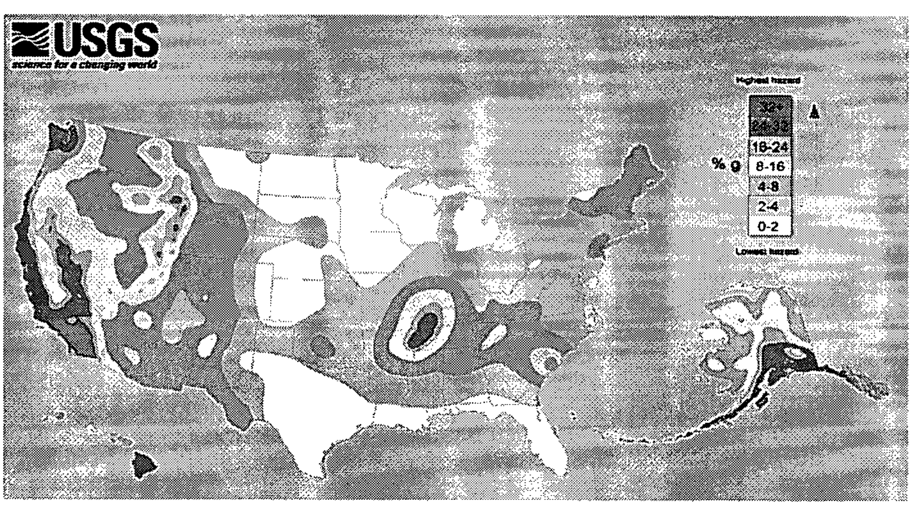



Figure 1: US Nuclear Plants overlain on the USGS National Seismic Hazard Map

As you can see the seismic source regions in the central and eastern east are not well defined. So to state a specific number of plants that are in the moderate seismicity zones is challenging and open to interpretation. This is just one interpretation, which is provided by the USGS.

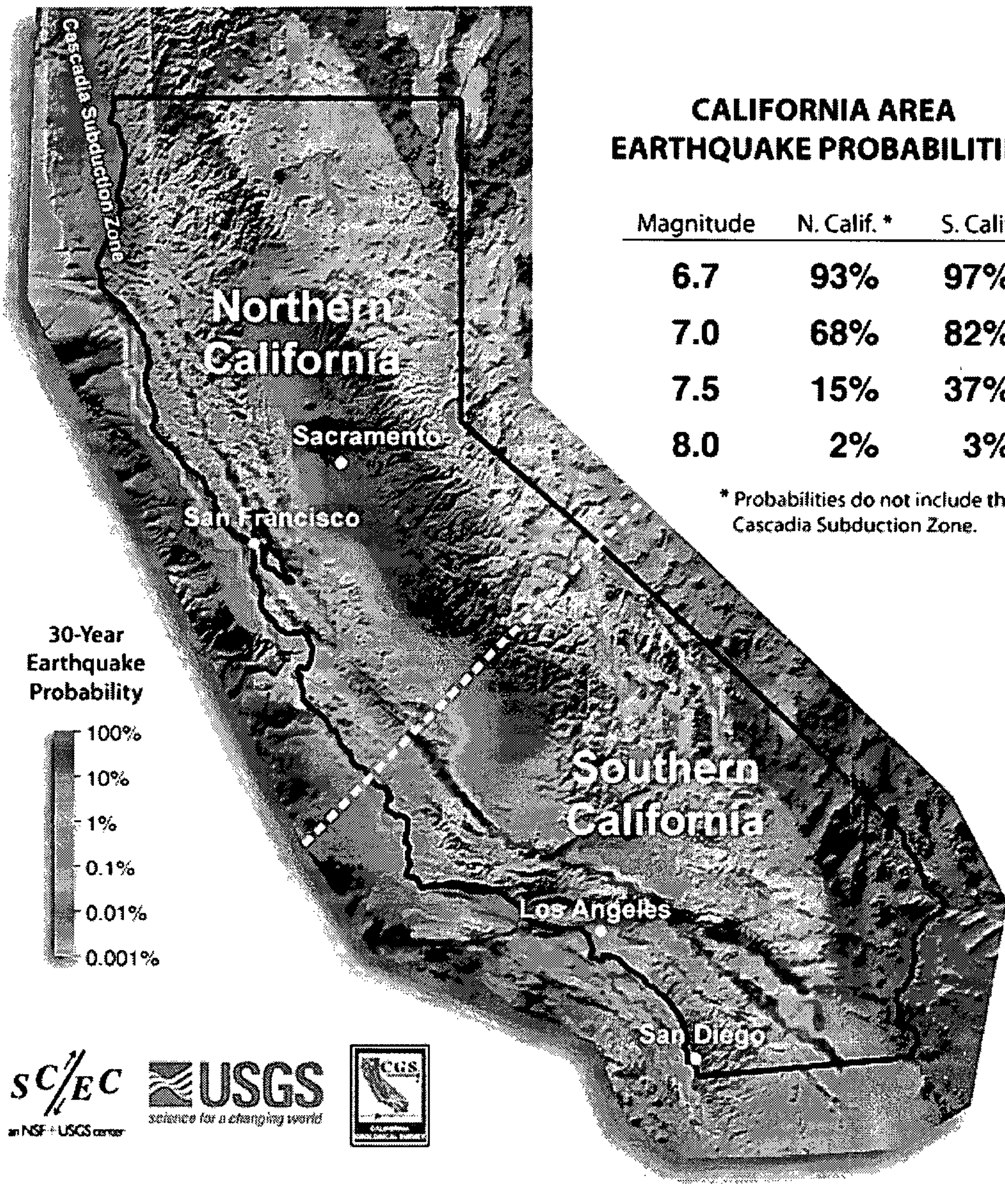
### USGS US National Seismic Hazard Maps

Many version of this map are available at the USGS website at http://earthquake.usgs.gov/hazards/



## UCERF Map of California Earthquake Probabilities for Northern versus Southern California

This is included in this document as Markey (inappropriately) used the below statistics to say that the probability of a magnitude 7 at SONGS was 82%. The dashed line of this California map is the boundary between northern and southern California used in the UCERF study. As shown in the table, the 30-year probability of an earthquake of magnitude 7.5 or larger is higher in the southern half of the state (37%) than in the northern half (15%).



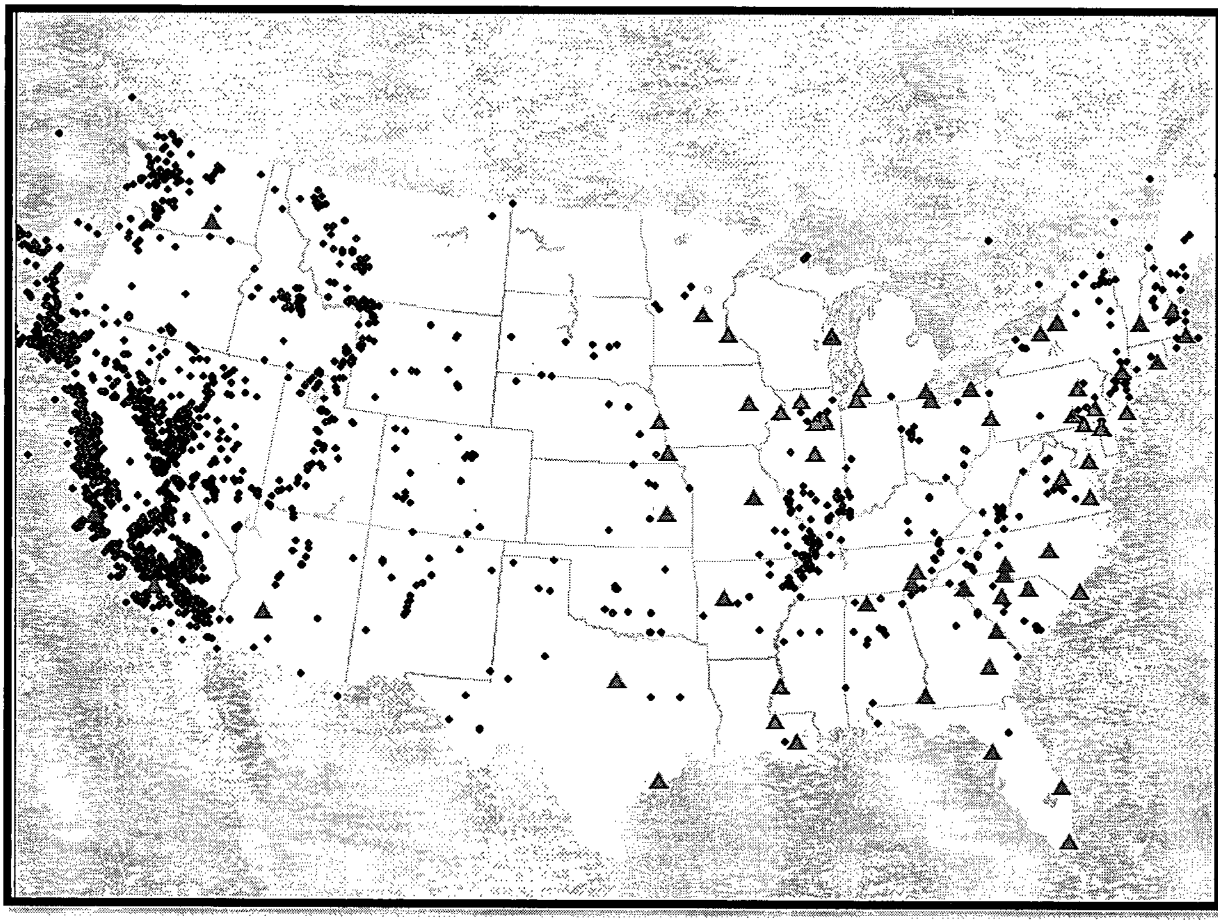

**CALIFORNIA AREA EARTHQUAKE PROBABILITIES**

| Magnitude | N. Calif. * | S. Calif. |
|---|---|---|
| 6.7 | 93% | 97% |
| 7.0 | 68% | 82% |
| 7.5 | 15% | 37% |
| 8.0 | 2% | 3% |

* Probabilities do not include the Cascadia Subduction Zone.

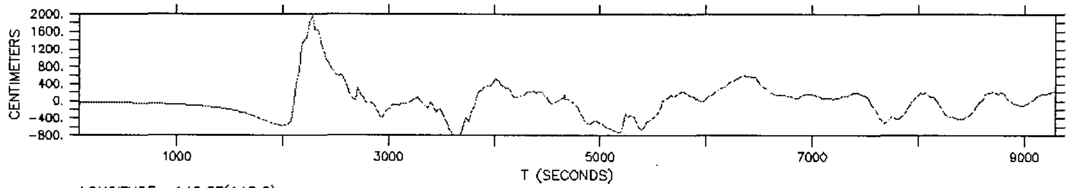
## Plot of Nuclear Plants in the US Compared to Recent Earthquakes

Not sure of the date on this...It's an awesome plot. can we get this updated with a date? Who made this originally (NRO?RES?)



## Plot of Tsunami Wave Heights at the Japanese Plants (NOAA)

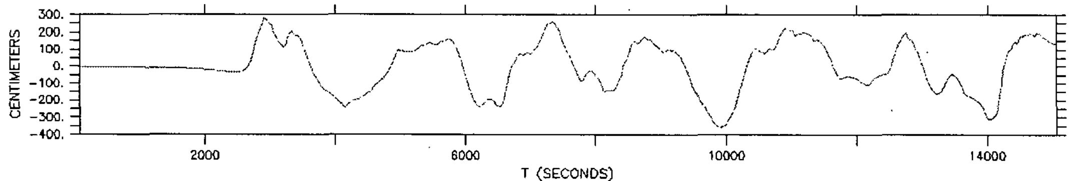
These are results from high-resolution models run by PMEL NOAA staff, who do modeling for the tsunami warning system. While the available bathymetry and topography data used in the model are not of the highest quality at that location, NOAA has confidence in the results, which show good comparisons between model flooding estimates and inundation observations inferred from satellite images. DART measurements are used in the modeling. The images show model time series very close to a shoreline, at about 5m depth. The runup heights (maximum elevation of flooded area) may be different from these amplitudes at shoreline (can be higher or lower, depending on the topographic profile).




LONGITUDE : 140.6E(140.6)
LATITUDE : 36.5N

DATA SET: tokai2_runup_ha

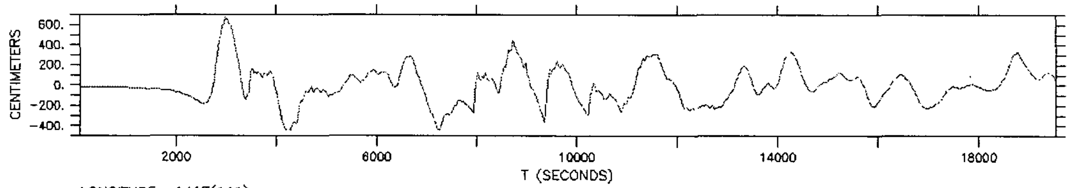
Onagawa
Linear Combination of files




LONGITUDE : 141E(141)
LATITUDE : 37.3N

DATA SET: sendai2_runup_ha

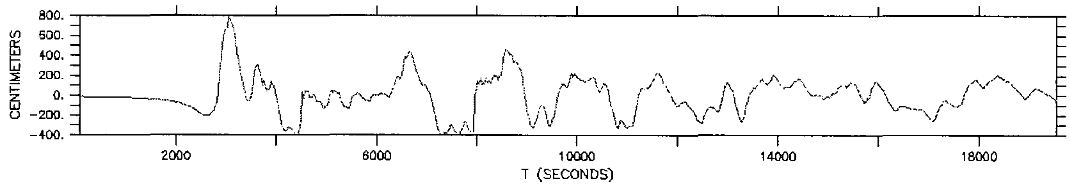
Tokai
Linear Combination of files



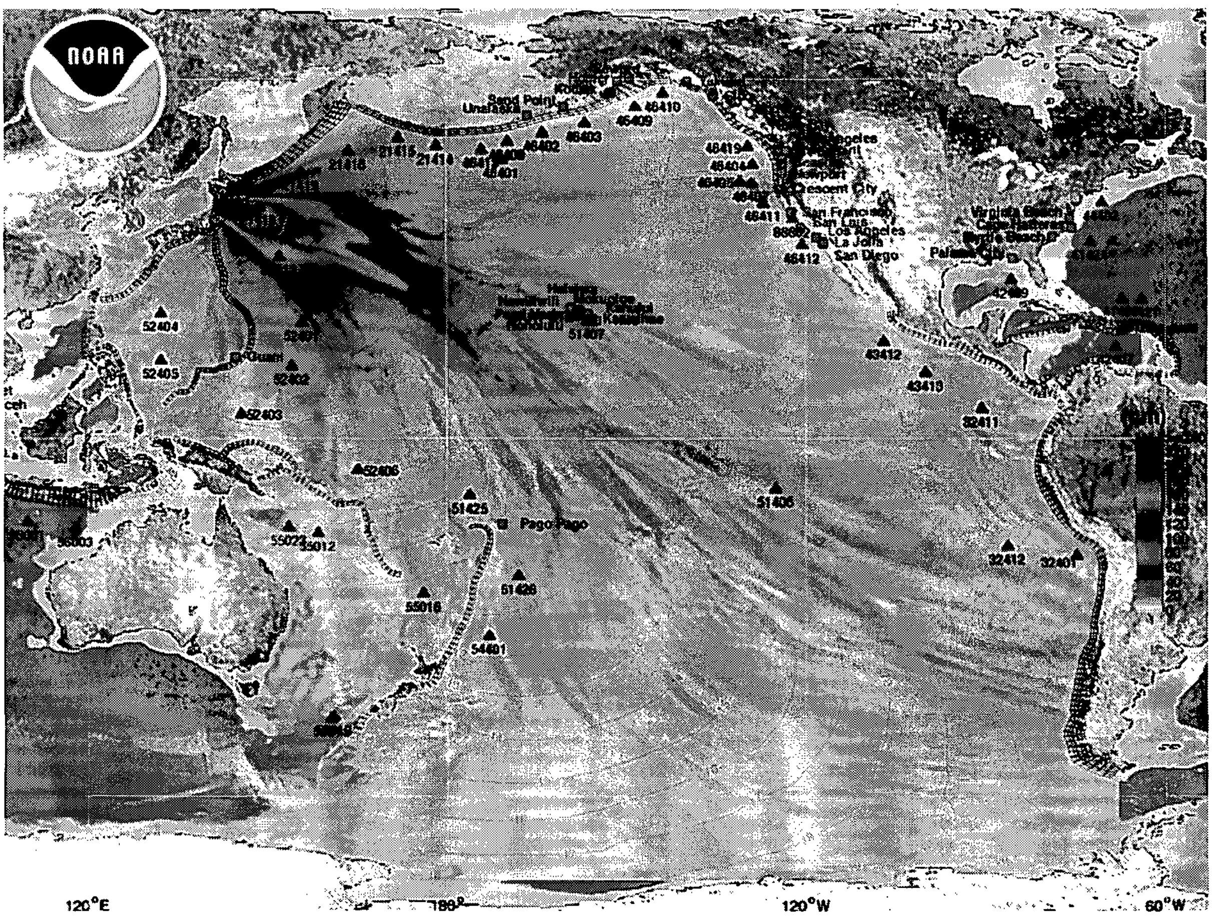

LONGITUDE : 141E(141)
LATITUDE : 37.4N

DATA SET: sendai2_runup_ha

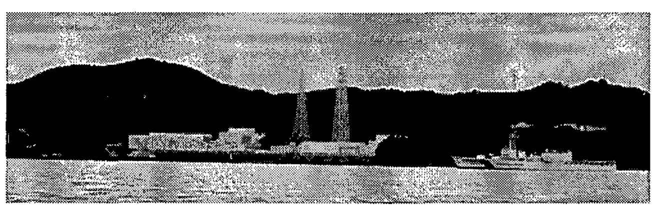
Fukushima Daini
Linear Combination of files




Fukushima Daiichi




This shows the effect on the US coastline.



I found the numbers at the Onagawa plant unimaginable, so I found a side view picture. It's hard to tell the elevation.

# Additional Information: Fact Sheets

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (High level overview)

The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations: 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part, which describes the general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that that the structures and components in nuclear power plants be designed to withstand the effects of natural phenomena, including earthquakes and tsunamis, without loss of capability to perform their intended safety functions. GDC 2 also requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The earthquake which could cause the maximum vibratory ground motion at the site is designated as the **Safe Shutdown Earthquake (SSE)**. Under SSE ground motions, nuclear power plant structures and components must remain functional and within applicable stress, strain, and deformation limits. Each plant must also have seismic instrumentation to determine if the **Operating Basis Earthquake (OBE)**, typically one-half or one-third the level of the SSE, has been exceeded. If the OBE is exceeded or significant plant damage has occurred, then the nuclear power plant must be shutdown.

Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of the earthquake, the distance of the earthquake to the site, and the local geology. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant. This required an assessment of earthquakes that had occurred in the region around each plant site.

Design basis loads for nuclear power plant structures include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Society of Mechanical Engineers, the American Concrete Institute, and the American Institute of Steel Construction, are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

In the mid to late 1990s, NRC staff reviewed the potential consequences of severe earthquakes (earthquakes beyond the safety margin included in each plant's design basis), as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs. Currently, the NRC staff is reassessing the seismic designs of operating plants through our Generic Issues program. The initial results of this assessment found that: 1) seismic hazard estimates have increased at some operating plants in the central and eastern US; 2) there is no immediate safety concern, plants have significant safety margin and overall seismic risk estimates remain small; and 3) assessment of updated seismic hazards and plant performance should continue.

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (The policy wonk version)

(Jon to clean up upon his return from vaca) NRC's regulatory framework for seismic safety of nuclear reactors and facilities is based on: reactor site suitability with respect to geological, seismological, hydrological and other site specific hazards; classification of structures, systems and componenets (SSCs) as Seismic Category I, seismic design of Seismic Category I SSCs, seismic and environmental qualification of Category I SSCs; and maintenance and in-service inspection of equipment and structures, including the containment structure. The NRC's regulatory framework with respect to seismic issues has evolved through time.

**Currently Operating Reactors (licensed prior to 1997):**

The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations: 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part which describes general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that that the SSCs important to safety be designed to withstand the effects of natural phenomena, including earthquakes, tsunamis, and seiches without loss of capability to perform their intended safety functions. GDC 2 requires that the design bases shall include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, and shall consider appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena. The earthquake which could cause the maximum vibratory ground motion at the site is designated the **Safe Shutdown Earthquake (SSE)**.

Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of an earthquake and the distance from the fault to the site. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant based on an assessment of earthquakes that had occurred in the region historically. There is no specification of frequency of occurrence in the deterministic approach. There is no requirement for a periodic reassessment of the seismic design basis.

Paragraph VI(a)(3) of Appendix A requires that suitable seismic instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be determined promptly after an earthquake to permit comparison of such response to that used as the design basis. Such a comparison is needed to decide whether the plant can continue to be operated safely and to permit appropriate action in a timely manner. Appendix A requires thatin addition to seismic loads, including aftershocks, applicable concurrent functional and accident induced loads shall be taken into account in the design of safety-related SSCs. Paragraph VI(c) requires that seismically induced flood, water waves from either locally or distantly generated seismic activity and other design conditions shall be taken into account in nuclear power plant design.

**Proposed New Reactors (submitted after 1997):**

In 1997 new rules governing reactor siting were established. 10 CFR Part 50 Appendix A (GDC 2), 100.23 and Appendix S establish the seismic design basis for plants licensed after January 10,1997. Similar to

pre-1997, Appendix S defines the SSE as *"the Safe-shutdown earthquake ground motion* is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional." 10 CFR Part 100.23 "Geologic and Seismic Siting Criteria" requires that the applicant determine the SSE **and its uncertainty**, the potential for surface tectonic and nontectonic deformations. Regulatory Guide 1.165 (and subsequently Regulatory Guide 1.208) provides guidance on satisfying 10 CFR Part 100.23, one of which is performing a probabilistic seismic hazard assessment (**PSHA**).

Appendix S to 10 CFR Part 50 requires for SSE ground motions, SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motions. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation elevation of structures must be an appropriate response spectrum with a peak ground acceleration (PGA) of at least 0.10g. Design basis loads for nuclear power plant structures, important to safety, include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the ASME B&PV Code, the American ~~Institute of~~ Concrete Institute (ACI-359/ASME Section III Division 2, ACI-349) and the American Institute of Steel Construction (AISC N690), are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

In contrast to the deterministic approach used prior to 1997, the probabilistic method is used and explicitly accounts for possible earthquakes of various magnitudes that come from all plausible potential sources (including background seismicity) and the likelihood that each particular hypothetical earthquake occurs. The PSHA process provides a complete characterization of the ground motion and comprehensively addresses uncertainties in nuclear power plant seismic demands. The PSHA results are major input to seismic risk evaluation using either SPRA or SMA approaches. As for plants licensed prior-to 1997, there is no requirement for a periodic reassessment of the seismic design basis.

In addition to the nominal seismic design, all new generation reactors have to demonstrate a **Seismic margin of 1.67** relative to the site-specific seismic demands. These designs are required to perform a Probabilistic Risk Assessment (PRA) based seismic margins analysis (SMA) to identify the vulnerabilities of their design to seismic events. The minimum high confidence, low probability of failure (HCLPF) for the plant should be at least 1.67 times the ground motion acceleration of the design basis safe-shutdown earthquake (SSE).

The Standard Review Plan (NUREG-0800), Regulatory Guides and Interim Staff Guidance provide the basis for staff reviews of existing reactors and new license applications. Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. Paragraph 10 CFR 50.54(ff) and Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) occurs. The OBE is typically one-half or one-third the level of the SSE. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after occurrence of the OBE, the licensee must consult with the NRC and must propose a plan for the timely, safe shutdown of the nuclear power plant. Paragraph IV(c) requires that seismically induced flood, water waves from either locally or distantly generated seismic activity and other design conditions shall be taken into account in nuclear power plant design so as to prevent undue risk to health and safety of the public.

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (The cliff notes)

NRC Regulations and Guidelines for Seismic Safety:

- The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations:
  - 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and
  - 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part, which describes the general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.
- In addition, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that:
  - The structures and components in nuclear power plants be designed to withstand the effects of natural phenomena, including earthquakes and tsunamis, without loss of capability to perform their intended safety functions.
  - GDC 2 also requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
    - The earthquake which could cause the maximum vibratory ground motion at the site is designated as the **Safe Shutdown Earthquake (SSE)**. Under SSE ground motions, nuclear power plant structures and components must remain functional and within applicable stress, strain, and deformation limits.
    - Each plant must also have seismic instrumentation to determine if the **Operating Basis Earthquake (OBE)**, typically one-half or one-third the level of the SSE, has been exceeded. If the OBE is exceeded or significant plant damage has occurred, then the nuclear power plant must be shutdown.

Plant Design /Design Basis (Seismic):

- Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of the earthquake, the distance of the earthquake to the site, and the local geology. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant. This required an assessment of earthquakes that had occurred in the region around each plant site.
- Design basis loads for nuclear power plant structures include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Society of Mechanical Engineers, the American Concrete Institute, and the American Institute of Steel Construction, are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Tsunami

**Review Guidance and Guidelines Related to Tsunami:**

1. General Design Criterion 2 (GDC 2), 10CFR50, requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Design bases for these SSCs are also required to reflect:
2. 10 CFR 100.23, requires, in part, that the size of seismically induced floods and water waves that could affect a site from either locally or distantly generated seismic activity must be determined.
3. RG 1.102 – Flood Protection for Nuclear Power Plants, describes types of flood protection acceptable to the NRC staff
    a. Exterior Barriers (e.g.)
        i. Levee – embankment to protect land from inundation
        ii. Seawall or floodwall - a structure separating land and water areas, primarily to prevent erosion and other damages due to wave action
        iii. Bulkhead – similar to seawall, purpose is to restrain the land area
    b. Incorporated Barriers
        i. Protection provided by specially designed walls and penetration closures. Walls are usually reinforced concrete designed to resist static and dynamic forces of a Design Basis Flood Level of a Probable Maximum Flood.
4. RG 1.59 – Design Basis Floods for Nuclear Power Plants
    a. The most severe seismically induced floods reasonably possible should be considered for each site.
    b. Tsunami requires consideration of seismic events of the severity of the Safe Shutdown Earthquake occurring at the location that would produce the worst such flood at the nuclear power plant site.
5. US NRC, Standard Review Plan, "Probable Maximum Tsunami Flooding," Section 2.4.6, Rev. 2
    a. Areas of Review
        i. Probable maximum tsunami postulated for a site should include wave runup and drawdown
        ii. Hydrologic characteristics of maximum locally and distantly generated tsunami (e.g., volcanoes, landslides)
        iii. Geological and seismic characteristics of potential tsunami faults (e.g., magnitude, focal depth, source dimensions, fault orientation, and vertical displacement)

**Questions and Answers for Tsunami Issues**

**165) Why do we have confidence that US nuclear power plants are adequately designed for earthquakes and tsunamis?**

Nuclear plants in both the US and Japan are designed for earthquake shaking. In addition to the design of the plants, significant effort goes into emergency response planning and accident mitigation. This approach is called defense-in-depth.

**166) Are nuclear power plants designed for tsunamis?**

Yes. Plants are built to withstand a variety of environmental hazards and those plants that might face a threat from tsunami are required to withstand large waves and the maximum wave height at the intake structure (which varies by plant.)

**167) What level of tsunami are we designed for?**

Like seismic hazard, the level of tsunami that each plant is designed for is site-specific and is appropriate for what may occur at each location.

**168) Can this happen here (i.e., an earthquake that significantly damages a nuclear powerplant)? Are the Japanese plants similar to US plants?**

All US nuclear power plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events.

The Japanese facilities are similar in design to several US facilities

**169) How many reactors are along coastal areas that could be affected by a tsunami (and which ones)?**

Many plants are located in coastal areas that could potentially be affected by tsunami. Two plants, Diablo Canyon and San Onofre, are on the Pacific Coast, which is known to have tsunami hazard. There are also two plants on the Gulf Coast, South Texas and Crystal River. There are many plants on the Atlantic Coast or on rivers that may be affected by a tidal bore resulting from a tsunami. These include St. Lucie, Turkey Point, Brunswick, Oyster Creek, Millstone, Pilgrim, Seabrook, Calvert Cliffs, Salem/Hope Creek, and Surry. Tsunami on the Gulf and Atlantic Coasts occur, but are very rare.

Generally the flooding anticipated from hurricane storm surge exceeds the flooding expected from a tsunami for plants on the Atlantic and Gulf Coast.

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Flooding

### Flooding Issues:

1. General Design Criterion 2 (GDC 2), 10CFR50, requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Design bases for these SSCs are also required to reflect:

    b. Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding region, with sufficient margin for the limited accuracy and quantity of the historical data and the period of time in which the data have been accumulated.

    c. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

    d. The importance of the safety functions to be performed.

6. Design basis floods for most of the present fleet of operating reactors were calculated using deterministic methods to determine the maximum credible flood levels at the site. These deterministic methods include the site specific calculation of parameters such as the probable maximum precipitation, which is defined as the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin. Other potential flooding hazards such as flooding due to storm surge, river flooding, coastal flooding including tsunamis, are evaluated at each site using maximum credible levels from each hazard. Over the life of the operating reactor, if new information becomes available that could affect the design basis, licensees are required to evaluate the new information. Based on this review, if needed, licensees are required to take appropriate mitigation measures, update their final safety analysis report and submit it to the NRC for review and approval.

7. In order to impose new requirements on existing plants, the NRC must be able to justify the new requirements in accordance with the "Backfit Rule" (10 CFR 50.109).

### Questions and Answers for Flooding Issues

### 170) Does the NRC consider severe floods in the design of nuclear power plants?

Yes. NRC regulations require that nuclear power plants are, at all times, capable of safely shutting down and maintaining a safe shutdown condition under severe flooding situations. Safety-related Structures, Systems and Components (SSCs) of Nuclear reactors in the U.S. are required to withstand the design basis flood (DBF). The design basis flood may be caused by the following natural Phenomena:

1) Intense rainfall occurring at the site (known as local intense precipitation).
2) Intense rainfall (known as the Probable Maximum Precipitation) occurring on other areas of the watershed leading to riverine or coastal flooding (known as Probable Maximum Flood" or "PMF".
3) Floods from upstream dam failure or a combination of upstream dam failures.
4) Failure of On-site Water Control or Storage Structures (i.e. tanks).
5) Storm Surge, Seiche and Tsunami including wave effects.(**See Tsunami Q&A Sheet**)
6) Flooding caused by ice effects (i.e. ice dams both upstream and downstream).
7) Floods caused by diversions of stream channels toward the site.

8) Other potential site specific flood hazard(s).

**171) What about droughts and conditions which lead to low water? Are these considered?**

Yes. Impacts to the plant from low water conditions brought about by ice effects, downstream dam breach, tsunamis, hurricanes and channel diversions away from the site are reviewed to ensure the plant remains safe under these scenerios.

**172) Periods of long rainfall can cause the groundwater elevation to rise which can cause structures such as deeply embedded tanks to fail due to buoyancy. Are nuclear power plants designed to withstand this effect?**

Yes. Worst-case groundwater levels are estimated for each site and the impacts of these levels are considered in the design of the plant to ensure the plant remains safe under these conditions. During the safety review, impacts due to groundwater levels and other hydrodynamic effects on the design bases of plant foundations and other safety-related structures systems and components (SSCs) are evaluated. Impacts to a safety-related structure such as a deeply embedded tank or a structure containing a deeply embedded tank are considered in the safety review.

**173) Some of the Reports from the National Weather Service used to estimate the design precipitation are 30-40 years old. Are these estimates still valid?**

The NRC has funded research by the U.S. Bureau of Reclamation to review the information and methods developed by the National Weather Service and the U.S. Army Corps of Engineers (HMR 51), focusing on South and North Carolina. To date, reviews of precipitation records from extreme storm events (e.g., tropical storms, hurricanes) since the publication of HMR 51 does not indicate any exceedance or potential for exceedance of those precipitation (PMP) estimates in this region. We have not seen any information or data that would indicate that HMR precipitation (PMP) estimates for the U.S. have been exceeded. As expected, individual point rainfall gauges have recorded rainfall amounts that have exceeded these areal estimates.

## Fact Sheet: Summarization of Seismological Information from Regional Instrumentation

Placeholder: to be developed.

## Fact Sheet: Protection of Nuclear Power Plants against Tsunami Flooding

Nuclear power plants are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The word tsunami literally means harbor wave. Tsunamis can be generated by large offshore earthquakes (usually greater than magnitude 6.5), submarine or on shore land slides or volcanoes. Some large onshore earthquakes close to the shoreline can generate tsunami. The Nuclear Regulatory Commission (NRC) requires all nuclear power plants to be protected against earthquakes, tsunamis and other natural hazards.

**Background**

Protection against tsunami effects was required for all operating plants and is required for all new reactors. Following the Indian Ocean tsunami on December 26, 2004, the President moved to protect lives and property by launching an initiative to improve domestic tsunami warning capabilities. This plan was placed under the auspices of the National Science and Technology Council through the President's initiative in July 2005 in the context of a broad national effort of tsunami risk reduction, and United States participated in international efforts to reduce tsunami risk worldwide. In response to the president's initiative, the NRC reviewed its licensing criteria and conducted independent studies and participated in international forums under the auspices of the International Atomic Energy Agency with many participating countries including India and Japan. The final report of the study was published in April 2009 as NUREG/CR 6966, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America," ADAMS Accession # ML0915901933. NRC revised its Standard Review Plan for conducting safety reviews of nuclear power plants in 2007. Section 2.4.6 specifically addresses tsunamis. The Office of Nuclear Regulatory Research is conducting tsunami studies in collaboration with the United States Geological Survey and has published a report on tsunami hazard in the Atlantic, Gulf and Pacific coastal areas. Selected nuclear power plants now get tsunami warning notification. The agency requires plant designs to withstand the effects of natural phenomena including effects of tsunamis. The agency's requirements, including General Design Criteria for licensing a plant, are described in Title 10 of the *Code of Federal Regulations* (10 CFR). These license requirements consist of incorporating margins in the initiating hazard and additional margins are due to traditional engineering practices such as "safety factors." Practices such as these add an extra element of safety into design, construction, and operations.

The NRC has always required licensees to design, operate, and maintain safety-significant structures, systems, and components to withstand the effects of natural hazards and to maintain the capability to perform their intended safety functions. The agency ensures these requirements are satisfied through the licensing, reactor oversight, and enforcement processes.

**Tsunami Hazard Evaluation**

Tsunami hazard evaluation is one component of the complete hydrological review requirements provided in the Standard Review Plan under Chapter 2.4. The safety determination of reactor sites require consideration of major flood causing events, including consideration of combined flood causing conditions. These conditions include Probable Maximum Flood (PMF) on Streams and Rivers, Potential Dam Failures, Probable Maximum Surge and Seiche Flooding and Probable Maximum Tsunami Hazards, among others. The most significant flooding event is called the design basis flood and flooding protection requirements are correlated to this flood level in 2.4.10.

The Probable Maximum Tsunami (PMT) is defined as that tsunami for which the impact at the site is derived from the use of best available scientific information to arrive at a set of scenarios reasonably expected to affect the nuclear power plant site taking into account (a) appropriate consideration of the most severe of the natural phenomena that have been historically reported or determine from geological and physical data for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (b) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (c) the importance of the safety functions to be performed.

Site-specific tsunami data are collected from historical tsunami records, paleotsunami evidence, regional tsunami assessments, site-specific tsunami mechanisms, site-specific data, such as submarine survey of sea bed and approach channel geometry. Effects of tsunami on a nuclear power plant can be flooding due to water run up, hydro-dynamic pressure on exterior walls of structures, impact of floating debris, and foundation scouring. In addition, tsunami can draw down water from the intake source of plant cooling water.

The tsunami database is available for interactive search and downloads on the internet at http://www.ngdc.noaa.gov/hazard/tsu.shtml.

**Tsunami Safety Assessment**

The licensing bases for existing nuclear power plants are based on historical data at each site. This data is used to determine probable maximum tsunami and the tsunami effects are evaluated for each site with potential for tsunami flooding. The potential for tsunami hazard is determined on a hierarchical analysis process that can identify tsunami potential based primarily on distance from tsunami source and site elevation. The NRC also required existing plants to assess their potential vulnerability to external events, as part of the Individual Plant Examination of External Events Program. This process ensured that existing plants are not vulnerable to tsunami hazard, and they continue to provide adequate public health and safety.

Today, the NRC utilizes a risk-informed regulatory approach, including insights from probabilistic assessments and traditional deterministic engineering methods to make regulatory decisions about existing plants (e.g., licensing amendment decisions). Any new nuclear plant the NRC licenses will use a probabilistic, performance-based approach to establish the plant's seismic hazard and the seismic loads for the plant's design basis.

**Operating Plants**

The NRC is fully engaged in national international tsunami hazard mitigation programs, and is conducting active research to refine the tsunami sources in the Atlantic, Gulf Coast and Pacific Coast areas. Diablo Canyon (DC) and San Onofre (SONGS) are two nuclear plant sites that have potential for tsunami hazard. Both the DC (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at DC are designed for combination of tsunami-storm wave activity to 45 ft msl. SONGS has a reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action, designed to protect at approximately 27 ft msl. These reactors are adequately protected against tsunami effects. Distant tsunami sources for DC include the Aleutian area, Kuril-Kamchatka region, and the South American coast (for Songs the Aleutian area). Distant sources for SONGS is limited by the presence of a broad continental shelf. Local or near sources for DC include the Santa Lucia Bank and Santa Maria Basin Faults (for Songs the Santa Ana wind).

**Additional Information**

To read more about risk-related NRC policy, see the fact sheets on Probabilistic Risk Assessment (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/probabilistic-risk-asses.html) and Nuclear Reactor Risk (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/reactor-risk.html). Each provides more information on the use of probability in evaluating hazards (including earthquakes) and their potential impact on plant safety margins. Other regulatory framework includes General Design Criterion 2, 10 CFR Part 100.23, Regulatory Guide 1.102 "Flood Protection for Nuclear Power Plants", Rev. 1 1976, Regulatory Guide 1.59 "Design Basis for Nuclear Power Plants" Rev. 2 1977 (update in progress), and USNRC Standard Review Plan "Probable Maximum Tsunami Flooding" Section 2.4.6, Rev. 2.

March 2011

INFORMATION FROM RES STILL NEEDS TO BE ADDED

## Fact Sheet: Seismic Zones and US Plants

Note: This is some basic information...staff is developing this into a fact sheet

Some Key Points:

- Although we often think of the US as having "active" and "non-active" earthquake zones, earthquakes can actually happen almost anywhere. Seismologists typically separate the US into low, moderate, and high seismicity zones; not into "active" and "inactive".
- The boundaries of the low, medium and high zones are not hard, are not well constrained, and are open to interpretation. Below we've pulled together a list based on our judgment and based on multiple interpretations in the technical community. But this is just for guidance; it is subjective.
- Faults are often well mapped and characterized in active zones, such as the west. But there are very few mapped faults in the east, which doesn't mean that there aren't earthquakes. For example, the most widely felt historical earthquakes in the US occurred in the New Madrid seismic zone in 1811 and 1812. The zones is (clearly shown on figure 1, the hazard map. However, the fault has never been identified and so is only shown as an area source on figure 2. In fact, most CEUS earthquakes are not tied to a known fault.
- The NRC has a seismic research program which has—with DOE and EPRI—sponsored and undertaken a ground breaking project to create a new state of the art seismic source model for the central and eastern US. This project, the Central and Eastern US Seismic Source Characterization for Nuclear Facilities project, is expected to finish at the end of this year.
- The NRC is also undertaking the Generic Issue 199 program to reassess seismic risk in light of the potential for higher seismic hazard (ground shaking) in the CEUS. This shows an ongoing dedication to seismic safety.
- The NRC requires that every nuclear plant be designed for site-specific ground motions that are appropriate for their locations. In addition, the NRC has specified a minimum ground motion level to which nuclear plants must be designed.

**This is a preliminary (and subjective) list from seismic staff: Please consider this sensitive information**

**High Seismicity:**

- Diablo Canyon
- SONGS

**Moderate Seismicity:**

**Charleston Seismic Zone**

- Brunswick
- Robinson
- Summer
- Vogtle
- Hatch (maybe depends on interpretation)

**Wabash Valley Seismic Zone**

- Clinton

**East Tennessee Seismic Zone (a real point of contention)**

- Watts Bar

- Sequoya

**Central Virginia Seismic Zone**

- North Anna

Notes:

Also minimum standard on shaking

Note that new Madrid has several subzones.

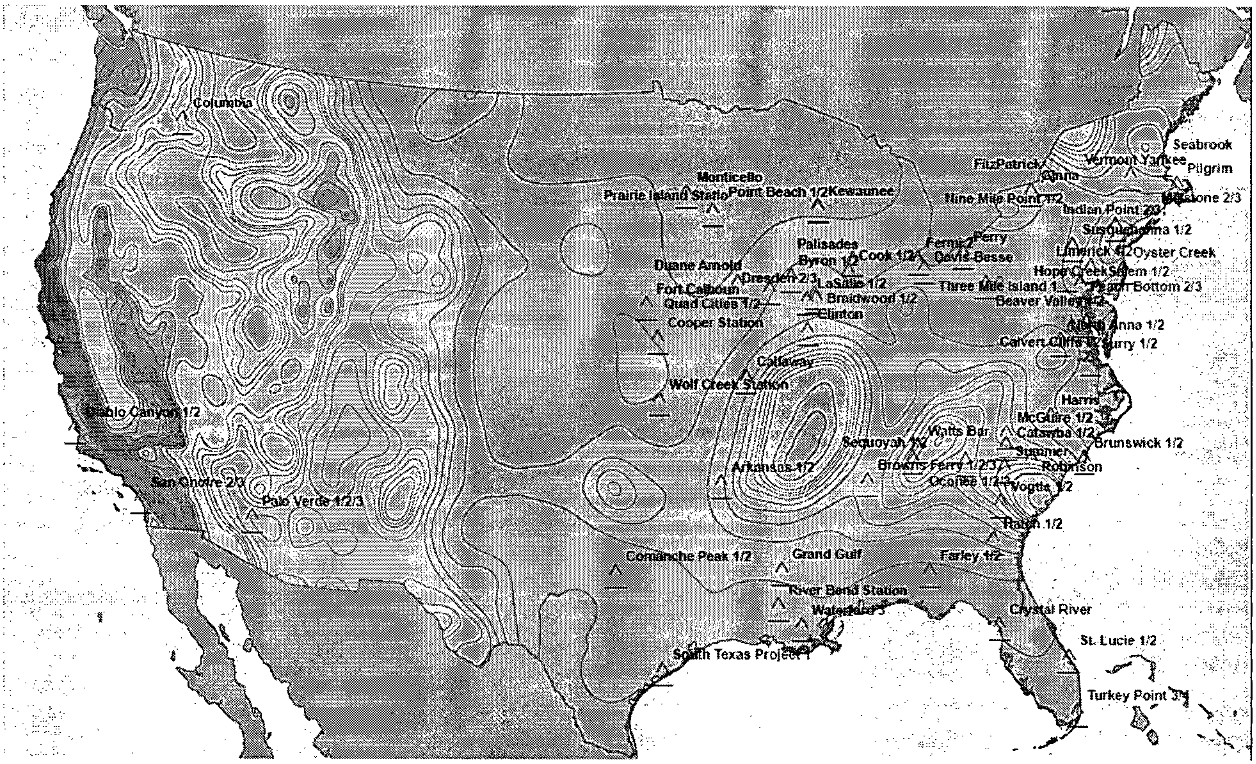



Figure 1: US Nuclear Plants overlain on the USGS National Seismic Hazard Map

As you can see the seismic source regions in the central and eastern east are not well defined. So to state a specific number of plants that are in the moderate seismicity zones is challenging and open to interpretation. This is just one interpretation, which is provided by the USGS.

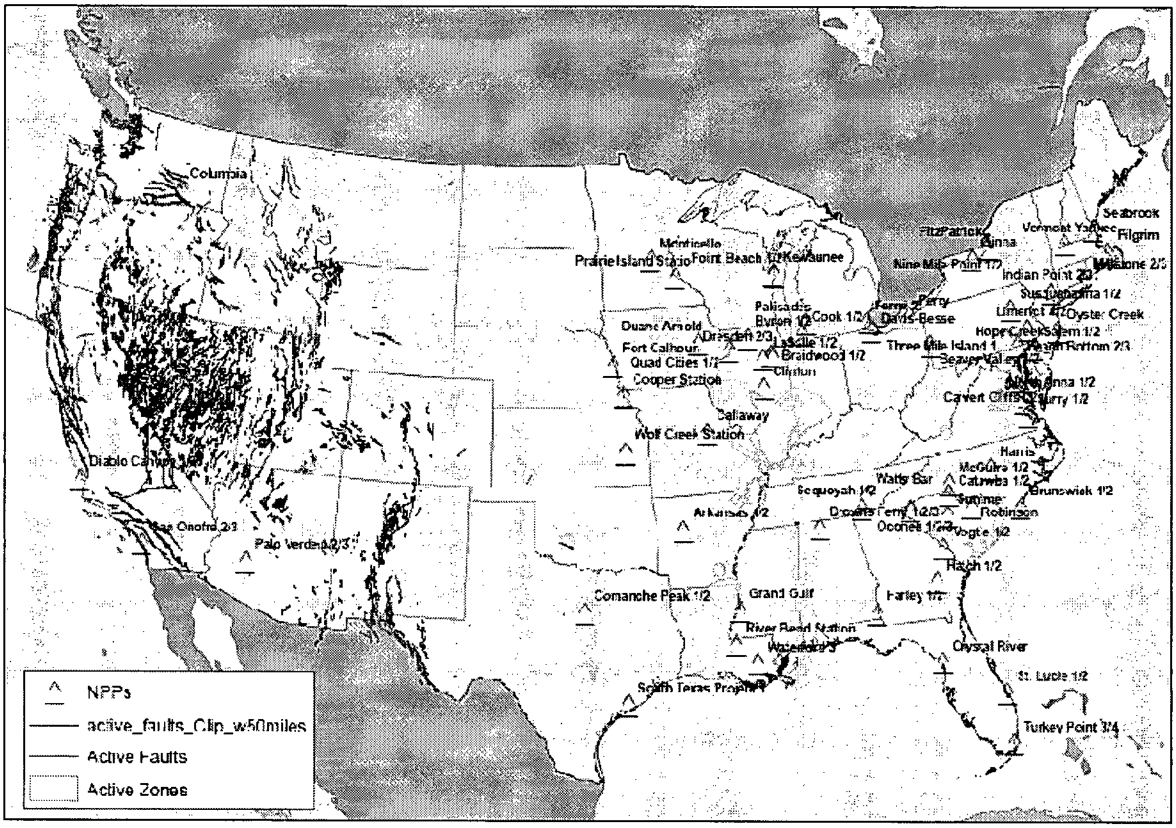



Figure 2: This figure shows mapped active faults and US Nuclear plants

As you can see, there are very few  mapped active faults in the east, which doesn't mean that there aren't earthquakes. The most widely felt historical earthquakes in the US happened in the New Madrid seismic zone (clearly shown on figure 1, the hazard map).  However, the fault is not shown here because we can't find it under all that Mississippi sand! You can (faintly) see the source one interpretation of a source zone on the figure.  However, this is just the interpretation that was in the GIS map we were working with.  We will likely put nested "blobs" onto this figure to the widest and narrowest zone interpretations.

If someone asks about plants being very near *mapped* active faults, there are two...but that doesn't mean that there isn't hazard elsewhere because in the central and eastern US the seismicity comes from "seismic zones" not faults.  It's a hard balance between saying things that make it seem that we have a lot of problems and saying things that make it seem we are underestimate the hazard or not taking it seriously.

Figure 3: Earthquakes Plotted with US Nuclear Plants

We are remaking a plot like this with a more complete set of earthquake (we're not sure that the time frame of the quakes is), this speaks to the fact that earthquakes occur everywhere, even where we don't have mapped faults.

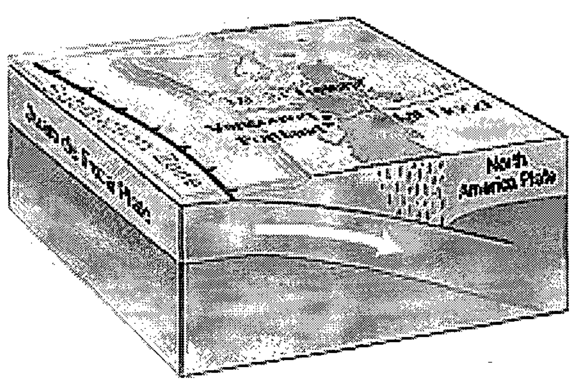
## Fact Sheet: Seismicity of the Central and Eastern US (In-depth technical information)

**Key Points**:

- To date, very large earthquakes (Magnitudes greater than 8.25) have only occurred in specific geological settings, in particular the interfaces between tectonic plates in major **subduction zones**. The only subduction zone that potentially impacts the continental US is the Cascadia zone off the coast of northern California, Oregon and Washington.
- Recent analyses of the magnitudes of the largest earthquakes **not associated** with subduction zones indicates magnitudes are less than ~8.25.
- The size (magnitude) of earthquakes is proportional to the fault area that slips in a given earthquake. The prediction of earthquake magnitudes for a specific fault considers the dimensions of the fault. Extremely large earthquakes do not occur on small faults.
- Nuclear power plants are licensed based on vibratory ground shaking, not earthquake magnitude. The ground shaking (accelerations) are used to estimate forces which are used in the seismic design process. In many cases smaller magnitude earthquakes closer to a site produce more severe ground shaking than larger, more distant earthquakes. Hence it is important to consider all potential earthquake sources regardless of magnitude.

**Discussion:** Earthquakes with very large magnitudes such as the March 2011 earthquake off the northeast coast of the Japanese island of Honshu occur within subduction zones, which are locations where one of the earth's tectonic plates is subducting beneath (being thrust under) another. The fault that defines the Japan Trench plate boundary dips to the west, i.e., becomes deeper towards the coast of Honshu. Large offshore earthquakes have historically occurred in the same subduction zone (in 1611, 1896, and 1933) all of which produced significant tsunami waves. The magnitudes of these previous large earthquakes have been estimated to be between 7.6 and 8.6. Prior to March 2011, the Japan Trench subduction zone has produced nine earthquakes with magnitudes greater than 7 just since 1973.

The only subduction zone that is capable of directly impacting the continental US is the Cascadia subduction zone, which lies off of the coast of northern California, Oregon, and Washington. The fault surface defined by this interface dips to the east (becomes deeper) beneath the coast. The Cascadia subduction zone is capable of producing very large earthquakes if all or a large portion of the fault area ruptures in a single event. However, the rate of earthquake occurrence along the Cascadia subduction zone is much less than has been observed along the Japan Trench subduction zone. The only operating nuclear power plant in that area is Columbia, which is far from the coast (~220 miles/350 km) and the Cascadia subduction zone. *The occurrence of earthquakes on the Cascadia subduction zone has been considered in the evaluation of the Columbia NPP.*



Schematic Illustration of the Cascadia Subduction Zone

The size (magnitude) of earthquakes is proportional to the surface area of a fault that slips in a given earthquake. Large earthquakes are associated with large (long) faults. Hence, the prediction of earthquake magnitudes for a specific fault considers the dimensions of the fault. Identification of fault size is usually based on geologic mapping or the evaluation of spatial patterns of small earthquakes. To provide **a point of comparison**, the length of the fault that slipped during the March 11, 2011 magnitude 9 Japanese earthquake was >620 km, the length of the fault(s) that slipped during the magnitude 7.3 1992 Landers, CA earthquake was ~90 km and the estimated length of the Hosgi fault near Diablo Canyon NPP is 140 km and a magnitude of 7.5 is assigned to that fault. A number of major crustal faults or fault zones (not associated with the Cascadia subduction zone) have been identified that have produced earthquakes of magnitude 7.5 to 8 in the continental US (including California). ***These fault sources have been identified and characterized in seismic hazard assessments.***

Seismic designs at US nuclear power plants are developed in terms of seismic ground motion spectra, which are called the Safe Shutdown Earthquake ground motion response spectra (SSE). Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location. Currently operating nuclear power plants developed their SSEs based on a "deterministic" or "scenario earthquake" basis that account for the largest earthquake expected in the area around the plant. Seismic activity in the regions surrounding US plants is much lower than that for Japan since **most US plants are located in the interior of the stable continental US** The largest earthquakes within the continental US are the 1811-12 New Madrid sequence and the 1886 Charleston, SC, which were estimated to be between about magnitude 6.8 to 7.5. On the west coast of the US, the two nuclear power plants are designed to specific ground motions from earthquakes of about magnitude 7+ on faults located just offshore of the plants. The earthquakes on these faults are mainly strike-slip (horizontal motion on near vertical planes) type earthquakes, not subduction zone earthquakes. This fault geometry does not produce large tsunamigenic waves. Therefore, the likelihood of a significant tsunami from these faults is very remote.

## Fact Sheet: US Portable Array Information

NOTE: This is provided because IRIS participants let us know that here was a discussion about the NRC's involvement in this program during a meeting with congressional staffers. We have been involved in this for the last couple years.

The Incorporated Research Institutions for Seismology is the Consortium of Unites States Universities with Major Research Programs in Seismology and Related Fields.

**The Transportable Array: A Science Investment that Can Be Leveraged**

IRIS is installing the Transportable Array – a set of 400 broadband seismic instruments – in each of more than 1600 sites across the contiguous United States. The instruments operate at each site for two years and then are removed and redeployed further east. Roughly 1100 stations have been installed since 2003, and instruments have been removed from more than 600 of those sites in the western United States.

The National Science Foundation is funding the full cost to "roll" the Transportable Array across the US, more than $90,000,000 over ten years. Comparatively small incremental investments could add significant data that are relevant to the safety of nuclear power plants. These efforts would be uniquely cost effective, since NSF is already funding installation, and they would feed data into an existing, standardized and widely used data management system that already incorporates the vast majority of seismic data from US networks. But these opportunities are time constrained: the array will be fully installed in the contiguous 48 states by late 2013.

**More Value from Longer Term Regional Observations**

A dense, uniform seismic network is necessary for long-term, broad-area seismic monitoring of the central and eastern United States due to low event recurrence rates and the risk of significant earthquakes ($M$>5) anywhere in the region. Monitoring seismicity in the central and eastern US can be improved by turning selected sites into permanent seismic stations. A total of more than 35 Transportable Array stations have already been "adopted" by several organizations, creating a permanent legacy, but only in the western United States.

A strategic "1-in-4" plan would involve "adoption" of systematically selected stations in the central and eastern United States – every other station in both the east-west and north-south directions, creating a uniform grid of some 250 stations. Long-term regional operation could be combined with two optional enhancements to create a unique observatory for the study of seismicity, source characteristics, attenuation, and local ground acceleration.

**Enhancement 1: Acquire Higher Frequency Data**

Crustal rigidity in the central and eastern US makes it desirable to record high frequency characteristics of local and regional earthquakes. The existing instruments could be reconfigured to record high frequencies but doing so would nearly triple the data flow, necessitating improvements to the communications infrastructure.

**Enhancement 2: Add Strong Motion Sensors**

Acquiring strong motion sensors and reconfiguring field computers that record and telemeter the data would help to measure unique effects of severe shaking. The design anticipated this augmentation, and several stations in California and Washington were operated that way. Upgrade would be more efficient at sites that have not yet been installed.

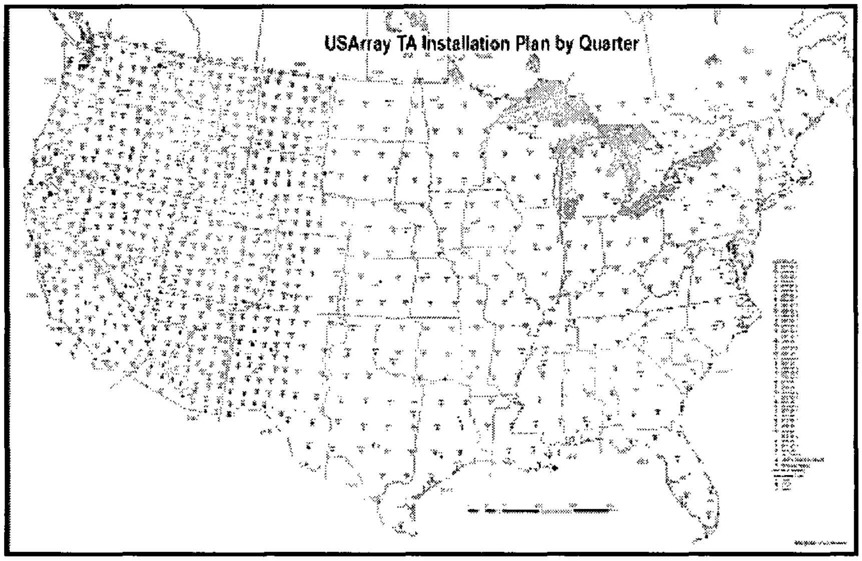
*Estimate of annual acquisition and O&M costs for the 1-in-4, 250-station network in central and eastern US.*

| Year | Stations | Acquisition[1] | O&M[2] | Total |
|---|---|---|---|---|
| 2011 | 50 | $1,800,000 | $ 400,000 | $2,200,000 |
| 2012 | 50 | $1,800,000 | $ 800,000 | $2,600,000 |
| 2013 | 50 | $1,800,000 | $1,200,000 | $3,000,000 |
| 2014 | 50 | $1,800,000 | $1,600,000 | $3,400,000 |
| 2015 | 50 | $1,800,000 | $2,000,000 | $3,800,000 |
| 2016 | – | – | $2,000,000 | $2,000,000 |

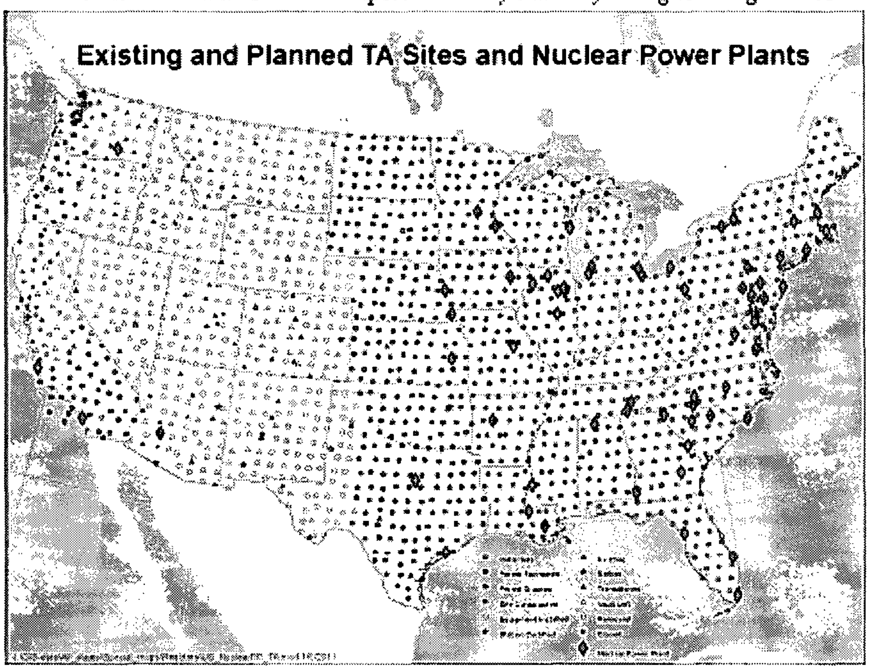
[1] Assumes upgrades to six channel data loggers with strong motion sensors.

[2] Assumes a conservative estimate of $8,000/station/year.

*The 1-in-4, 250-station network that could be created in the central and eastern US by "leaving behind" one out of every four Transportable Array stations during the years 2011 through 2015.*




*A large majority of nuclear power plants are located in the central and eastern parts of the US, where it is still possible to "leave behind" 1-in-4 Transportable Array stations for long-term regional observations.*



## Additional Information: Terms and Definitions

***Annual exceedance frequency (AEF)*** – Number of times per year that a site's ground motion is expected to exceed a specified acceleration.

***Active or seismogenic fault***- need to add definition of active fault from

***Capable Tectonic Source*** – A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation such as faulting or folding at or near the earth's surface in the present seismotectonic regime. It is described by at least one of the following: characteristics:

(1) presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years or at least once in the last approximately 50,000 years

(2) a reasonable association with one or more moderate to large earthquakes or sustained earthquake activity that are usually accompanied by significant surface deformation

(3) a structural association with a capable tectonic source that has characteristics of either item a or b (above), such that movement on one could be reasonably expected to be accompanied by movement on the other

In some cases, the geological evidence of past activity at or near the ground surface along a potential capable tectonic source may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the structure from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence is to be used in determining whether the structure is a capable tectonic source within this definition. Notwithstanding the foregoing paragraphs, the association of a structure with geological structures that are at least pre-Quaternary, such as many of those found in the central and eastern regions of the United States, in the absence of conflicting evidence, will demonstrate that the structure is not a capable tectonic source within this definition.

***Certified Seismic Design Response Spectra (CSDRS)*** – Site-independent seismic design response spectra that have been approved under Subpart B of 10 CFR Part 52 as the seismic design response spectra for an approved certified standard design nuclear power plant. The input or control location for the CSDRS is specified in the certified standard design.

***Combined License*** – A combined construction permit and operating license with conditions for a nuclear power facility issued pursuant to Subpart C of 10 CFR Part 52.

***Controlling Earthquakes*** – Earthquakes used to determine spectral shapes or to estimate ground motions at the site for some methods of dynamic site response. There may be several controlling earthquakes for a site. As a result of the probabilistic seismic hazard analysis (PSHA), controlling earthquakes are characterized as mean magnitudes and distances derived from a deaggregation analysis of the mean estimate of the PSHA.

***Core damage frequency (CDF)* – Expected number of core damage events per unit of time.** *Core damage* refers to the uncovery and heat-up of the reactor core, to the point that prolonged oxidation and severe fuel damage are not only anticipated but also involve enough of the core to result in off-site public health effects if released. *Seismic core damage frequency* refers to the component of total CDF that is due to seismic events.

***Cumulative Absolute Velocity (CAV)*** – For each component of the free-field ground motion, the CAV should be calculated as follows: (1) the absolute acceleration (g units) time-history is divided into 1-second intervals, (2) each 1-second interval that has at least 1 exceedance of 0.025g is integrated over time, and (3) all the integrated values are summed together to arrive at the CAV. The CAV is exceeded if the calculation is greater than 0.16 g-second. The application of the CAV in siting requires the development of a CAV model because the PSHA calculation does not use time histories directly.

***Deaggregation*** – The process for determining the fractional contribution of each magnitude-distance pair to the total seismic hazard. To accomplish this, a set of magnitude and distance bins are selected and the annual probability of exceeding selected ground acceleration parameters from each magnitude-distance pair is computed and divided by the total probability for earthquakes.

***Design basis earthquake* or *safe shutdown earthquake (SSE)*** – A *design basis earthquake* is a commonly employed term for the *safe shutdown earthquake* (*SSE)*; the SSE is the earthquake ground shaking for which certain structures, systems, and components are designed to remain functional. In the past, the SSE has been commonly characterized by a standardized spectral shape associated with a peak *ground acceleration* value.

***Design Factor*** – The ratio between the site-specific GMRS and the UHRS. The design factor is aimed at achieving the target annual probability of failure associated with the target performance goals.

***Early Site Permit*** – A Commission approval, issued pursuant to Subpart A of 10 CFR Part 52, for a site or sites for one or more nuclear power facilities.

***Earthquake Recurrence*** – The frequency of occurrence of earthquakes as a function of magnitude. Recurrence relationships or curves are developed for each seismic source, and they reflect the frequency of occurrence (usually expressed on an annual basis) of magnitudes up to the maximum, including measures of uncertainty.

***Frequency of Onset of Significant Inelastic Deformation (FOSID)*** – The annual probability of the onset of significant inelastic deformation (OSID). OSID is just beyond the occurrence of insignificant (or localized) inelastic deformation, and in this way corresponds to "essentially elastic behavior." As such, OSID of a structure, system, or component (SSC) can be expected to occur well before seismically induced core damage, resulting in much larger frequencies of OSID than seismic core damage frequency (SCDF) values. In fact, OSID occurs before SSC "failure," where the term failure refers to impaired functionality.

***Ground acceleration*** – Acceleration produced at the ground surface by seismic waves, typically expressed in units of *g*, the acceleration of gravity at the earth's surface.

***Ground Motion Response Spectra (GMRS)*** – A site-specific ground motion response spectra characterized by horizontal and vertical response spectra determined as free-field motions on the ground surface or as free-field outcrop motions on the uppermost in-situ competent material using performance-based procedures. When the GMRS are determined as free-field outcrop motions on the uppermost in-situ competent material, only the effects of the materials below this elevation are included in the site response analysis.

***Ground Motion Slope Ratio*** – Ratio of the spectral accelerations, frequency by frequency, from a seismic hazard curve corresponding to a 10-fold reduction in hazard exceedance frequency. (See Equation 3 in Regulatory Position 5.1.)

***High confidence of low probability of failure (HCLPF) capacity*** – A measure of *seismic margin*. In *seismic risk* assessment, *HCLPF capacity* is defined as the earthquake motion level, at which there is high confidence (95%) of a low probability (at most 5%) of failure of a structure, system, or component.

***In-column Motion*** – Motion that is within a soil column, as opposed to the motion at the surface or treated as if it is at the surface.

***Intensity*** – The intensity of an earthquake is a qualitative description of the effects of the earthquake at a particular location, as evidenced by observed effects on humans, on human-built structures, and on the earth's surface at a particular location. Commonly used scales to specify intensity are the Rossi-Forel, Mercalli, and Modified Mercalli. The Modified Mercalli Intensity (MMI) scale describes intensities with values ranging from I to XII in the order of severity. MMI of I indicates an earthquake that was not felt except by a very few, whereas MMI of XII indicates total damage of all works of construction, either partially or completely.

***Large early release frequency (LERF)*** – The expected number of large early releases per unit of time. A *large early release* is the rapid, unmitigated release of airborne fission products from the containment building to the environment, occurring before the effective implementation of off-site emergency response and protective actions, such that there is a potential for early health effects. *Seismic large early release frequency* refers to the component of total LERF that is due to seismic events.

***Magnitude*** – An earthquake's magnitude is a measure of the strength of the earthquake as determined from seismographic observations and is an objective, quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, Surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the most commonly used magnitude measurement is the Moment Magnitude, Mw, which is based on the seismic moment computed as the rupture force along the fault multiplied by the average amount of slip, and thus is a direct measure of the energy released during an earthquake.

***Maximum Magnitude*** – The maximum magnitude is the upper bound to earthquake recurrence curves.

***Mean Site Amplification Function*** – The mean amplification function is obtained for each controlling earthquake, by dividing the response spectrum from the computed surface motion by the response spectrum from the input hard rock motion, and computing the arithmetic mean of the individual response spectral ratios.

***Nontectonic Deformation*** – Nontectonic deformation is distortion of surface or near-surface soils or rocks that is not directly attributable to tectonic activity. Such deformation includes features associated with subsidence, karst terrain, glaciation or deglaciation, and growth faulting.

***Response Spectrum*** – A plot of the maximum responses (acceleration, velocity, or displacement) of idealized single-degree-of-freedom oscillators as a function of the natural frequencies of the oscillators for a given damping value. The response spectrum is calculated for a specified vibratory motion input at the oscillators' supports.

***Ring Area*** – Annular region bounded by radii associated with the distance rings used in hazard deaggregation (RG 1.208, Appendix D, Table D.1, "Recommended Magnitude and Distance Bins").

***Safe Shutdown Earthquake Ground Motion (SSE)*** – The vibratory ground motion for which certain structures, systems, and components are designed, pursuant to Appendix S to 10 CFR Part 50, to remain functional. The SSE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface.

***Seismic hazard*** – Any physical phenomenon, such as ground motion or ground failure, that is associated with an earthquake and may produce adverse effects on human activities (such as posing a risk to a nuclear facility).

***Seismic margin*** – The difference between a plant's capacity and its seismic design basis (*safe shutdown earthquake, or SSE*).

***Seismic risk*** – The risk (frequency of occurrence multiplied by its consequence) of severe earthquake-initiated accidents at a nuclear power plant. A severe accident is an accident that causes core damage, and, possibly, a subsequent release of radioactive materials into the environment. Several risk metrics may be used to express *seismic risk*, such as seismic *core damage frequency* and seismic *large early release frequency*.

***Seismic Wave Transmission (Site Amplification)*** – The amplification (increase or decrease) of earthquake ground motion by rock and soil near the earth's surface in the vicinity of the site of interest. Topographic effects, the effect of the water table, and basin edge wave-propagation effects are sometimes included under site response.

***Seismogenic Source*** – A portion of the earth that is assumed to have a uniform earthquake potential (same expected maximum earthquake and recurrence frequency), distinct from that of surrounding sources. A seismogenic source will generate vibratory ground motion but is assumed to not cause surface displacement. Seismogenic sources cover a wide range of seismotectonic conditions, from a well-defined tectonic structure to simply a large region of diffuse seismicity.

***Spectral Acceleration*** – Peak acceleration response of an oscillator as a function of period or frequency and damping ratio when subjected to an acceleration time history. It is equal to the peak relative displacement of a linear oscillator of frequency, f, attached to the ground, times the quantity $(2Bf)^2$. It is expressed in units of gravity (g) or cm/second$^2$.

***Stable Continental Region (SCR)*** – An SCR is composed of continental crust, including continental shelves, slopes, and attenuated continental crust, and excludes active plate boundaries and zones of currently active tectonics directly influenced by plate margin processes. It exhibits no significant deformation associated with the major Mesozoic-to-Cenozoic (last 240 million years) orogenic belts. It excludes major zones of Neogene (last 25 million years) rifting, volcanism, or suturing.

***Stationary Poisson Process*** – A probabilistic model of the occurrence of an event over time (or space) that has the following characteristics: (1) the occurrence of the event in small intervals is constant over time (or space), (2) the occurrence of two (or more) events in a small interval is negligible, and (3) the occurrence of the event in non-overlapping intervals is independent.

***Target Performance Goal (PF)*** – Target annual probability of exceeding the 1 E-05 frequency of onset of significant inelastic deformation (FOSID) limit state.

***Tectonic Structure*** – A large-scale dislocation or distortion, usually within the earth's crust. Its extent may be on the order of tens of meters (yards) to hundreds of kilometers (miles).

***Uniform Hazard Response Spectrum (UHRS)*** – A plot of a ground response parameter (for example, spectral acceleration or spectral velocity) that has an equal likelihood of exceedance at different frequencies.

***Within Motion*** – An earthquake record modified for use in a site response model. Within motions are developed through deconvolution of a surface recording to account for the properties of the overburden material at the level at which the record is to be applied. The within motion can also be called the "bedrock motion" if it occurs at a high-impedance boundary where rock is first encountered.

## What are the definitions of the SSE and OBE?

CLEAN UP BELOW information – and add above

From RG1.208 Safe Shutdown Earthquake Ground Motion (SSE). The vibratory ground motion for which certain structures, systems, and components are designed, pursuant to Appendix S to 10 CFR Part 50, to remain functional. The SSE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface

Appendix S to 10 CFR Part 50 (3) has the following information: Required Plant Shutdown. If vibratory ground motion exceeding that of the Operating Basis Earthquake Ground Motion or if significant plant damage occurs, the licensee must shut down the nuclear power plant. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after the occurrence of the Operating Basis Earthquake Ground Motion, the licensee must consult with the Commission and must propose a plan for the timely, safe shutdown of the nuclear power plant. Prior to resuming operations, the licensee must demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public and the licensing basis is maintained.

The ratio is provided in guidance as the ratio that the licensees can chose without additional analysis. The OBE mostly used to be half for existing plants, but now it's a 1/3 unless you do analyses to show why it should be ½.

| | |
|---|---|
| **Definition of Safe Shutdown Earthquake** | The safe-shutdown earthquake (SSE) for the site is the ground motion response spectra (GMRS), which also satisfies the minimum requirement of paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Code of Federal Regulations (10 CFR Part 50). |
| **Definition of Operating Basis Earthquake:** | To satisfy the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE) ground motion is defined as follows:<br>(iv) For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.<br>(v) For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in design control document (DCD).<br>(vi) The spectrum ordinate criterion to be used in conjunction with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," issued March 1997, is the lowest of (i) and (ii). |

## List of Questions

## Bensi, Michelle

**From:** Bensi, Michelle
**Sent:** Monday, March 21, 2011 8:06 PM
**To:** Kammerer, Annie
**Subject:** end of the day update
**Attachments:** Seismic Questions for Incident Response 3-21-11 8pm_MB.docx

**Requests:**

- Please send the Word version of the commission briefing document

**Summary of document changes/additions:**

- Replaced questions #11 and #91
- Added PGA contour map (without location of plants on the map)
- Added B.5.b fact sheet (unedited from text used in Commission Document)
- Stephanie is currently compiling the definition list. I will add to it if necessary and put it in the Q&A document tomorrow.

**Tasks for tomorrow:**

- Add GI-199 factsheet
- Add station blackout rule factsheet
- Add SOARCA Q&A document
- Create spent fuel pool section (rearrange questions from other sections into a spent fuel section; add additional questions contained in the Commission Briefing report to the Q&A document).
- Add tsunami data from NEI until Japan section of Q&A document.
- Create factsheet on the current Japanese approach to tsunami (note: JSCE is currently finalizing guidance PTHA = prob tsunami hazard analysis for Japan)
- Create a factsheet using the ICAPP presentation (seismic considerations of WUS)
- Look at Wikipedia page for images that could be added long term (e.g. add to fact sheet)
- Stephanie may start a document with the acronyms. If she doesn't have time, I will compile it.

---

**From:** Kammerer, Annie
**Sent:** Monday, March 21, 2011 5:42 PM
**To:** Bensi, Michelle
**Subject:**

**Please replace teh original text with this...**

**How was the seismic design basis for an existing nuclear power plant established?**

**Public Answer:** The seismic ground motions used for the design basis of existing nuclear plants were determined from the evaluation of the maximum historic earthquake within 200 miles of the site, without explicitly considering the time spans between such earthquakes; safety margin was then added beyond this maximum historic earthquake to form a hypothetical *design basis earthquake*. The relevant regulation for currently operating plants is 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-appa.html).



TT\28

**Bensi, Michelle**

**From:** Kammerer, Annie
**Sent:** Tuesday, March 22, 2011 10:04 AM
**To:** Bensi, Michelle
**Subject:** FW: tsunami hazard studies from TEPCO experts (2 of 2)
**Attachments:** 09b-TSakai-Tsunami.ppt

We can later if there is anything useful from this.

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**From:** Sheron, Brian
**Sent:** Tuesday, March 22, 2011 9:08 AM
**To:** Case, Michael; Richards, Stuart; Hogan, Rosemary; Kammerer, Annie
**Subject:** FW: tsunami hazard studies from TEPCO experts (2 of 2)

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**From:** Adams, Ian [mailto:Ian.Adams@Hq.Doe.Gov]
**Sent:** Tuesday, March 22, 2011 9:03 AM
**To:** Adams, Ian; Aoki, Steven; Binkley, Steve; Bob Budnitz; Sheron, Brian; Brinkman, Bill; DAgostino, Thomas; Dick Garwin; Dick Garwin; Finck, Phillip; Grossenbacher, John (INL); Hurlbut, Brandon; John Holdren; Kelly, John E (NE); Koonin, Steven; Lyons, Peter; McFarlane, Harold; Owens, Missy; Per Peterson; Poneman, Daniel; Rolando Szilard; Steve Fetter
**Subject:** FW: tsunami hazard studies from TEPCO experts (2 of 2)

Attached is the 2nd of 2 files sent to the nuclear group via Bob Budnitz.

Thanks,
Ian

---

**From:** Bob Budnitz [mailto:rjbudnitz@lbl.gov]
**Sent:** Tuesday, March 22, 2011 6:17 AM
**To:** Adams, Ian
**Subject:** tsunami hazard studies from TEPCO experts (2 of 2)

TO: Ian Adams
FROM: Robert Budnitz (LBNL)

**TSUNAMI HAZARD STUDIES FOR JAPAN AND SPECIFICALLY FOR FUKUSHIMA**
[Ian, can you please distribute this to the science group? Thanks. Bob]

**SENDING THE MAIN FILE NEXT. SEPARATE EMAIL NEEDED DUE TO FILE SIZE**

Dear Colleagues,

Dr. Antonio Godoy, a long-standing colleague and friend of mine, retired a few months ago from a post at the IAEA in Vienna were he was responsible for the program in seismic and tsunami hazards. In an email that I just received, and responding to my inquiry, Godoy explained to me that in May 2010 he sponsored an IAEA "Experts Meeting regarding the Site Selection and Evaluation for Philippines NPP" in Vienna. Two presentations at that meeting are directly relevant to the tsunami hazard at Fukushima, and the view graphs from both are attached here. Both are from experts at TEPCO, Drs. Takao and Sakai.



T\29

One of these presentations gives a general methodology overview, while the other is "Appendix A" and uses Fukushima as a case study.

There is a lot of jargon in these viewgraphs, which I am intimately familiar with but which some of our group may not be familiar with. Oh well .......

I will try to see if any original papers exist to back up these slides, and if so whether they are available.

By the way, since his retirement Godoy has been rehired by the IAEA part-time, but has also set up a consulting practice in Vienna and in fact has done a small piece of consulting work for me at LBNL recently. He is also very close professionally to Annie Kammerer of the NRC staff, one of NRC's top seismic experts.

Bob Budnitz

# Tsunami Assessment Method for NPP in Japan and Recent Studies

Makoto TAKAO, P.E.
마고도 다가오

TOKYO ELECTRIC POWER COMPANY



## Agenda

Part A
- Tsunami assessment method for NPP in Japan
  - A-1. Deterministic approach by JSCE
  - A-2. Assessment example

Part B
- Recent Studies on,
  - B-1. Probabilistic approach
  - B-2. Other phenomena due to tsunami



## Agenda

Part A
- Tsunami assessment method for NPP in Japan
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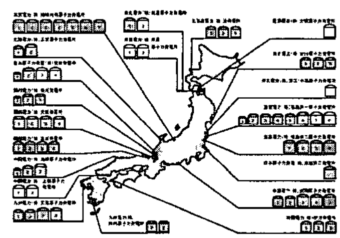
Part B
- Recent Studies on,
  - B-1. Probabilistic approach
  - B-2. Other phenomena due to tsunami



## Nuclear Power Plants(NPP) in Japan



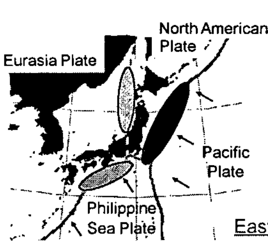
: 55 NPP in operation
: 2 NPP under construction
: 11 NPP under preparation for construction

All the NPP are located at coastal area

tsunami assessment is important for NPP in Japan



## Plate Boundaries Around Japan




Japan Trench
- Keicho Sanriku, $M_w$=8.6, 1611
- Meiji Sanriku, $M_w$=8.3, 1896
- Showa Sanriku, $M_w$=8.4, 1933

Nankai Trough
- Houei, $M_w$=8.8, 1707
- Tounankai, $M_w$=8.4, 1944
- Nankai, $M_w$=8.5, 1946

Eastern Margin of the Japan Sea
- Nihonkai-Chubu, $M_w$=7.7, 1983
- Southwest Hokkaido, $M_w$=7.8, 1993



## A-1. Deterministic approach

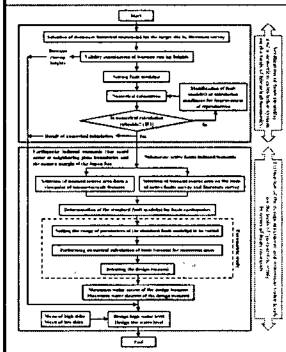
"Tsunami Assessment Method for Nuclear Power Plants in Japan"

published by

Tsunami Evaluation Subcommittee,
Nuclear Civil Engineering Committee,
JSCE (Japan Society of Civil Engineers)

English version
http://www.jsce.or.jp/committee/ceofnp/Tsunami/eng/tsunami_eng.html

## Overview of the JSCE Method



1st Part
'Verification of fault model and a numerical calculation system'
( preparation for assessment )

2nd Part
'Determination of the design high and low water levels'
(the main part )



## Verification of fault model and a numerical calculation system

Start
↓
Select dominant **historical tsunamis** for the target site by literature survey
↓
Examine validity of recorded tsunami heights
↓
Setting fault models of historical tsunamis
↓
Numerical calculation ← Fault models or calculation conditions are modified for improvement of reproduction
↓
Is numerical calculation reliable? — NO →
YES ↓ Go to 2nd part



## Scenario Earthquakes

↓ From 1st part
Select tsunami source area
↓
Determine the **standard fault models** for scenario earthquakes
↓

Parametric Study
the method of taking account of uncertainties and errors into design

- Set the range of parameters of the standard fault model(s)
- Numerous cases of numerical calculation ( **Scenario Tsunami** )

select ↓
**The design tsunami**



## Scenario Earthquakes

1) along the plate boundaries
2) eastern margin of the Japan Sea
3) submarine active faults
4) oversea plate boundaries ; such as; off the west coast of South America

The standard fault model for scenario earthquakes must;
— be able to reproduce historical tsunami run-up heights
— have the maximum magnitude in the region ($M_w$)



## Parametric study

↓
Determine **the standard fault models** for scenario earthquakes
↓

Parametric Study
the method of taking account of uncertainties and errors into design

- Set the range of parameters of the standard fault models ( **Scenario Earthquakes** )
- Numerous cases of numerical calculation ( **Scenario Tsunamis** )

Why parametric study is needed? ⇨
Earthquakes and tsunamis are natural phenomena
Various uncertainties and errors intervene in the process of tsunami assessment



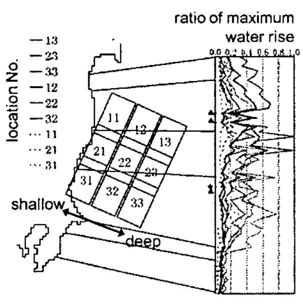
## Uncertainties and Errors

Major Influence on Tsunami Assessment

| Tsunami Source | Numerical Simulation | Data |
|---|---|---|
| • fault position<br>• depth of upper edge of the fault plane<br>• strike direction<br>• dip angle<br>• dip direction<br>• slip angle<br>• combination of segments | ▪ governing equation<br>▪ boundary conditions<br>▪ initial conditions<br>▪ grid division | • modeling of bathymetry data<br>• reliability of run-up heights |

It is rather difficult to estimate one by one quantitatively.
⇨ Uncertainties of tsunami source are focused.

## Tsunami Source - fault position -




Each fault model has the same parameters except for

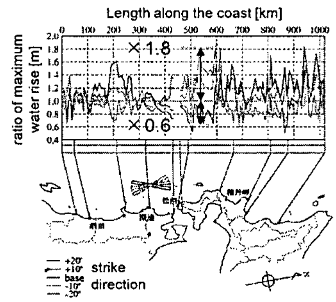
- its location
- depth of upper edge of the fault plane

Tsunami height becomes larger, in case tsunami source located

- in front of the target site
- farther



## Tsunami Source - strike direction -




Each fault model has the same parameters except for

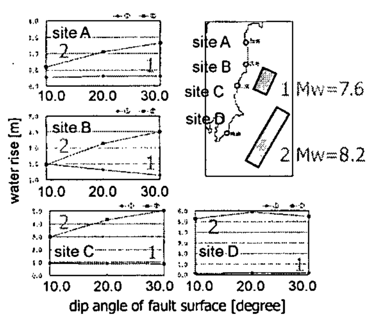
- strike direction

Tsunami height varies

- from 0.6 times to 1.8 times



## Tsunami Source - dip angle -



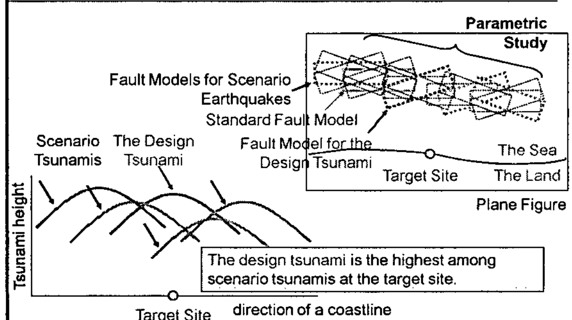

Each fault model has the same parameters except for

- dip angle

- the effect differ from site by site



## Parametric Study of Tsunami Source






## Design tsunami

Determine the **standard fault models** for scenario earthquakes

Parametric Study

the method of taking account of uncertainties and errors into design

Setting the range of parameters of the standard fault model(s) to be varied

Numerous cases of numerical calculation ( **Scenario Tsunami** )

select

**The design tsunami**

the highest among all historical and possible tsunamis at the site in order to make sure of the safety of coastal power plants



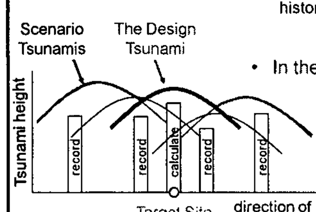
## Verification of the design tsunami

Selecting the Highest Tsunami at the Site

### 2 points are confirmed

- At the Target Site

  The design tsunami height exceeds all the recorded & calculated historical tsunami heights.




- In the Vicinity of the Target Site

  The envelope of scenario tsunamis exceeds all the recorded historical tsunami heights.

## Consideration of tide and safety evaluation

The Design Tsunami

⇩ ⇦ Tidal Conditions

Design High Water Level

= Maximum water rise + Mean of high tides

Design Low Water Level

= Maximum water fall + Mean of low tides

⇩

Evaluation of the safety of NPP



## Agenda

Part A

Tsunami assessment method for NPP in Japan

A-1. Deterministic approach by JSCE

A-2. Assessment example

Part B

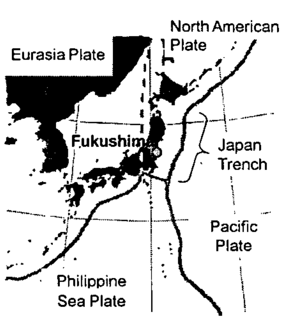
Recent Studies on,

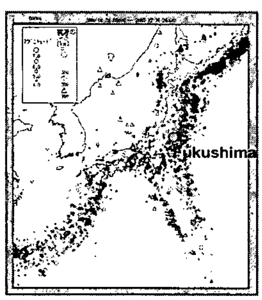
B-1. Probabilistic approach

B-2. Other phenomena due to tsunami



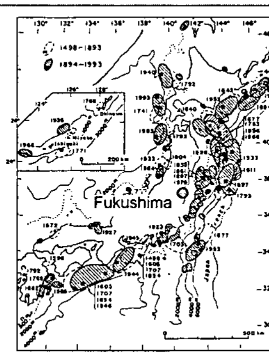
## A-2. Assessment example



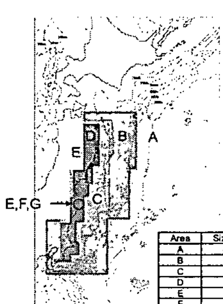



## Historical Tsunami at the Site






## Numerical Model



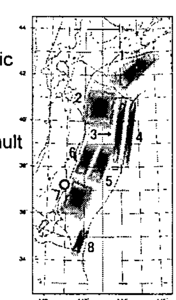

| Area | Size of Grid |
|---|---|
| A | 4320m |
| B | 2160m |
| C | 720m |
| D | 240m |
| E | 80m |
| F | 40m |
| G | 20m |

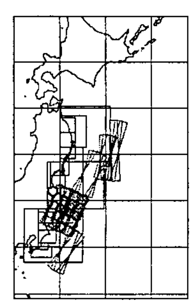


## Standard Fault Model and General parametric study stage

General parametric study stage

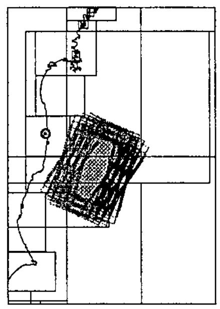
- location
- direction of fault



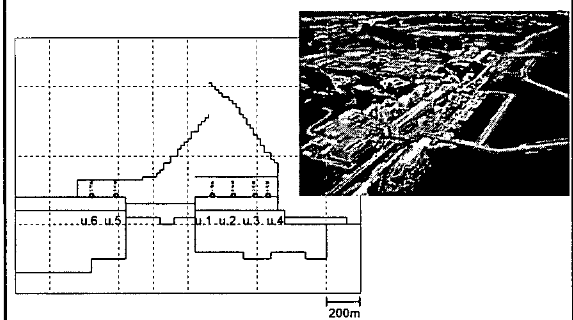
## Detailed parametric study stage

Detailed parametric study stage
- location
- direction angle
- dip angle
- slip angle



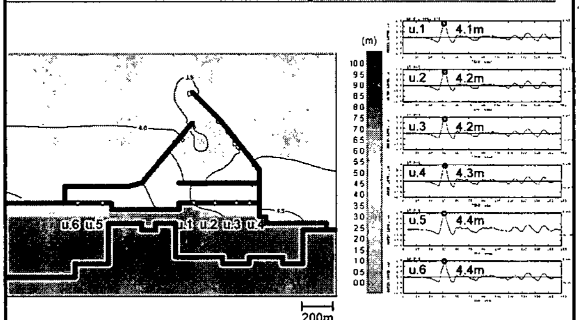


## Location of Evaluation



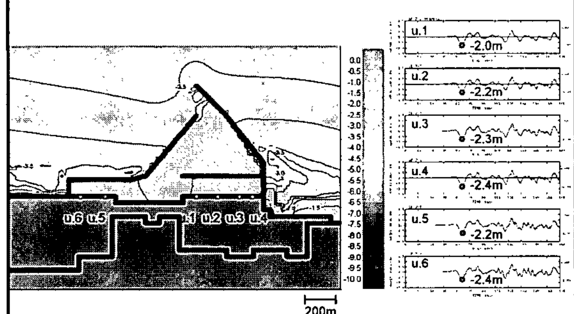



## Maximum Water Level by Near Field Tsunami



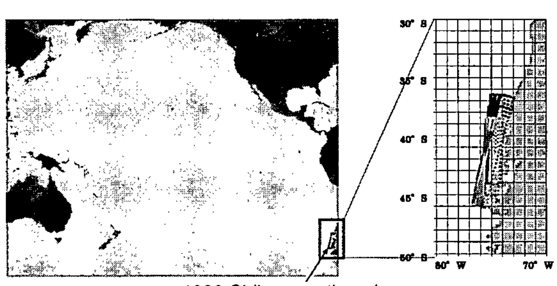



## Minimum Water Level by Near Field Tsunami





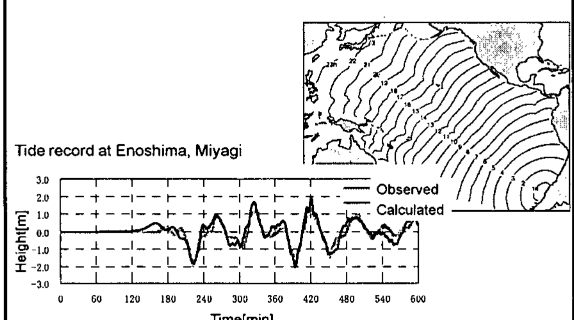

## Tsunami Occurred the Area Far From Japan



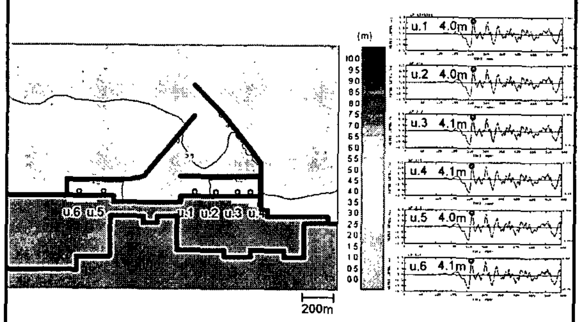

1960 Chilean earthquake



## Tsunami Occurred the Area Far From Japan

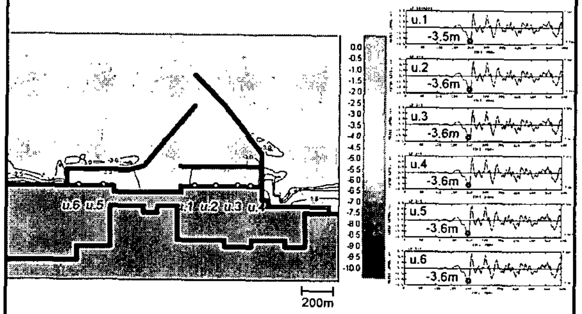


## Maximum Water Level by Far Field Tsunami



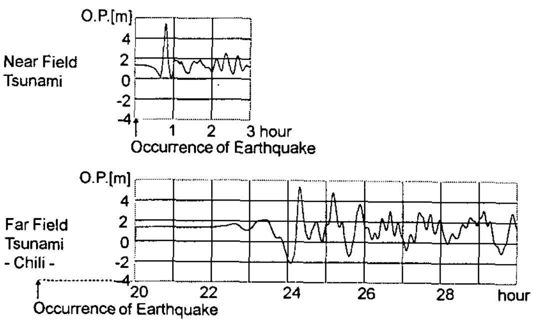



## Minimum Water Level by Far Field Tsunami






## Time History

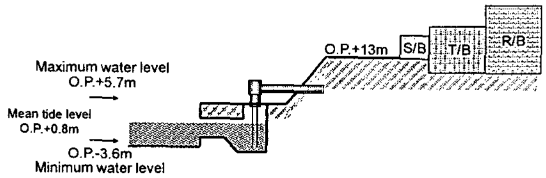





## Summary of Evaluation

Maximum water level = 4.4 + O.P.+1.3 = O.P.+5.7m

Minimum water level = -3.6 – O.P.0.0 = O.P.-3.6m






## Summary of Part A

- The scenario tsunamis can be estimated by the standard fault models taking account of historical tsunamis and seismo-tectonics.
- Uncertainties and errors can be taken account in the process of numerical simulation with parametric study.
- The design tsunami is selected as the greatest influence on the site among scenario tsunamis.
- To make sure of the safety of coastal power plants, the design tsunami is selected as the highest among all historical and possible tsunamis in the future at the site.



## Agenda

Part A

Tsunami assessment method for NPP in Japan

A-1. Deterministic approach by JSCE

A-2. Assessment example

Part B

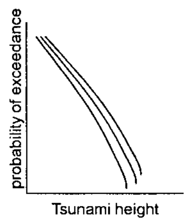
Recent Studies on,

B-1. Probabilistic approach

B-2. Other phenomena due to tsunami

## B-1. Probabilistic approach

- PTHA (Probabilistic Tsunami Hazard Analysis) is a methodology for estimating tsunami hazard curves indicating the relationship between tsunami height and exceedance probability.
- Probabilistic approach is effective and useful when we take into account many uncertainties existing in a process of estimating tsunami heights.

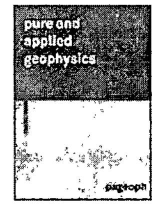





## B-1. Probabilistic approach

Paper

"Logic-tree Approach for Probabilistic Tsunami Hazard Analysis and its Applications to the Japanese Coasts"



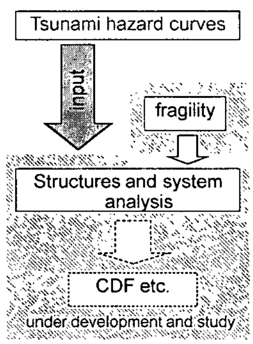

written by the members of Tsunami Evaluation Subcommittee of JSCE

Tadashi Annaka, Kenji Satake, Tsutomu Sakakiyama, Ken Yanagisawa, Nobuo Shuto

Pure and Applied Geophysics, Birkhäuser, vol. 164, no. 2, pp. 577-592



- Tsunami hazard curves are the reasonable input data for structures and system analysis.
- However the evaluation method for estimating fragility of structures and the procedure of system analysis is now being developed.






## Uncertainties

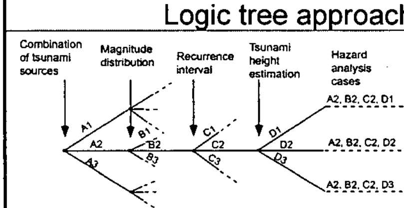
- Aleatory uncertainty
  - Due to the unpredictable random nature
  - A traditional hazard curve is obtained by the integration over the aleatory uncertainties

    Ex) stiffness, strength of material
- Epistemic uncertainty
  - Due to incomplete knowledge and data
  - Using the logic-tree approach

    Ex) the maximum magnitude of earthquake



## Logic tree approach




Weights of branches are determined based on the future probabilities of being truth.

- Branches represent alternative hypotheses, interpretations and the error of estimated parameters
- Questionnaire survey of tsunami and earthquake experts (maximum 35, in this report)

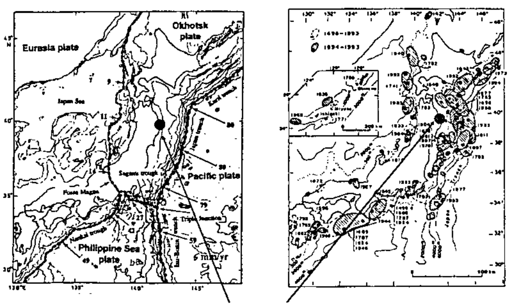


## Tsunami source model

Setting of tsunami source models for probabilistic approach

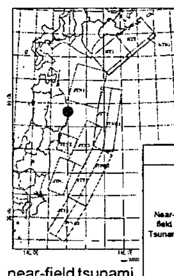
1. Identification of tsunami source zones
   - Near-field tsunami sources
   - Far-field tsunami sources
2. Determination of size and frequency of characteristic tsunami-generating earthquakes
3. Determination of fault models used for numerical tsunami simulation by scaling relations

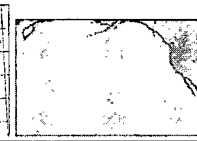
## Plate boundaries and tsunami source areas in and around Japan

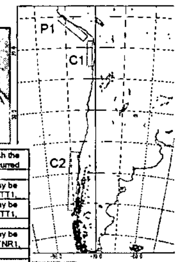





## Setting for distribution and magnitude of tsunami source zones



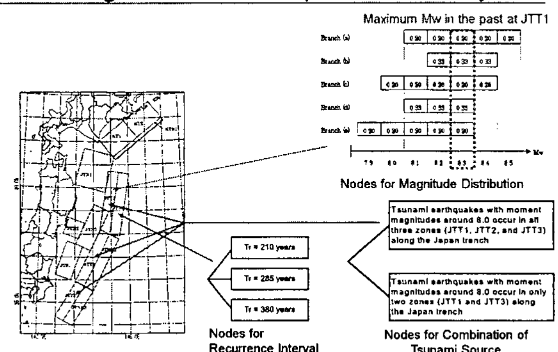






| | | The maximum Mw in the past | Year in which the tsunami occurred |
|---|---|---|---|
| Near-field Tsunami | JTT1 | 8.3 | 1896 |
| | JTT2 | There is no historical record. It may be assumed to be the same Mw as JTT1. | |
| | JTT3 | There is no historical record. It may be assumed to be the same Mw as JTT1. | |
| | JTNR1 | 8.6 | 1611 |
| | JTNR2 | There is no historical record. It may be assumed to be the same Mw as JTNR1. | |
| | JTNR3 | 8.2 | 1677 |
| | JTS1 | 7.9 | 1938 |
| | JTN2 | 7.7 | 1978 |
| | JTN3 | 8.2 | 1793 |
| Far-field Tsunami | P1 | 9.0 | 1868 |
| | C1 | 8.8 | 1877 |
| | C2 | 9.3 | 1960 |



## Setting conditions for plate boundary



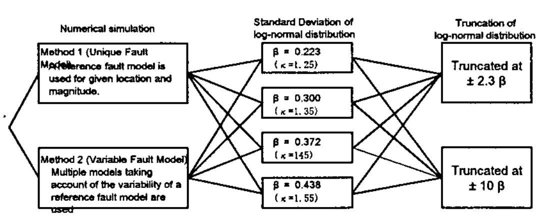



## Tsunami height estimation model

- Numerical simulation would be better for estimating the median tsunami height rather than empirical relation.
- Fault models are determined by scaling relations from the optimal fault models of the historical tsunami-generating earthquakes.
- The optimal fault models were determined based on the comparison between historical tsunami run-up height data and numerical simulation.



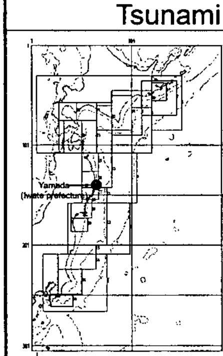
## Logic-tree for Tsunami Height Estimation




- Truncated log-normal distribution is assumed for tsunami-height distribution.



## Tsunami hazard calculation




By combining the tsunami source model and the tsunami height estimation model, we can calculate tsunami hazard curves.

Numerical tsunami simulation:

- 540 near-field tsunami sources
- 75 far-field tsunami sources.

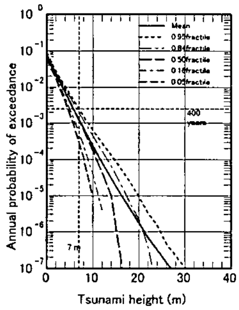
Long-term stationary tsunami hazard:

- Poisson process is assumed.

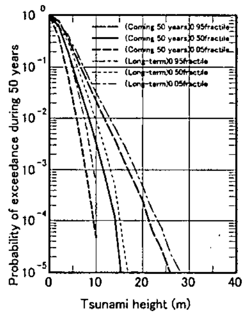
Instantaneous tsunami hazard for the coming 50 years:

- BPT (Brownian Passage Time) distribution is used.

## Tsunami hazard curves




Long-term : Near-field + Far-field




Comparison of fractile hazard curves between the long-term and coming 50 years



## Summary of B-1

- We proposed a logic-tree approach to estimate tsunami hazard curves and present some examples for Japan.
- The proposed method will be used for quantitative assessments of the tsunami risk for important facilities located on coastal area.
- Probabilistic approach method is under study to improve by electric power companies and the results of the study is under discussion in the tsunami evaluation subcommittee of JSCE.



## Agenda

Part A

Tsunami assessment method for NPP in Japan

A-1. Deterministic approach by JSCE

A-2. Assessment example

Part B

Recent Studies on,

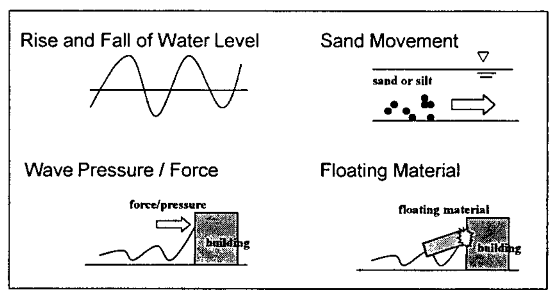
B-1. Probabilistic approach

B-2. Other phenomena due to tsunami



## B-2. Other phenomena due to tsunami

Possible influences to NPP site by tsunami

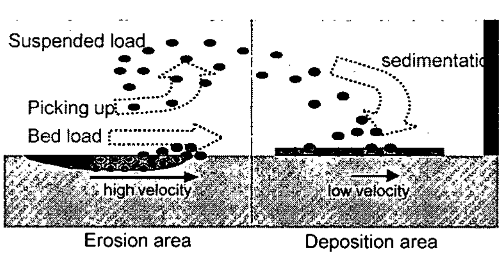





## Sand movement

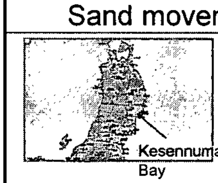
Characteristic of sand movement model

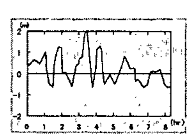
mixing model : Bed load + Suspended load

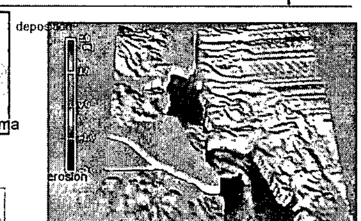





## Sand movement simulation example

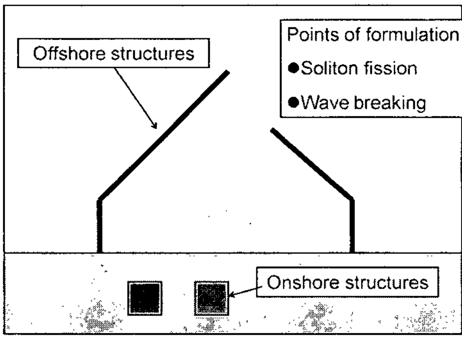





Change of submarine topography at 8 hours 15 minutes after Chilean tsunami arrived in Kesennuma Bay

## Wave pressure distribution formulae

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## Wave pressure distribution formulae

| Wave type | | Offshore | Onshore |
|---|---|---|---|
| WITHOUT Soliton fission | | Tanimoto et al. (1983) long wave approximation of Goda's formula (1973) | Ikeno et al. (2006) |
| Soliton fission | WITHOUT wave breaking | Ikeno et al. (2005) different formula to the one for the wave with wave breaking | Ikeno et al. (2006) additional wave pressure distribution to the one for the wave without soliton fission |
| | Wave breaking | Ikeno et al. (2005) different formula to the one for the wave without wave breaking | |

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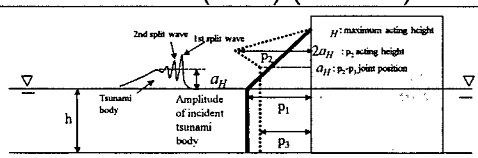
## Ikeno et al. (2005) (offshore)




(1) Wave pressure strength at peak of tsunami force in collision of 1st split wave (occurring at starting point of breaking of 1st split wave)

$p_2=1.2* p_1$

$p_3=0.8* p_1$

(2) Wave pressure strength in formation of standing wave of tsunami body and split waves on and after 2nd wave (occurring after breaking of 1st split wave)

$p_1/(\rho g a_H)=2.0$ ; $0 \leqq h/L \leqq 0.001$

$p_1/(\rho g a_H)=250*(h/L)+1.75$ ; $0.001 \leqq h/L \leqq 0.005$

$p_1/(\rho g a_H)=3.0$ ; $0.005 \leqq h/L$

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## Ikeno et al. (2006) (onshore)

Wave pressure of tsunami body

$P_1(Z)/(\rho g \eta_{max}) = -Z/\eta_{max} + \alpha$

Wave pressure of the wave which soliton fission is predominant

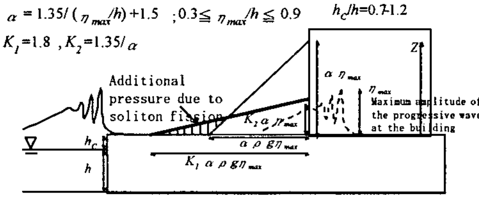
$P_2(Z)/(\rho g \eta_{max}) = K_1(-Z/(K_2 \eta_{max}) + \alpha)$

Wave pressure

$P(Z) = \max(P_1(Z), P_2(Z))$

$\alpha = 1.35/(\eta_{max}/h)+1.5$ ; $0.3 \leqq \eta_{max}/h \leqq 0.9$ $h_c/h=0.7\text{-}1.2$

$K_1=1.8$ , $K_2=1.35/\alpha$

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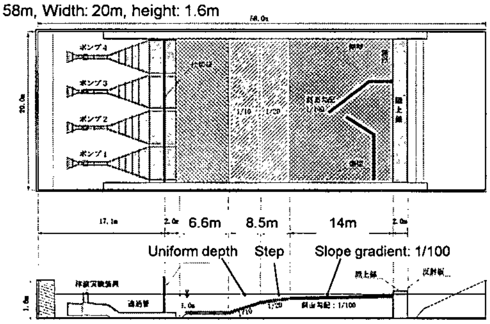
## Experiment of floating material

Flat water tank
Length: 58m, Width: 20m, height: 1.6m

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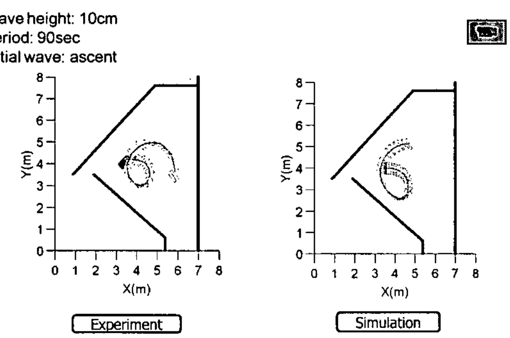
## Comparison with simulation

Wave height: 10cm
Period: 90sec
Initial wave: ascent

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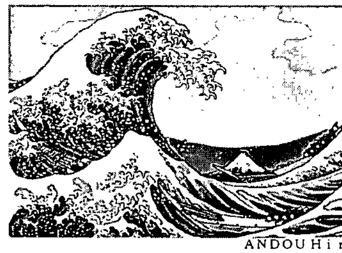
## Summary of B-2

- Evaluation methods for other tsunami phenomena are now under study and development.
- Results of the studies conducted by TEPCO or electric power companies are being discussed in the tsunami evaluation subcommittee of JSCE.



## End

Thank you very much for your kind attention.



ANDOU Hiroshige



# Appendix 1



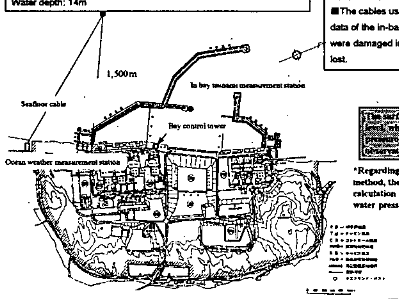
Report of Tsunami Measurement Records at Kashiwazaki-Kariwa NPS during Niigataken Chuetsuoki earthquake on July 16, 2007



## Location of Wave Observation Equipment at Kashiwazaki-Kariwa NPS

Outside bay wave observation equipment (ocean weather gage)
East longitude: 138° 34' 47"
North latitude: 37° 25' 39"
Water depth: 14m

■ Surface waves and water pressure are measured by outside-bay wave observation equipment (ocean weather gage)
■ The cables used for transmitting and receiving data of the in-bay wave observation equipment were damaged in the earthquake and data was lost.




The surface wave and tsunami water level, which is calculated from the water pressure using the outside-bay wave observation equipment.

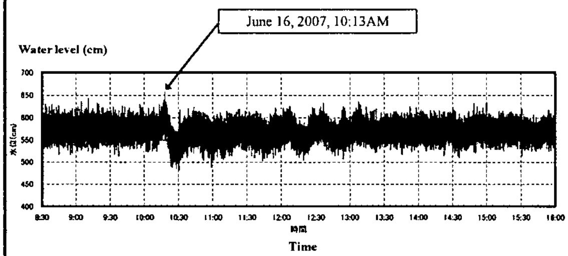
*Regarding the tsunami water level measurement method, the surface wave is indicated but calculation is made with the same method for water pressure.



## Measurement Specifications

| Surface Wave (outside-bay ocean measurement gauge) | |
|---|---|
| Start time | 00:10:00, July 16, 2007 |
| Stop time | 00:09:59.5, July 17, 2007 |
| Data sample | 500ms (0.5 sec) |
| Amount of data | 172,800 |

## Measurement Results




Measurement record waveform (surface wave)



## Extraction of Tsunami Waveform (Processing Flow)

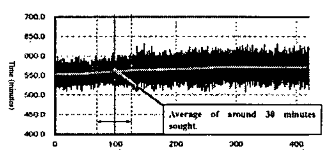
Original Waveform
↓
Baseline Correction
↓
High Cut Processing
↓
Tsunami Waveform



## Extraction of Tsunami Waveform (Baseline Correction)

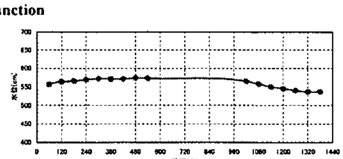
**Setting baseline by moving-average**

Baseline is set by calculating the average of the data for 30 minutes before and after the time of the target point.




**Setting baseline using spline function**

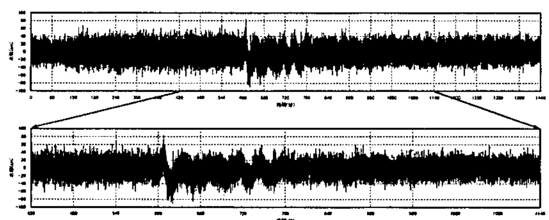
Baseline is set by the spline function, using the data excluding those for 600 minutes after the earthquake, which is considered as the main motion of a tsunami.





## Extraction of Tsunami Waveform (Baseline Correction)

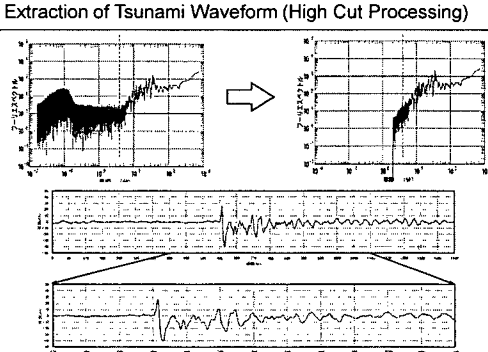
Waveform before Baseline Correction (in the case of Surface Wave)



Waveform after Baseline Correction (in the case of Surface Wave)



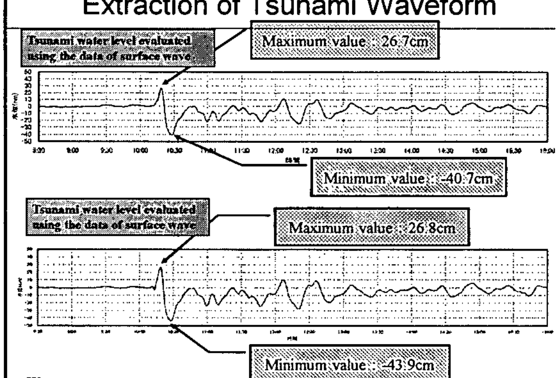
## Extraction of Tsunami Waveform (High Cut Processing)



Waveform after High Cut Processing



## Extraction of Tsunami Waveform



## Summary

- In the Niigata-Chuetsu-Oki Earthquake, outside the bay attached to the power station, it is observed that the tsunami has a maximum water level rise of about 27cm and a maximum water level drop of around 40cm, and it did not affect the station.
- Further analysis of tsunamis are to be conducted, considering the source models being studied by various research institutions and the tsunami measurement records obtained this time.

(Reference)

| Time | Estimated max. water level (m) | Estimated min. water level (m) |
|---|---|---|
| At time of building permit | T.P.+3.7m | T.P.-3.4m |
| Evaluation using Japan Society of Civil Engineers' evaluation method (2002) | T.P.+3.5 ~ +3.7m | T.P. -2.9 ~ -3.5m |



# Appendix 2



## Reliability of Numerical Simulation (1)

Aida's indexes K and κ (1977)

K : geometric average , κ : variance

$K_i = \frac{R_i}{H_i}$ where $R_i$ : recorded tsunami height at point i, $H_i$ : calculated tsunami height at point i

$$\log K = \frac{1}{n}\sum_{i=1}^{n}\log K_i \qquad \log \kappa = \left[\frac{1}{n}\left\{\sum_{i=1}^{n}(\log K_i)^2 - n(\log K)^2\right\}\right]^{1/2}$$

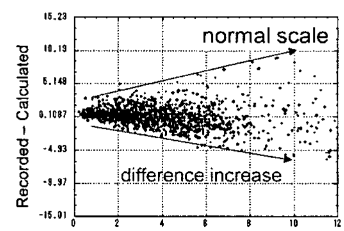
$0.95 < K < 1.05,\ \kappa < 1.45$

- Apply Non-linear Long Wave Theory
- Carry out Run-up Analysis
- By Using Finite Difference Method



## Reliability of Numerical Simulation (2)

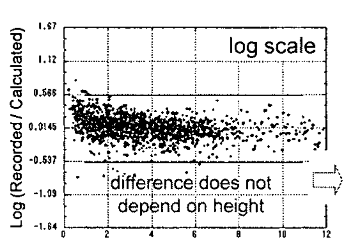
Difference between recorded tsunami heights and calculated tsunami heights






## Reliability of Numerical Simulation (3)

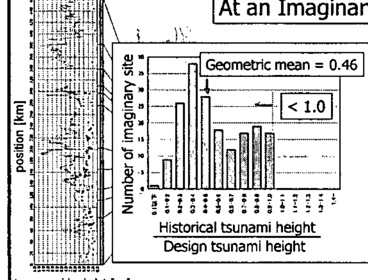
Difference between recorded tsunami heights and calculated tsunami heights




Aida's index is appropriate



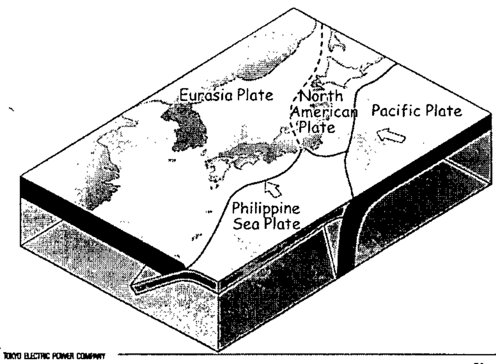
At an Imaginary Site




If the design tsunami height exceeds all the recorded & calculated historical tsunami heights at the imaginary site.

The Design Tsunami is fixed

## Plates around Japan

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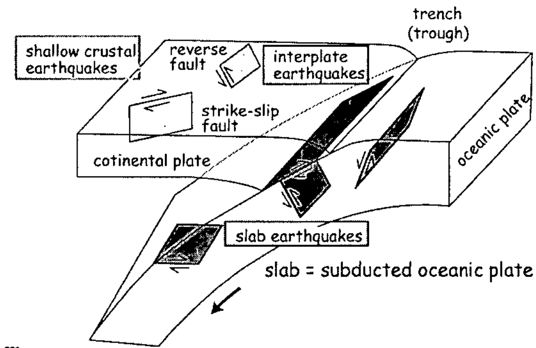
## Earthquake types in and around Japan

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## Bensi, Michelle

**From:** Kauffman, John
**Sent:** Tuesday, March 22, 2011 10:34 AM
**To:** Beasley, Benjamin
**Cc:** Bensi, Michelle; Ibarra, Jose; Killian, Lauren; Lane, John; Reisifard, Mehdi; Perkins, Richard; Smith, April
**Subject:** OEGIB Weekly Activities Summary for 3/14-18/2011

Ben,
Please see below. JVK

**OEGIB Weekly Activities (3/14-18/2011)**

**Generic Issues**

John K.

- Supported/participated with RI phonecon with local officials around IP to discuss seismic issues/GI-199.
- Manned Ops Ctr on Saturday night midnight shift.
- Reviewed dam issue screening evaluation and provided comments.
- Discussed TEC-01 with Mary, Ben, and Jose.
- Supported OPA by working on responses to MSNBC reporter (Dedmon) questions on GI-199 S/RA.
- Provided seismic contacts to RI State Liaison Officer (McNamara).
- Assisted Jeanne Dion with information on mods to BWRs in support of senior management presentations/speeches.
- Responded to Steve Jones questions on documenting completion of GIs.

Jose

- Performed TA functions including participating in the weekly meetings. Collected RIC feedback on lesions learned and sent the information to PMDA. Collected and compiled DRA list of staff to man the IRC during the Japan nuclear emergency. This effort also identified the staff available to go to Japan. Started reviewing the last Info Digest in order to update the information. Reported to the branch the highlights of the weekly RES meeting.

Shelby

- Course: Westinghouse Technology Overview (R-104P) (Mon-Fri)
- Final touches on screening report related to flooding due to upstream dam failure

Lauren

- Completed 3 PM training courses: Negotiating Project Terms and Conditions (#5), Developing Proposal Evaluation Factors (#3), Source Evaluation Panel Procedures (#4)
- GIMCS Q2 Report: followed-up with GIP POCs about GIMCS inputs, worked on memo, drafted distribution lists helpful-hints document for later GIMCS reports
- Japanese events: monitored and addressed GI-199 related queries from management, will call in to Fri. All-Hands meeting bridge line

Richard

- Completed final draft of dam failure analysis report



TT/30

Mehdi

- NUREG-0933 Technology Update: Participated in NUREG-0933 Business Analysis meetings.
- NOTE 5 issues: Completed a draft of the memo for administratively closing NOTE 5 issues. Received comments from Ben and made the changes. Prepared the memo for review by Doug Coe.
- Data.gov project: Continued working on the table.
- GI-193: Reviewed part of the Purdue test results, followed up on the status of the communications plan review by John L.
- LOW priority issues memo: Followed up on the status of the package that had been sent to Office Director for approval. Memo has been approved with two minor comments, which will be incorporated today or next week.

April

- Attended OIS business analysis meetings w/ B. Beasley, and M. Reisifard on NUREG-0933 improvement (3/14, 3/15)
- Revised the Generic Issues Program pamphlet
- Attended PM training 3/15
- Coordinated plans for Pre-GI report
- Out of office 3/17 – 3/18

Next Week (3/21-25/2011) (Planned Activities)

John K.

- Provide mid-year input.
- Continue supporting GI-199 communications issues.

Jose (no items noted)

Shelby

- Review common cause failure documents
- Attend Common Cause Failures Workshop

Lauren

- Finish GIMCS FY2011 Q2 memo and report
- Compose GIP input for report to Congress
- Generic Issues Program promotion: review brochure updates, lead meeting on Taglines
- Out Friday (CREDU)

Richard

- Schedule and prepare for briefings to GIRP
- Receive comments on report from Joe Zable and resolve those
- Coordination and discussion with the GI submitters on status
- Prepare for joint branch meeting presentation
- Work on GI Input form

Mehdi

- Continue working on the table for Data.gov.
- Continue working on the NOTE 5 memo.
- CHU on Friday 03/25.

April
- Out of office 3/21 – 3/23
- Attend Generic Issues Program promotion meeting
- Complete draft of Pre-GI report
- Continue revision of TEC-002

**GI Meetings (not mentioned above)**
None

**<u>Operating Experience</u>**

John L.
- Data:
  --forwarded SUNSI review of SRV report in preparation for publishing
  --issued Office Director memo to NRR announcing NUREG/CR-7037
  --provided some input to on-going issue resolution in Japan
- GI-193
  --received final report from Purdue PUMA facility; put into ADAMS; began review

Larry
- AL

Art
- Incremental funding request for N6884, IROD project with ISL
- Incremental funding requests for INL projects are being prepared
- Continued review of background material for hierarchical Bayesian updates, including material on Bayesian inference and general Bayes theory.
- OEGIB meeting
- LMPC meeting
- 3WFN Occupant Team meeting
- Reviewed specific drift analysis calculations for Oconee; provided comments/questions to NRR for resolution prior to preparation of SAR

Mary
**Ongoing major events:**
**Crystal River 3**
Tensioning is on hold. After completion of the first sequence (sequence 100 of 112) of Pass 11, the acoustic monitors at the upper level of Bay 5-6 began picking up a noise signal. The noise signals transitioned downward to the lower acoustic monitors. The signals from the three embeded strain gages in Bay 5-6 slowly increase then failed. Workers on the containment roof heard popping sounds. Workers outside of Bay 5-6 heard noise coming from the containment. The licensee implemented their contingency plan. Impulse response (IR) testing is ongoing and should be completed later on March 15. Laser scan measurements inside containment were completed last night. Preliminary IR results indicate a delamination in Bay 5-6 of which the extent is not yet determined. Bay 5-6 is adjacent to the spent fuel pool and contains the two transfer tubes. For the current Mode, containment integrity only relies on an intact containment liner. There is currently no impact on the spent fuel pool, however the licensee is still reviewing any potential impacts to the pool. The inspectors walked down the outside of Bay 5-6 and did not see any noticeable cracking. The inspectors will follow-up on the licensee's review with respect to the spent fuel pool.
Additional Details: Unlike the Bay that delaminated in 2009, Bay 5-6 is adjacent to the auxiliary building's spent fuel pool and contains the two transfer tubes. This will increase the difficulty associated with repairs. See attached photos. For the current Mode, containment integrity relies only on an intact containment liner. The

liner was inspected with no problems noted. There is currently no impact on the spent fuel pool. The inspectors walked down the outside of Bay 5-6 and did not see any noticeable cracking.

**Current Events: Earthquake in Japan**
Fukushima Daiichi units 1, 2, and 3

Next Week (3/21-25/2011) (Planned Activities)

John L.
- Sunday—Ops Center (7 am-3 pm)
- Tuesday-Fri: Common Cause Workshop

Larry (no input)

Art
- CCF workshop

Mary
- Continue OpE.

**OpE Meetings (not mentioned above)**
None

## Bensi, Michelle

**From:** Kammerer, Annie
**Sent:** Tuesday, March 22, 2011 6:56 PM
**To:** Bensi, Michelle
**Subject:** RE: updated file (with changes listed)

Thanks!!!!!!

---

**From:** Bensi, Michelle
**Sent:** Tuesday, March 22, 2011 6:12 PM
**To:** Kammerer, Annie
**Subject:** updated file (with changes listed)

Hi Annie,

I have attached the updated document with changes tracked as you requested. I have included a comment for each change so you know why I made the change and where I got the information. You should be able to "page-down" the document looking for my comments and accept/reject the associated changes. I have primarily been "dumping data" from various sources. I have not done any significant editing.

The changes that have been made are:

### Changes made on Monday (3/21):

- Replaced questions #11 and #91
- Added PGA contour map (without location of plants on the map)
- Added B.5.b fact sheet (unedited from text used in Commission Document)
- Stephanie is currently compiling the definition list. I will add to it if necessary and put it in the Q&A document tomorrow.

### Changes made on Tuesday (3/22):

- Added question (#18) regarding "mega-tsunami" on east coast of the US.
- Added new information from TEPCO (via update on NEI website) related to estimates for tsunami water height relative to the design basis height. This quote also lists the design basis earthquake magnitude. Both the inundation wave height and the DBE magnitude conflict with information contained in other questions. See question #63.
- Added GI-199 factsheet based on information from the Commission Briefing document.
- Added station blackout rule fact sheet using information contained in the Commission Briefing document. Additionally, the abstract for NUREG/CR-6890, "Reevaluation of Station Blackout Risk at Nuclear Power Plants" has been added based on a reference made by Scott Burnell in a email exchange with a reporter. I have not had an opportunity to go through the details of that NUREG/CR and do not know its applicability.
- Added SOARCA Q&A based on information contained in the Commission Briefing document
- Added PGA k-net map with plant locations (figure from Annie)
- Added a spent fuel pools section to the document. The questions contained in the section are taken from other sections of the report, the Commission Briefing document, and the answer emailed from Randy Hall.
- Added updated definition list
- Added placeholder for including fact sheet on the Japanese approach to tsunami assessment



TT\31\

## Remaining tasks:

- Create factsheet on the current Japanese approach to tsunami (ML110770010)
    1. Note: JSCE is currently finalizing guidance PTHA (= prob tsunami hazard analysis) for Japan
    2. Add information from TEPCO tsunami presentation
- Create a factsheet using the ICAPP presentation (seismic considerations of WUS)
- Stephanie is working on a document with the acronyms. When she's done, I will add it.
- Look at Wikipedia page for images that could be added long term (e.g. add to fact sheet) http://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami

## Question:

- Is there is any information in the document "Summary of seismological information from regional instrumentation" that needs to be added?

# Compiled Seismic Questions for NRC Response to the March 11, 2011 Japanese Earthquake and Tsunami

**This is current as of 3-22-11 at 10 pm.**

***The keeper of this file is Annie Kammerer. Please provide comments, additions and updates to Annie with CC to Clifford Munson, Jon Ake and Michelle Bensi.***

***A SharePoint site has been set up so that anyone can download the latest Q&As. The site is found at NRC>NRR>NRR TA or at*** ***http://portal.nrc.gov/edo/nrr/NRR%20TA/FAQ%20Related%20to%20Events%20Occuring%20in%20Japan/Forms/AllItems.aspx***

***A list of topics is shown in the Table of Contents at the front of this document.***

***A list of all questions is provided at the end of the document.***

***A list of terms and definitions is included at the end of the document.***

*We greatly appreciate the assistance of the many people who have contributed to this document. Please do not distribute beyond the NRC.*



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# CONTENTS

# Natural Hazards and Ground Shaking Design Levels

### 1) Does the NRC consider earthquakes of magnitude 9?

**Public response:** This earthquake was caused by a "subduction zone" event, which is the type of earthquake that can produce the largest magnitudes. A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington. As a result, magnitude 9 events would only be considered for this particular seismic source. The NRC requires all credible earthquakes that may impact a site to be considered.

**Additional, technical, non-public information:** None.

### 2) Did the Japanese underestimate the size of the maximum credible earthquake that could affect the plants?

**Public response:** The magnitude of the earthquake was somewhat greater than was expected for that part of the subduction zone. However, the Japanese nuclear plants were recently reassessed using ground motion levels similar to those that are believed to have occurred at the sites. The ground motions against which the Japanese nuclear plants were reviewed were expected to result from earthquakes that were smaller, but were much closer to the sites. The NRC does not currently have information on the maximum tsunami height that was expected at the sites.

**Additional, technical, non-public information:** Jon Ake is doing some review of the data to determine the likely return period of this motion.

### 3) Can an earthquake and tsunami as large as happened in Japan also happen here?

**Public response:** See below.

### 4) What if an earthquake like the Sendai earthquake occurred near a US plant?

**Public response:** This earthquake occurred on a "subduction zone", which is the type of tectonic region that produces earthquakes of the largest magnitude. A subduction zone is a tectonic plate boundary where one tectonic plate is pushed under another plate. Subduction zone earthquakes are also required to produce the kind of massive tsunami seen in Japan. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington. So, a continental earthquake and tsunami as large as in Japan could only happen there. The only nuclear plant near the Cascadia subduction zone is the Columbia Generating Station. This plant is located a large distance from the coast (approximately 225 miles) and the subduction zone (approximately 300 miles), so the ground motions estimated at the plant are far lower than those seen at the Fukushima plants. This distance also precludes the possibility of a tsunami affecting the plant. Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximately 8. Magnitude is measured on a log scale and so a magnitude 9 earthquake produces about ten times stronger shaking and releases about 31 times more energy than a magnitude 8 earthquake.

**Additional, technical, non-public information:** None.

### 5) What magnitude earthquake are US nuclear plants designed to?

**Public Answer:** Ground motion is a function of both the magnitude of an earthquake and the distance from the fault to the site. Nuclear plants, and in fact all engineered structures, are actually designed based on ground motion levels, not earthquake magnitudes. The existing nuclear plants were designed based on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquakes expected in the area around the plant. A margin is further added to the predicted ground motions to provide added robustness.

**Additional, technical non-public information:** In the past, "deterministic" or "scenario based" or "maximum credible earthquake" analyses were used to determine ground shaking (seismic hazard) levels. Seismic hazard for the new plants is determined using a probabilistic seismic hazard assessment approach that explicitly addresses uncertainty and the potential for beyond-design-basis earthquakes, as described in Regulatory Guide 1.208. Probabilistic methods account for possible earthquakes of various magnitudes that come from potential sources (including background seismicity) and the likelihood that each particular hypothetical earthquake occurs. The ground motions that are used as seismic design bases at US nuclear power plants are called the Safe Shutdown Earthquake ground motion (SSE) and are described mathematically through use of a response spectrum. On the west coast of the US, the two nuclear power plants are designed to specific ground motions that are determined from earthquakes of about magnitude 7 (SONGS) and 7.5 (Diablo) on faults located just offshore of the plants. Because the faults are well characterized, the magnitude and distances are known. However the design and licensing bases are still the ground motions...not the earthquakes. The earthquakes on these faults are mainly strike-slip (horizontal motion) type earthquakes, not subduction zone earthquakes. Therefore, the likelihood of a tsunami from these faults is remote.

The NRC also requires that adequate margin beyond the design basis ground shaking levels is assured. The NRC further enhances seismic safety for beyond-design-basis events through the use of a defense-in-depth approach. In addition, the NRC reviews the seismic risk at operating reactors as needed when information may have changed. Over the last few years the NRC has undertaken a program called Generic Issue 199, which is focused on assessing hazard for plants in the central and eastern US using the latest techniques and data and determining the possible risk implications of any increase in the anticipated ground shaking levels. This program will help us assure that the plants are safe under exceptionally rare and extreme ground motions that represent beyond-design-basis events.

### 6) How many US reactors are located in active earthquake zones?

**Public Answer:** Although we often think of the US as having "active" and "non-active" earthquake zones, earthquakes can actually happen almost anywhere. Seismologists typically separate the US into low, moderate, and high seismicity zones. The NRC requires that every nuclear plant be designed for site-specific ground motions that are appropriate for their locations. In addition, the NRC has specified a minimum ground motion level to which nuclear plants must be designed.

**Additional, technical non-public information:** The preliminary consensus opinion by NRC staff is that there are approximately 9 plants in the moderate seismicity zones in the CEUS: 4 or 5 in the Charleston SZ (depending on whose interpretation you use, it varies widely), 1 in the Wabash valley SZ, 2 in the East Tennessee SZ, 1 in the Central Virginia SZ. But some of these are open to interpretation and debate. This does not have a simple answer and NRC seismic staff are developing a fact sheet to respond to this question. There are also two plants that are in highly seismicity areas of California. Unfortunately, the extent of the moderate seismicity zones in the US are open to interpretation and are a matter of scientific debate.

Please note that although the earthquakes in the CEUS are rare, they can be big. The most widely felt earthquakes within the continental US were the 1811-12 New Madrid sequence and the 1886 Charleston, SC, which were estimated to be between about magnitude 7.0 to 7.75.

**7) Has this changed our perception of earthquake risk to the plants in the US?**

**Public Answer:** The NRC continues to determine that US nuclear plants are safe. This does not change the NRC's perception of earthquake hazard (i.e., ground motion levels) at US nuclear plants. It is too early to tell what the lessons from this earthquake are. The NRC will look closely at all aspects of response of the plants to the earthquake and tsunami to determine if any actions need to be taken in US nuclear plants and if any changes are necessary to NRC regulations.

**Additional, technical, non-public information:** We expect that there would be lessons learned and we may need to seriously relook at common cause failures, including dam failure and tsunami.

**8) Why do we have confidence that US nuclear power plants are adequately designed for earthquakes and tsunamis?**

**Public Answer:** [use the first paragraph of the response below]

**Additional, technical, non-public information:** None.

**9) Can significant damage to a nuclear plant like we see in Japan happen in the US due to an earthquake? Are the Japanese nuclear plants similar to US nuclear plants?**

**Public Answer:** All US nuclear plants are built to withstand environmental hazards, including earthquakes and tsunamis. Even those nuclear plants that are located within areas with low and moderate seismic activity are designed for safety in the event of such a natural disaster. The NRC requires that safety-significant structures, systems, and components be designed to take into account even rare and extreme seismic and tsunami events. In addition to the design of the plants, significant effort goes into emergency response planning and accident management. This approach is called defense-in-depth.

The Japanese facilities are similar in design to some US facilities. However, the NRC has required modifications to the plants since they were built, including design changes to control hydrogen and pressure in the containment. The NRC has also required plants to have additional equipment and measures to mitigate damage stemming from large fires and explosions from a beyond-design-basis event. The measures include providing core and spent fuel pool cooling and an additional means to power other equipment on site.

**Additional technical, non-public information:** See notes under question "What magnitude earthquake are US nuclear plants designed to?"

**10) If the earthquake in Japan was a larger magnitude than considered by plant design, why can't the same thing happen in the US?**

**Public response:** *Discuss in terms of, IPEEE, Seismic PRA to be provided by Nilesh*

**Additional, technical, non-public information:** ADD

**11) What level of earthquake hazard are the US reactors designed for?**

**Public Answer:** Each reactor is designed for a different ground motion that is determined on a site-specific basis. The existing nuclear plants were designed on a "deterministic" or "scenario earthquake" basis that accounts for the largest earthquakes expected in the area around the plant, without consideration of the likelihood of the earthquakes considered, and with an additional factor applied for conservatism. New reactors are designed using probabilistic techniques that characterize both the ground motion levels and uncertainty at the proposed site. These probabilistic techniques account for the ground motions that may result from all potential seismic sources in the region around the site.

Technically speaking, this is the ground motion with an annual frequency of occurrence of $1x10^{-4}$/year, but this can be thought of as the ground motion that occurs every 10,000 years on average. One important aspect is that probabilistic hazard and risk-assessment techniques account for beyond-design basis events. NRC's Generic Issue 199 (GI-199) project is using the latest probabilistic techniques used for new nuclear plants to review the safety of the existing plants. [see questions in the section about GI-199 for more information]

**Additional technical, non-public information:** Note to OPA: This may perhaps seem like an oddly worded general question because the word "hazard" has several meanings, but in fact it is a specific technical question. If you see "earthquake hazard levels" or similar language, check with the seismic staff.

### 12) How was the seismic design basis for existing nuclear plants established?

**Public Answer:** The seismic ground motions used for the design basis of existing nuclear plants were determined from the evaluation of the maximum historic earthquake within 200 miles of the site, without explicitly considering the time spans between such earthquakes; safety margin was then added beyond this maximum historic earthquake to form a hypothetical *design basis earthquake.* The relevant regulation for currently operating plants is 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-appa.html).

**Additional, technical, non-public information:** None.

### 13) What is the likelihood of the design basis or "SSE" ground motions being exceeded over the life of a nuclear plant?

**Public response:** The ground motions that are used as seismic design bases at US nuclear plants are called the Safe Shutdown Earthquake ground motion (SSE). In the mid to late 1990s, the NRC staff reviewed the potential for ground motions beyond the design basis as part of the Individual Plant Examination of External Events (IPEEE). From this review, the staff determined that seismic designs of operating nuclear plants in the US have adequate safety margins for withstanding earthquakes. Currently, the NRC is in the process of conducting GI-199 to again assess the resistance of US nuclear plants to earthquakes. Based on NRC's preliminary analyses to date, the mean probability of ground motions exceeding the SSE over the life of the plant for the plants in the Central and Eastern United States is less than about 1%.

It is important to remember that structures, systems and components are required to have "adequate margin," meaning that they must continue be able withstand shaking levels that are above the plant's design basis.

**Additional technical, non-public information:** There is a section of this document focused on questions related to GI-199.

### 14) What is magnitude anyway? What is the Richter Scale? What is intensity?

**Public Answer:** An earthquake's magnitude is a measure of the strength of the earthquake as determined from seismographic observations. Magnitude is essentially an objective, quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, Surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the most commonly used magnitude measurement is the Moment Magnitude, Mw, which is based on the strength of the rock that ruptured, the area of the fault that ruptured, and the average amount of slip. Moment magnitude is, therefore, a direct measure of the energy released during an earthquake. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology and was based on the behavior of a specific seismograph that was manufactured at that time. The instruments are no longer in use and the magnitude scale is, therefore, no longer used in the technical community. However, the Richter Scale is a term that is so commonly used by the public that scientists generally just answer questions about "Richter" magnitude by substituting moment magnitude without correcting the misunderstanding.

The intensity of an earthquake is a qualitative assessment of effects of the earthquake at a particular location. The intensity assigned is based on observed effects on humans, on human-built structures, and on the earth's surface at a particular location. The most commonly used scale in the US is the Modified Mercalli Intensity (MMI) scale, which has values ranging from I to XII in the order of severity. MMI of I indicates an earthquake that was not felt except by a very few, whereas MMI of XII indicates total damage of all works of construction, either partially or completely. While an earthquake has only one magnitude, intensity depends on the effects at each particular location.

**Additional, technical non-public information:** None.

### 15) How do magnitude and ground motion relate to each other?

**Public Answer:** The ground motion experienced at a particular location is a function of the magnitude of the earthquake, the distance from the fault to the location of interest, and other elements such as the geologic materials through which the waves pass.

**Additional, technical non-public information:** None.

### 16) Which reactors are along coastal areas that could be affected by a tsunami?

**Public Answer:** Many nuclear plants are located in coastal areas that could potentially be affected by a tsunami. Two nuclear plants, Diablo Canyon and San Onofre, are on the Pacific Coast, which is known to have a tsunami hazard. Two nuclear plants on the Gulf Coast, South Texas and Crystal River, could also be affected by tsunami. There are many nuclear plants on the Atlantic Coast or on rivers that may be affected by a tidal bore resulting from a tsunami. These include St. Lucie, Turkey Point, Brunswick, Oyster Creek, Millstone, Pilgrim, Seabrook, Calvert Cliffs, Salem/Hope Creek, and Surry. Tsunami on the Gulf and Atlantic Coasts occur, but are very rare. Generally the flooding anticipated from hurricane storm surge exceeds the flooding expected from a tsunami for nuclear plants on the Atlantic and Gulf Coast. Regardless, all nuclear plants are designed to withstand a tsunami.

**Additional, technical non-public information:** A table with information on tsunami design levels is provided in the "Additional Information" section of this document.

### 17) How are combined seismic and tsunami events treated in risk space? Are they considered together?

The PRA Standard (ASME/ANS-Ra-Sa2009) does address the technical requirements for both seismic events and tsunamis (tsunami hazard under the technical requirements for external flooding analysis). But together? The standard does note that uncertainties associated with probabilistic analysis of tsunami hazard frequency are large and that an engineering analysis can usually be used to screen out tsunamis.

### 18) How are aftershocks treated in terms of risk assessment?

Seismic PRAs do not consider the affect of aftershocks since there are not methods to predict equipment fragility after the first main shock.

### 19) Could a "mega-tsunami" strike the U.S. East Coast as indicated in a recent Washington Post Weather Gang article?

Public Answer: Please verify information before public release.

**Additional, technical, non-public information:** The Washington Post Weather Gang article is based on a scenario involving a mega-tsunami caused by a massive landslide in the Canary Islands. This scenario has been debunked by the scientific community (including the NRC's tsunami research program). Volcanic flank failures on the Canary Islands will produce a mega-tsunami in the very near area, but won't be noticeable in the United States. Refer to the 2008 USGS report on tsunamis for additional information: [insert citation].

## Design Against Natural Hazards & Plant Safety in the US

### 20) Are US nuclear plants designed for tsunamis? If so, what level of tsunami are they designed for?

**Public Answer:** Yes. Plants are built to withstand a variety of environmental hazards and those plants that might face a threat from tsunami are required to withstand large waves and the maximum wave height at the intake structure (which varies by plant.) Like seismic hazard, the level of tsunami that each plant is designed for is site-specific and is appropriate for what may occur at each location. [See table with tsunami design heights in Tables section of document]

**Additional, technical, non-public information:** Tsunami are considered in the design of US nuclear plants. Nuclear plants are designed to withstand flooding from not only tsunami, but also hurricane and storm surge; therefore there is often significant margin against tsunami flooding. However, it should be noted that Japanese experience (prior to the March 2011 earthquake) has shown that drawdown can be a significant problem.

Currently the US NRC has a tsunami research program that is focused on developing modern hazard assessment techniques and additional guidance through cooperation with the National Oceanic and Atmospheric Administration and the United States Geological Survey. This has already lead to several technical reports and an update to NUREG 0-800. The NOAA and USGS contractors are also assisting with NRO reviews of tsunami hazard. A new regulatory guide on tsunami hazard assessment is currently planned in the office of research, although it is not expected to be available in draft form until 2012.

### 21) Is there a minimum earthquake shaking that nuclear plants designed for?

**Public Answer:** Yes. According to Appendix S to 10 CFR Part 50, the foundation level ground motion must be represented by an appropriate response spectrum with a peak ground acceleration of at least 0.1g.

**Additional, technical, non-public information:** NOTE TO OPA: this comes straight from RG1.208 and it, therefore, approved for public release. If you get this question, we can help make it more user friendly.

### 22) Which plants are close to known active faults? What are the faults and how far away are they from the plants?

**Public Answer:** Jon to develop answer with Dogan's help. I created a placeholder table for your use "Table of Plants Near Known Active Faults" to be populated in the additional information section. The plots that Dogan made are in the additional information section under "Plot of Mapped Active Quaternary Faults and Nuclear Plants in the US".

**Additional, technical, non-public information:** ADD

### 23) Is there margin above the design basis?

**Public Answer:** Yes, there is margin beyond the design basis. In the mid to late 1990s, NRC staff reviewed the plants' assessments of potential consequences of severe earthquakes (earthquakes beyond the safety margin included in each plant's design basis), which licensees performed as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

**Additional, technical, non-public information:** None.

### 24) Are US plants safe? Would a plant in the U.S. be able to withstand a large earthquake?

**Public Answer:** US plants are designed for appropriate earthquake shaking levels that are based on historical data for the site plus additional margin to account for uncertainties. Currently, the NRC is conducting a program called Generic Issue 199, which is reviewing the adequacy of the earthquake design of US NPPs in central and eastern North America based on the latest data and analysis techniques. The NRC will look closely at all aspects of the response of the plants in Japan to the earthquake and tsunami to determine if any actions need to be taken in US plants and if any changes are necessary to NRC regulations.

**Additional, technical, non-public information:** None.

### 25) Could an accident sequence like the one at Japan's Fukushima Daiichi nuclear plants happen in the US?

**Public response:** It is difficult to answer this question until we have a better understanding of the precise problems and conditions that faced the operators at Fukushima Daiichi. We do know, however, that Fukushima Daiichi Units 1-3 lost all offsite power and emergency diesel generators. This situation is called "station blackout." US nuclear power plants are designed to cope with a station blackout event that involves a loss of offsite power and onsite emergency power. The Nuclear Regulatory Commission's detailed regulations address this scenario. US nuclear plants are required to conduct a "coping" assessment and develop a strategy to demonstrate to the NRC that they could maintain the plant in a safe condition during a station blackout scenario. These assessments, proposed modifications to the plant, and operating procedures were reviewed and approved by the NRC. Several plants added additional AC power sources to comply with this regulation.

In addition, US nuclear plant designs and operating practices since the terrorist events of September 11, 2001, are designed to mitigate severe accident scenarios such as aircraft impact, which include the complete loss of offsite power and all on-site emergency power sources.

US nuclear plant designs include consideration of seismic events and tsunamis'. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations.

**Additional technical, non-public information:** None

### 26) Should US nuclear facilities be required to withstand earthquakes and tsunamis of the kind just experienced in Japan? If not, why not?

**Public response:** US nuclear reactors are designed to withstand an earthquake equal to the most significant historical event or the maximum projected seismic event and associated tsunami without any breach of safety systems.

The lessons learned from this experience must be reviewed carefully to see whether they apply to US nuclear power plants. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards, however. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations.

The United States Geological Survey (USGS) conducts continuous research of earthquake history and geology, and publishes updated seismic hazard curves for various regions in the continental US. These curves are updated approximately every six years. NRC identified a generic issue (GI-199) that is currently undergoing an evaluation to assess implications of this new information to nuclear plant sites located in the central and eastern United States. The industry is working with the NRC to address this issue.

**Additional technical, non-public information:** None

### 27) Do any plants have special design considerations associated with seismic design?

**Public response:** Many plants have unique features. However, the most notable design element is the automatic reactor trip systems in Diablo Canyon and San Onofre.

**Additional, technical, non-public information:** None

### 28) How do we know equipment will work if the magnitude is bigger than expected, like in Japan?

**Public response:** [see below]

### 29) How do we know that the equipment in plants is safe in earthquakes?

**Public response:** All equipment important to safety (required to safely shutdown a nuclear power plant) has significant seismic margin and is qualified to withstand earthquakes in accordance with plants' licensing basis and NRC regulations.

**Additional, technical, non-public information:** 10 CFR 50, Appendix A, General Design Criterion 2 and 4, 10 Part 100, and Appendix S. Guidance: Regulatory Guides 1.100, IEEE 344 and ASME QME-1. See also part 100 Reactor Site Criteria

### 30) Are US plants susceptible to the same kind of loss of power as happened in Japan?

**Public response:** NRC previously recognized that there is the possibility of a total loss of AC power at a site, called a 'Station Blackout', or SBO. Existing Regulations require the sites to be prepared for the possibility of an SBO. In addition to battery powered back-up system to immediately provide power for emergency systems, NRC regulations require the sites to have a detailed plan of action to address the loss of AC power while maintaining control of the reactor.

There has also been an understanding that sites can lose offsite power as well. Of course, this can be caused by earthquake. However, hurricane- or tornado-related high winds may potentially damage the transmission network in the vicinity of a nuclear plant as well. Flood waters can also affect transformers used to power station auxiliary system. These types of weather related events have the potential to degrade the offsite power source to a plant.

The onsite Emergency Diesel Generators need fuel oil stored in tanks that are normally buried underground. These tanks and associated pumps and piping require protection from the elements. Above ground tanks have tornado and missile protection.

In case both offsite and onsite power supplies fail, NRC has required all licensee to evaluate for a loss of all AC power (station blackout) scenario and implement coping measures to safely shutdown the plant law 10 CFR 50.63.

**Additional, technical, non-public information:** Additional SBO information is found in a fact sheet on the subject at the back of the document. Some plants have safeguards equipment below sea level and rely on watertight doors or Bilge pumps to remove water from equipment required to support safe shutdown. Overflowing rivers can result in insurmountable volume of water flooding the vulnerable areas. SBO definition in 10CFR50.2, SBO plan requirements in 10CFR50.63.

### 31) How do we know that the emergency diesel generators will not fail to operate like in Japan?

**Public response:** Emergency Diesel Generators (EDGs) are installed in a seismically qualified structure and are seismic Category I equipment. Even if these EDGs did fail, plants can safely shutdown using station blackout power source law 10 CFR 50.63. In 1988 the NRC concluded that additional regulatory requirements were justified in order to provide further assurance that a loss of both offsite and onsite emergency ac power systems would not adversely affect public health and safety and the station blackout rule was enacted. Studies conducted by the NRC since this rule has been in effect confirms that the hardware and procedures that have been implemented to meet the station blackout requirements have resulted in significant risk reduction and have further enhanced defense-in-depth. However, we plan to carefully evaluate the lessons learned from the events in Japan to determine if enhancements to the station blackout rule are warranted..

**Additional, technical, non-public information:** None.

### 32) Is there a risk of loss of water during tsunami drawdown? Is it considered in design?

**Public response:** Yes. Section 2.4.6 (Tsunami Hazards) of NUREG 0800 Standard Review Plan) specifically addresses tsunami drawdown in the safety review of new reactor applications.

**Additional, technical, non-public information:** None.

### 33) Are aftershocks considered in the design of equipment at the plants? Are aftershocks considered in design of the structure?

**Public response:** ADD

**Additional, technical, non-public information:** ADD

### 34) Are there any special issues associated with seismic design at the plants? For example, Diablo Canyon has special requirements. Are there any others?

**Public response:** Both SONGS and Diablo canyon are licensed with an automatic trip for seismic events.

**Additional, technical, non-public information:** ADD

### 35) Is the NRC planning to require seismic isolators for the next generation of nuclear power plants? How does that differ from current requirements and/or precautions at existing US nuclear power plants?

**Public response:** The NRC would not require isolators for the next generation of plants. However, it is recognized that a properly designed isolation system can be very effective in mitigating the effect of earthquake. Currently the NRC is preparing guidance for plant designers considering the use of seismic isolation devices.

**Additional, technical, non-public information:** A NUREG is in the works in the office of research. It is expected to be available for comment in 2011.

**36) Are there any US nuclear power plants that incorporate seismic isolators? What precautions are taken in earthquake-prone areas?**

**Public response:** No currently constructed nuclear power plants in the US use seismic isolators. However seismic isolation is being considered for a number of reactor designs under development. Currently seismic design of plants is focused on assuring that design of structures, systems, and components are designed and qualified to assure that there is sufficient margin beyond the design basis ground motion.

**Additional, technical, non-public information:** None.

**37) Do you think that the recent Japan disaster will cause any rethinking of the planned seismic isolation guidelines, particularly as it regards earthquakes and secondary effects such as tsunamis?**

**Public response:** Whenever an event like this happens, the NRC thoroughly reviews the experience and tries to identify any lessons learned. The NRC further considers the need to change guidance or regulations. In this case, the event will be studied and any necessary changes will be made to the guidance under development. However, it should be noted that Japan does not have seismically isolated nuclear plants.

**Additional, technical, non-public information:** None.

## Seismically Induced Fire

### 38) How does the NRC address seismic-induced fire?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The NRC's rules for fire protection are independent of the event that caused the fire. The power plant operators are required to evaluate all the fire hazards in the plant and make sure a fire will not prevent a safe plant shutdown. The NRC's guidance says that power plant operators should assume that a fire can happen at any time. The rules do not require specific consideration of a fire that starts as a result of an earthquake. In addition, we do not require analysis of more than one fire at a time at one reactor.

### 39) Does the NRC require the fire protection water supply system be designed to withstand an earthquake?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The NRC recommends the licensee follow the applicable National Fire Protection Association (NFPA) codes and standards for the fire protection systems or provide an acceptable alternative. This would include local building code earthquake requirements. Since 1976, the NRC has recommended that, "At a minimum, the fire suppression system should be capable of delivering water to manual hose stations located within hose reach of areas containing equipment required for safe plant shutdown following the safe shutdown earthquake (SSE)." For plants located, "in areas of high seismic activity, the staff will consider on a case-by-case basis the need to design the fire detection and suppression system to be functional following the SSE." This is the guidance provided to plants that were licensed to operate, or had construction permits prior to July 1, 1976. For plants with applications docketed but construction permit not received as of July 1, 1976, they were required, " in the event of the most severe earthquake, i.e., the SSE, the fire suppression system should be capable of delivering water to manual hose stations located within hose reach of areas containing equipment required for safe plant shutdown."

The NRC's guidance since 1976 also recommends that fire detection, alarm, and suppression systems function as designed after less severe earthquakes that are expected to occur once every 10 years. The guidance further recommends plant operators in areas of high seismic activity consider the need to design those fire protection systems to function after a severe earthquake.

### 40) How are safe shutdown equipment protected from an oil spill which can cause potential fire?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** In general, the NRC recommends that curbing and dikes be located around all equipment that presents an oil fire hazard. In one special case, the Reactor Cooling Pumps (RCPs) located inside the containment of Pressurized Water Reactors (PWRs) the NRC requires that plants have a seismically qualified oil collection system. The purpose of this requirement is that in the event of a severe earthquake the lubrication oil is not spread out inside containment.

**41) How are safe shutdown equipment protected from a hydrogen fire?**

**Public Response:** The below is from an internal document. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** Hydrogen can be normally found in a couple areas of the plant. For example, most all large electric generating stations (Nuclear, Coal, Oil, Gas and Hydro) use hydrogen as a blanket in the electric generator. This hydrogen storage is typically well separated from safe shutdown equipment. Hydrogen may also be generated in Battery Rooms during charging and discharging of the stations emergency batteries. The battery rooms are typically equipped with hydrogen detectors set to alarm at about 2% (Hydrogen's lower flammable limit is 4.1%). The ventilation system is typically run to prevent any hydrogen build up. In PWR's hydrogen is used as a cover gas in the Volume Control Tank (VCT). This gas is kept at a normally lower pressure (15-20 psig) to allow oxygen scavenging in the tank. Systems like this typically have devices such as excess flow check valves that automatically isolate the system if excess flow occurs. The NRC recommends that pipes that contain hydrogen are designed to withstand a severe earthquake. This design includes a separate pipe wrapped around the hydrogen pipe that vents any leaked hydrogen to the outside.

*[Also please note that this is general information. Mark Salley noted that if the question relates to H2 generated as a part of fuel failure there is a whole other conversation that needs to happen. Please contact him with questions.]*

## Seismically Induced Internal Flooding

### 42) How does the NRC consider seismically induced equipment failures leading to internal flooding?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** 10 CFR Part 50 Appendix A General Design Criterion (GDC) 2 requires, in part, that structures, systems, and components (SSCs) important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. 10 CFR Part 50 Appendix A, GDC 4 requires the SSCs important to safety being designed to accommodate the effects of the flooding associated with seismic events. NUREG-0800, Standard Review Plan, Section 3.4.1, "Internal Flood Protection for Onsite Equipment Failures," provide guidance for the NRC staff to consider seismically induced equipment failures (pipe breaks, tank failures) that could affect safety-related SSCs to perform their safety functions.

The specific areas of review include the following :

- Identify all safety-related SSCs that must be protected against flooding;
- The location of the safety-related SSCs relative to the **internal flood level** (from internal flood analysis) in various buildings, rooms, and enclosures that house safety-related SSCs;
- Possible flow paths from interconnected non-safety-related areas to rooms that house safety-related SSCs;
- The adequacy of the isolation, if applicable, from sources causing the flood (e.g., tank of water )
- Provisions for protection against possible in-leakage sources (from outside to inside of the structures)
- All SSCs that could be a potential source of internal flooding (e.g. pipe breaks and cracks, tank and vessel failures, backflow through drains), **which includes seismically induced equipment failures,** are included for the internal flood analysis – see Q&A (2);
- Design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.);
- Safety-related structures that are protected from below-grade groundwater seepage by means of a permanent dewatering system.

### 43) How is the potential source of internal flooding from the seismically induced equipment failures postulated in the internal flood analysis?

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** All of the non-safety-related systems in the room are assumed to fail. However, the analysis systematically considers the flooding condition/level caused by only one system at a time. By considering the pipe size, volume of the source tank, and the isolation valves, the limiting case, which is the one that releases the largest volume of water, is used to determine the internal flood level. All of the safety-related SSCs are designed to be located above the calculated flood level caused by the limiting case.

**44) Are the non-safety-related equipment failures assumed to occur at the same time?**

**Public Response:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** No. As stated earlier, for design basis flood analysis, it is assumed that a system (containing water source) fails one at a time. Then, the most limiting case, a system breach that causes highest level of flooding, is applied in the design of the location of the safety-related systems.

## About Japanese Hazard, Design and Earthquake Impact

### 45) Was the damage to the Japanese nuclear plants mostly from the earthquake or the tsunami?

**Public response:** Because this event happened in Japan, it is hard for NRC staff to make the assessment necessary to understand exactly what happened at this time. In the nuclear plants there may have been some damage from the shaking, and the earthquake caused the loss of offsite power. However, the tsunami appears to have played a key role in the loss of other power sources at the site producing station blackout, which is a critical factor in the ongoing problems.

**Additional, technical, non-public information:** None

### 46) What was the disposition of the plant during the time after the earthquake struck and before the tsunami arrived? Was there indication of damage to the plant solely from the earthquake (if so, what systems) and did emergency procedures function during this time.

**Public response:** Given that the Fukushima plant is not in the US, the NRC does not yet have enough information to answer this question.

**Additional, technical, non-public information:** Typically there would be the opportunity to get this data, but given the situation it is not clear.

### 47) What magnitude earthquake was the plant designed to withstand? For example, what magnitude earthquake was the plant expected to sustain with damage but continued operation? And with an expected shutdown but no release of radioactive material?

**Public response:** There are two shaking levels relevant to the Fukushima plant, the original design level ground motion and a newer review level ground motion. As a result of a significant change in seismic regulations in 2006, NISA, the Japanese regulator initiated a program to reassess seismic hazard and seismic risk for all nuclear plants in Japan. This resulted in new assessments of higher ground shaking levels (i.e. seismic hazard) and a review of seismic safety for all Japanese plants. The program is still on-going, but has already resulted in retrofit in some plants. Therefore, it is useful to discuss both the design level and a review level ground motion for the plants. A relevant table is found a few questions down, and also in the "Additional Information: Useful Tables" section.

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Fukushima | Magnitude 7.1 Earthquake near the site | 600 gal (0.62g) | 370 gal (0.37g) |

**Additional, technical, non-public information:** Add

### 48) Did this reactor sustain damage in the July 16, 2007 earthquake, as the Kashiwazaki power plant did? What damage and how serious was it?

**Public response:** Neither Fukushima power plant was affected by the 2007 earthquake.

**Additional, technical, non-public information:** None.

### 49) Was the Fukushima power plant designed to withstand a tsunami of any size? What specific design criteria were applied?

**Public response:** Japanese plants are designed to withstand both earthquake and tsunami. An English explanation of how Tsunami hazard assessments are undertaken for Japanese plants is found in Annex II to IAEA Guidance on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations Assessment of Tsunami Hazard: Current Practice in Some States in Japan. The design ground motions are as shown above. We do not have information on the design basis tsunami.

**Additional, technical, non-public information:** Annie has a copy of the draft annex and will put them into ADAMS

### 50) What is the design level of the Japanese plants? Was it exceeded?

**Public response:** As a result of a significant change in seismic regulations in 2006, the Japanese regulator initiated a program to reassess seismic hazard and seismic risk for all nuclear plants in Japan. This resulted in new assessments of higher ground shaking levels (i.e. seismic hazard) and a review of seismic safety for all Japanese plants. The program is still on-going, but has already resulted in retrofit in some plants. Therefore, it is useful to discuss both the design level and a review level ground motion for the plants, as shown below.

Currently we do not have official information. However, it appears that the ground motions (in terms of peak ground acceleration) are similar to the $S_s$ shaking levels, although the causative earthquakes are different. Thus the design basis was exceeded, but the review level may not have been.

**Table: Original Design Basis Ground Motions ($S_2$) and New Review Level Ground Motions ($S_s$) Used for Review of Japanese Plants**

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 gal (0.59g) | 375 gal (0.38g) |
| Fukushima | Earthquake near the site (M7.1) | 600 gal (0.62g) | 370 gal (0.37g) |
| Tokai | Earthquakes specifically undefined | 600 gal (0.62g) | 380 gal (0.39g) |
| Hamaoka | Assumed Tokai (M8.0), etc. | 800 gal (0.82g) | 600 gal (0.62g) |

**Additional, technical, non-public information:** A PDF file provided by John Anderson (prepared by Japanese colleagues) indicates that the majority of the recorded ground motions during the main shock were below the attenuation curve by Si & Midorikawa (1999). Most of the recorded motions fit well to median minus 1 sigma of their GMPE. There are also about a dozen stations with the recorded ground motions above 1g. The highest recorded PGA (~3g) is at the K-Net station MYG004. We can use this information to try to estimate motions at the plants as soon as someone catches a breath.

### 51) What are the Japanese $S_1$ and $S_s$ ground motions and how are they determined?

**Public response:** Japanese nuclear power plants are designed to withstand specified earthquake ground motions, previously specified as $S_1$ and $S_2$, but now simply $S_S$. The design basis earthquake ground motion $S_1$ was defined as the largest earthquake that can reasonably be expected to occur at the site of a nuclear power plant, based on the known seismicity of the area and local faults that have shown activity during the past 10,000 years. A power reactor could continue to operate safely during an $S_1$ level earthquake, though in practice they are set to trip at lower levels. The $S_2$ level ground motion was based on a larger earthquake from faults that have shown activity during the past 50,000 years and assumed to be closer to the site. The revised seismic regulations in May 2007 replaced $S_1$ and $S_2$ with $S_S$. The $S_S$ design basis earthquake is based on evaluating potential earthquakes from faults that have shown activity during the past 130,000 years. The ground motion from these potential earthquakes are simulated for each of the sites and used to determine the revised $S_S$ design basis ground motion level. Along with the change in definition, came a requirement to consider "residual risk", which is a consideration of the beyond-design-basis event.

**Additional, technical, non-public information:** None

### 52) Did this earthquake affect the Kashiwazaki-Kariwa nuclear power plant?

**Public response:** No, this earthquake did not affect Kashiwazaki-Kariwa nuclear power plant and all reactors remained in the state of operation prior to the March 11, 2011, Japan earthquake. It also did not trip during an earthquake of magnitude XX that occurred on the western side subsequent to the 8.9 earthquake. This is very important for the stability of Japan's energy supply due to the loss of production at TEPCO's Fukushima nuclear power plants.

**Additional, technical, non-public information:** None

### 53) How high was the tsunami at the Fukushima nuclear power plants?

**Public response:** The tsunami modeling team at the National Oceanic and Atmospheric Administration's Pacific Marine Environmental Lab have estimated the wave height offshore (at the 5 meter bathymetric line) to be approximately 8 meters in height at Fukushima Daiichi and approximately 7 meters in Fukushima Daini. This is based on recordings from NOAA's Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys and a high resolution numerical model developed for the tsunami warning system. NEI subsequently reported that TEPCO believes that TEPCO believes the tsunami that inundated the Fukushima Daiichi site was 14 meters high at the plant location. This is not inconsistent as wave heights increase as they come ashore. NEI also noted that design basis tsunami for the site was 5.7 meters, and the reactors and backup power sources were located 10 to 13 meters above sea level, according to TEPCO.

**Additional, technical, non-public information:** NOAA's PMEL center has provided us their best numbers for all the plants on the NW coast of Japan. These can be found in the Additional Information section in the back of this document.

### 54) Wikileaks has a story that quotes US embassy correspondence and some un-named IAEA expert stating that the Japanese were warned about this ... Does the NRC want to comment?

http://www.dailymail.co.uk/news/article-1366721/Japan-tsunami-Government-warned-nuclear-plants-withstand-earthquake.html

**Public response:** TBD Annie to explain the history of their recent retrofit program.

**Additional, technical, non-public information:** The article talks about that the plants and that they were checked for a magnitude 7, but the earthquake was a 9. The reality is that they assumed the magnitude 7 close in had similar ground motions to a 9 farther away. They did check (and retrofit) the plant to the ground motions that they probably saw (or nearly). The problem was the tsunami. We probably need a small write up so that staff understands, even if we keep it internal.

# Impact at US Nuclear Power Plants During the March 11, 2011 Earthquake and Tsunami?

## 55) Was there any damage to US reactors from either the earthquake or the resulting tsunami?

**Public Answer:** No

**Additional, technical non-public information**: Two US plants on the Pacific Ocean (Diablo Canyon and San Onofre) experienced higher than normal sea level due to tsunami. However, the wave heights were consistent with previously predicted levels and this had no negative impact to the plants. In response, Diablo Canyon Units 1 and 2 declared an "unusual event" based on tsunami warning following the Japanese earthquake. They have since exited the "unusual event" declaration, based on a downgrade to a tsunami advisory.

## 56) Have any lessons for US plants been identified?

**Public Answer:** The NRC is in the process of following and reviewing the event in real time. This will undoubtedly lead to the identification of issues that warrant further study. However, a complete understanding of lessons learned will require more information than is currently available to NRC staff.

**Additional, technical non-public information:** We need to take a closer look at common cause failures, such as earthquake and tsunami, and earthquake and dam failure.

## NRC Response and Future Licensing Actions

### 57) What is the NRC doing about the emergencies at the nuclear power plants in Japan? Are you sending staff over there?

**Public Answer:** We are closely following events in Japan, working with other agencies of the federal government and with our counterparts in that country. In addition, we currently have a team of experts in boiling water reactors working in Japan.

**Additional technical, non-public information:** NOTE TO OPA: please check the current staffing in Japan to provide more accurate information. This is changing on an ongoing basis. We are taking the knowledge that the staff has about the design of the US nuclear plants and we are applying this knowledge to the Japan situation. For example, this includes calculations of severe accident mitigation that have been performed.

### 58) With NRC moving to design certification, at what point is seismic capability tested – during design or modified to be site-specific? If in design, what strength seismic event must these be built to withstand?

**Public Answer:** During design certification, vendors propose a seismic design in terms of a ground motion spectrum for their nuclear facility. This spectrum is called a standard design response spectrum and is developed so that the proposed nuclear facility can be sited at most locations in the central and eastern United States. The vendors show that this design ground motion is suitable for a variety of different subsurface conditions such as hard rock, deep soil, or shallow soil over rock. Combined License and Early Site Permits applicants are required to develop a site specific ground motion response spectrum that takes into account all of the earthquakes in the region surrounding their site as well as the local site geologic conditions. Applicants estimate the ground motion from these postulated earthquakes to develop seismic hazard curves. These seismic hazard curves are then used to determine a site specific ground motion response spectrum that has a maximum annual likelihood of $1x10^{-4}$ of being exceeded. This can be thought of as a ground motion with a 10,000 year return period. This site specific ground motion response spectrum is then compared to the standard design response spectrum for the proposed design. If the standard design ground motion spectrum envelopes the site specific ground motion spectrum then the site is considered to be suitable for the proposed design. If the standard design spectrum does not completely envelope the site specific ground motion spectrum, then the COL applicant must do further detailed structural analysis to show that the design capacity is adequate. Margin beyond the standard design and site specific ground motions must also be demonstrated before fuel loading can begin.

**Additional technical, non-public information:** None.

### 59) What are the near term actions that U.S. plants are taking in consideration of the events in Japan?

**Public Answer**: The U.S. nuclear energy industry has already started an assessment of the events in Japan and is taking steps to ensure that U.S. reactors could respond to events that may challenge safe operation of the facilities. These actions include:

- Verify each plant's capability to manage major challenges, such as aircraft impacts and losses of large areas of the plant due to natural events, fires or explosions.
  Verify each plant's capability to manage a total loss of off-site power.

- Verify the capability to mitigate flooding and the impact of floods on systems inside and outside the plant.
- Perform walk-downs and inspection of important equipment needed to respond successfully to extreme events like fires and floods.

**Additional technical, non-public information:** Note to OPA: This was a Q&A from the 3/21 briefing. please check that this is OK to provide to the public before doing so.

### 60) What are the immediate steps NRC is taking?

**Public Answer**: To date (march 20, 2011) the NRC has taken the following steps:

- The Nuclear Regulatory Commission has issued an Information Notice to all currently operating U.S. nuclear power plants, describing the effects of the March 11 earthquake and tsunami on Japanese nuclear power plants.
- The notice provides a brief overview of how the earthquake and tsunami are understood to have disabled several key cooling systems at the Fukushima Daiichi nuclear power station, and also hampered efforts to return those systems to service. The notice is based on the NRC's current understanding of the damage to the reactors and associated spent fuel pools as of Friday, March 18.
- The notice reflects the current belief that the combined effects of the March 11 earthquake and tsunami exceeded the Fukushima Daiichi plant's design limits. The notice also recounts the NRC's efforts, post-9/11, to enhance U.S. plants' abilities to cope with severe events, such as the loss of large areas of a site, including safety systems and power supplies.

The NRC expects U.S. nuclear power plants will review the entire notice to determine how it applies to their facilities and consider actions, as appropriate.

**Additional technical, non-public information:** Note to OPA: This was a Q&A from the 3/21 briefing. please check that this is OK to provide to the public before doing so.

### 61) Should U.S. residents be using Potassium iodide?

**Public Response**: It is the responsibility of the individual States to decide on the use of KI. It is EPAs responsibility to inform states of projected doses. Due to the extremely low levels of radioactivity expected on the U.S. West coast and Pacific States/territories, the NRC staff does not recommend use of KI.

**Additional technical, non-public information:** None.

## Reassessment of US Plants and Generic Issue 199 (GI-199)

### 62) What is Generic Issue 199 about?

**Public Answer:** Generic Issue 199 investigates the safety and risk implications of updated earthquake-related data and models. These data and models suggest that the probability for earthquake ground motion above the seismic design basis for some nuclear plants in the Central and Eastern United States, although is still low, is larger than previous estimates.

**Additional, technical, non-public information:** See additional summary/discussion of GI-199 and terms below.

### 63) Does the NRC have a position on the MSNBC article that ranked the safety of US plants?

**Public Response:** [see below]

### 64) A recent Can we get the rankings of the plants in terms of safety? (Actually this answer should be considered any time GI-199 data is used to "rank" plants)

**Public Response:** The NRC does not rank nuclear plants by seismic risk. The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The results of the GI-199 safety risk assessment should not be interpreted as definitive estimates of plant-specific seismic risk because some analyses were very conservative making the calculated risk higher than in reality. The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool.

**Additional, technical, non-public information:** NOTE TO OPA: Add the answer to "What are the current findings of GI-199", to create a longer answer if it is appropriate.

### 65) What are the current findings of GI-199?

Currently operating nuclear plants in the US remain safe, with no need for immediate action. This determination is based on NRC staff reviews of updated seismic hazard information and the conclusions of the first stage of GI-199. Existing nuclear plants were designed with considerable margin to be able to withstand the ground motions from the "deterministic" or "scenario earthquake" that accounted for the largest earthquakes expected in the area around the plant. The results of the GI-199 assessment demonstrate that the probability of exceeding the design basis ground motion may have increased at some sites, but only by a relatively small amount. In addition, the probabilities of seismic core damage are lower than the guidelines for taking immediate action. Although there is not an immediate safety concern, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** None.

### 66) If the plants are designed to withstand the ground shaking why is there so much risk from the design level earthquake

Much of the risk in the total risk levels provided in the report comes from earthquakes stronger than the safe shutdown ground motion. The anything indicated in the geologic record used to determine the design requirements at these sites. The numbers are based on an evaluation of all of the potential seismic sources in the CEUS and are used to produce seismic hazard estimates (curves) for each site. The GI-199 effort to date has performed a screening assessment to determine if further, more detailed studies are warranted. This study has utilized information from plant-specific evaluation of external hazards, including earthquakes. That information was gathered to identify potential seismic vulnerabilities, not to produce robust risk estimates. Therefore, the GI-199 results should be viewed as preliminary and not definitive.

### 67) Overall, how would the NRC characterize the CDF numbers? A quirk of numbers? A serious concern?

**Public Response:** The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted consistent with NRC directives. The results of the GI-199 SRA should not be interpreted as definitive estimates of plant-specific seismic risk. The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

The study is still underway and it is too early to predict the final outcome. However, staff has determined that there is no immediate safety concern and that overall seismic risk estimates remain small. If at any time the NRC determines that an immediate safety concern exists, action to address the issue will be taken. However, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue.

**Additional, technical, non-public information:** None.

### 68) Describe the study and what it factored in – plant design, soils, previous quakes, etc.

**Public Response:** The study considers the factors that impact estimates of both the seismic hazard (i.e. ground shaking levels) at the site and the plants resistance to earthquakes (mathematically represented by the plant level fragility curve). Previous quakes, the tectonic environment, and the soils that underlie the site are all used in the development of the ground shaking estimates used in the analyses. Plant design and the seismic resistance of the important structures, systems, and components are all used in the development of plant level fragility curves.

**Additional, technical, non-public information:** None.

### 69) Explain "seismic curve" and "plant level fragility curve".

**Public Response:** A seismic curve is a graphical representation of seismic hazard. Seismic hazard in this context is the highest level of ground motion expected to occur (on average) at a site over different periods of time. Plant level fragility is the probability of damage to plant structures, systems and components as a function of ground shaking levels.

**Additional, technical, non-public information:** None.

70) **Explain the "weakest link model".**

**Public Response:** The weakest link model is a method for evaluating the importance of different frequencies of ground vibration to the overall plant performance. The model and its details are not integral to understanding the fundamental conclusions of the study.

**Additional, technical, non-public information:** None.

71) **What would constitute fragility at a plant?**

**Public Response:** Fragility is a term that relates the probability of failure of an individual structure, system or component to the level of seismic shaking it experiences. Plant level fragility is the probability of damage to sets of plant structures, systems and components as a function of ground shaking levels.

**Additional, technical, non-public information:** None.

72) **Can someone put that risk factor into perspective, using something other than MSNBC's chances of winning the lottery?**

**Public Response:** As noted above, the risk factors determined in GI-199 were conservative estimates of risk intended for use as a screening tool. Use of these factors beyond this intended purpose is inappropriate.

**Additional, technical, non-public information:** None.

73) **What, if anything, can be done at a site experiencing such a risk? (Or at Limerick in particular.)**

**Public Response:** The probabilistic seismic risk analyses (SPRA) that are performed to determine the core damage frequency (CDF) numbers also provides a significant amount of information on what the plant vulnerabilities are. This allows the analyst to determine what can be done to the plant to address the risk.

**Additional, technical, non-public information:** None.

74) **Has anyone determined that anything SHOULD be done at Limerick or any of the other PA plants?**

**Public Response:** The fundamental conclusion of the report is that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." The NRC is planning to issue a Generic Communication to operating reactor licensees in the CEUS requesting additional information. This includes the plants in PA.

**Additional, technical, non-public information:** None.

75) **Page 20 of the report: This result confirms NRR's conclusion that currently operating plants are adequately protected against the change in seismic hazard estimates because the guidelines in NRR Office Instruction LIC-504 "Integrated Risk-Informed Decision Making Process for Emergent Issues" are not exceeded. Can someone please explain?**

**Public response:** Can someone help with this?

**Additional, technical, non-public information:** None.

### 76) Is the earthquake safety of US plants reviewed once the plants are constructed?

**Public response:** Yes, earthquake safety is reviewed during focused design inspections, under the Generic Issues Program (GI-199) and as part of the Individual Plant Evaluation of External Events program (IPEEE) that was conducted in response to Generic Letter 88-20 Supplement 4.

**Additional, technical, non-public information:** None.

### 77) Does the NRC ever review tsunami risk for existing plants?

**Public Answer:** The NRC has not conducted a generic issue program on tsunami risk to date. However, some plants have been reviewed as a result of the application for a license for a new reactor. In the ASME/ANS 2009 seismic probabilistic risk assessment standard, all external hazards are included.

**Additional, technical, non-public information:** None.

### 78) Does GI-199 consider tsunami?

**Public response:** GI-199 stems from the increased in perceived seismic hazard focused on understanding the impact of increased ground motion on the risk at a plant. GI-199 does not consider tsunami

**Additional, technical, non-public information:** In the past there has been discussion about a GI program on tsunami, but the NRC's research and guidance was not yet at the point it would be effective. We are just getting to this stage and the topic should be revisited.

### 79) Where can I get current information about Generic Issue 199?

**Public Answer:** The public NRC Generic Issues Program (GIP) website (http://www.nrc.gov/about-nrc/regulatory/gen-issues.html) contains program information and documents, background and historical information, generic issue status information, and links to related programs. The latest Generic Issue Management Control System quarterly report, which has regularly updated GI-199 information, is publicly available at http://www.nrc.gov/reading-rm/doc-collections/generic-issues/quarterly/index.html. Additionally, the US Geological Survey provides data and results that are publicly available at http://earthquake.usgs.gov/hazards/products/conterminous/2008/.

**Additional, technical, non-public information:** The GI-199 section of the NRC internal GIP website (http://www.internal.nrc.gov/RES/projects/GIP/Individual%20GIs/GI-0199.html) contains additional information about Generic Issue 199 (GI-199) and is available to NRC staff.

### 80) Are all US plants being evaluated as a part of Generic Issue 199?

**Public Answer:** Currently the scope of the Generic Issue 199 (GI-199) Safety/Risk Assessment is limited to all plants in the Central and Eastern United States. Although plants at the Columbia, Diablo Canyon, Palo Verde, and San Onofre sites are not included in the GI-199 Safety/Risk Assessment, the Information Notice on GI-199 is addressed to all operating power plants in the US (as well as all independent spent fuel storage installation licensees). The staff will also consider inclusion of operating reactors in the Western US in its future generic communication information requests.

**Additional, technical, non-public information:** The staff is currently developing specific information needs to be included in a Generic Letter to licensees in the CEUS.

### 81) Are the plants safe? If you are not sure they are safe, why are they not being shut down? If you are sure they are safe, why are you continuing evaluations related to this generic issue?

**Public Answer:** Yes, currently operating nuclear plants in the United States remain safe, with no need for immediate action. This determination is based on NRC staff reviews associated with Early Site Permits (ESP) and updated seismic hazard information, the conclusions of the Generic Issue 199 Screening Panel (comprised of technical experts), and the conclusions of the Safety/Risk Assessment Panel (also comprised of technical experts).

No immediate action is needed because: (1) existing plants were designed to withstand anticipated earthquakes with substantial design margins, as confirmed by the results of the Individual Plant Examination of External Events program; (2) the probability of exceeding the *safe shutdown earthquake* ground motion may have increased at some sites, but only by a relatively small amount; and (3) the Safety/Risk Assessment Stage results indicate that the probabilities of seismic core damage are lower than the guidelines for taking immediate action.

Even though the staff has determined that existing plants remain safe, the Generic Issues Program criteria (Management Directive 6.4) direct staff to continue their analysis to determine whether any cost-justified plant improvements can be identified to make plants enhance plant safety.

**Additional, technical, non-public information :** The Safety/Risk Assessment results confirm that plants are safe. The relevant risk criterion for GI-199 is total *core damage frequency* (CDF). The threshold for taking immediate regulatory action (found in NRR Office Instruction LIC-504, see below) is a total CDF greater than or on the order of $10^{-3}$ (0.001) per year. For GI-199, the staff calculated seismic CDFs of $10^{-4}$ (0.0001) per year and below for nuclear power plants operating in the Central and Eastern US (CEUS) (based on the new US Geological Survey seismic hazard curves). The CDF from internal events (estimated using the staff-developed Standardized Plant Analysis of Risk models) and fires (as reported by licensees during the IPEEE process and documented in NUREG-1742), when added to the seismic CDF estimates results in the total risk for each plant to be, at most, $4 \times 10^{-4}$ (0.0004) per year or below. This is well below the threshold (a CDF of $10^{-3}$ [0.001] per year) for taking immediate action. Based on the determination that there is no need for immediate action, and that this issue has not changed the licensing basis for any operating plant, the CEUS operating nuclear power plants are considered safe. In addition, as detailed in the GI-199 Safety/Risk Assessment there are additional, qualitative considerations that provide further support to the conclusion that plants are safe.

Note: The NRC has an integrated, risk-informed decision-making process for emergent reactor issues (NRR Office Instruction LIC-504, ADAMS Accession No. ML100541776 [not publically available]). In addition to deterministic criteria, LIC-504 contains risk criteria for determining when an emergent issue requires regulatory action to place or maintain a plant in a safe condition.

### 82) What do you mean by "increased estimates of seismic hazards" at nuclear power plant sites?

**Public Answer:** *Seismic hazard* (earthquake hazard) represents the chance (or probability) that a specific level of ground motion could be observed or exceeded at a given location. Our estimates of seismic hazard at some Central and Eastern United States locations have changed based on results from recent research, indicating that earthquakes occurred more often in some locations than previously estimated. Our estimates of seismic hazard have also changed because the models used to predict the level of ground motion, as caused by a specific magnitude earthquake at a certain distance from a site, changed. The increased estimates of seismic hazard at some locations in the Central and Eastern United States were discussed in a memorandum to the Commission, dated July 26, 2006. (The memorandum is available in the NRC Agencywide Documents Access and Management System [ADAMS] under Accession No. ML052360044).

**Additional, technical, non-public information:** See additional discussion of terms at the end of the document.

**83) Does the SCDF represent a measurement of the risk of radiation RELEASE or only the risk of core damage (not accounting for secondary containment, etc.)?**

**Public Response:** Seismic core damage frequency is the probability of damage to the core resulting from a seismic initiating event. It does not imply either a meltdown or the loss of containment, which would be required for radiological release to occur. The likelihood of radiation release is far lower.

**84) Did an NRC spokesperson tell MSNBC's Bill Dedman that the weighted risk average was invalid and useless? He contends to us that this is the case.**

**Public Response:** No. See Answers below.

**85) 3. If it was "invalid" as he claims, why would the USGS include that metric?**

**Public Response:** The weighted average is not invalid (see Answer 5 below). All of the values in Appendix D were developed by NRC staff. Table D-1 in Appendix D uses the (2008) US Geological Survey (USGS) seismic source model, but the Seismic Core Damage Frequency results were developed by US NRC staff. The USGS seismic source model is the same one used to develop the USGS National Seismic Hazard Maps.

**86) Can you explain the weighted average and how it compares to the weakest link average?**

**Public Response:** Tables D-1 through D-3 in Appendix D of the US NRC study show the "simple" average of the four spectral frequencies (1, Hz, 5 Hz, 10 Hz, peak ground acceleration (PGA)), the "IPEEE weighted" average and the "weakest link" model. These different averaging approaches are explained in Appendix A.3 (simple average and IPEEE weighted average) and Appendix A.4 (weakest link model). The weighted average uses a combination of the three spectral frequencies (1, 5, and 10 Hz) at which most important structures, systems, and components of nuclear power plants will resonate. The weakest link is the largest SCDF value from among the four spectral frequencies noted above.

**87) Ultimately would you suggest using one of the models (average, weighted, weakest link) or to combine the information from all three?**

**Public Response:** Most nuclear power plant structures, systems, and components resonate at frequencies between 1 and 10 Hz, so there are different approaches to averaging the Seismic Core Damage Frequency (SCDF) values. By using multiple approaches, the NRC staff gains a better understanding of the uncertainties involved in the assessments.

**88) Were there any other factual inaccuracies or flaws in Mr. Dedman's piece you would like clarify/point out.**

**Public Response:** The US Nuclear Regulatory Commission study, released in September, 2010, was prepared as a screening assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern US (CEUS) are warranted, consistent with NRC directives. The report clearly states that "work to date supports a decision to continue ...; the methodology, input assumptions, and data are not sufficiently developed to support other regulatory actions or decisions." Accordingly, the results were not used to rank or compare plants. The study produced plant-specific results of the estimated change in risk from seismic hazards. The study did not rely on the absolute value of the seismic risk except to assure that all operating plants are safe. The plant-specific results were used in aggregate to determine the need for continued evaluation and were included in the report for openness and transparency. The use of the absolute value of the seismic hazard-related risk, as done in the MSNBC article, is not the intended use, and the NRC considers it an inappropriate use of the results.

**89) Mr. Dedman infers that the plant quake risk has grown (between the 1989 and 2008 estimates) to the threshold of danger and may cross it in the next study. Is this the NRC's position?**

**Public Response:** The US NRC evaluation is still underway and it is too early to predict the final outcome. However, staff has determined that there is no immediate safety concern and that overall seismic risk estimates remain small. If at any time the NRC determines that an immediate safety concern exists, action to address the issue will be taken. However, the NRC is focused on assuring safety during even very rare and extreme events. Therefore, the NRC has determined that assessment of updated seismic hazards and plant performance should continue

**90) What document has the latest seismic hazard estimates (probabilistic or not) for existing nuclear power plants in the <u>western</u> US?**

**Public Response:** At this time the staff has not formally developed updated probabilistic seismic hazard estimates for the existing nuclear power plants in the Western US However, NRC staff during the mid- to late-1990's reviewed the plants' assessments of potential consequences of severe ground motion from earthquakes beyond the plant design basis as part of the Individual Plant Examination of External Events (IPEEE) program. From this review, the NRC staff determined that the seismic designs of operating plants in the US have adequate safety margin. NRC staff has continued to stay abreast of the latest research on seismic hazards in the Western US and interface with colleagues at the US Geological Survey. The focus of Generic Issue 199 has been on the CEUS. However, the Information Notice that summarized the results of the Safety/Risk Assessment was sent to all existing power reactor licensees. The documents that summarize existing hazard estimates are contained in the Final Safety Analysis Reports (FSARS) and in the IPEEE submittals. It must be noted that following 9/11 the IPEEE documents are no longer publicly available.

**Additional, technical, non-public information:** None

**91) The GI-199 documents refer to newer data on the way. Have NRC, USGS et al. released those? I'm referring to this: "New consensus seismic-hazard estimates will become available in late 2010 or early 2011 (these are a product of a joint NRC, US Department of Energy, US Geological Survey (USGS) and Electric Power Research Institute (EPRI) project). These consensus seismic hazard estimates will supersede the existing EPRI, Lawrence Livermore National Laboratory, and USGS hazard estimates used in the GI-199 Safety/Risk Assessment."**

**Public Response:** The new consensus hazard curves are being developed in a cooperative project that has NRC, US Department of Energy, US Geological Survey (USGS) and Electric Power Research Institute (EPRI) participation. The title is: The Central and Eastern US Seismic Source Characterization (CEUS-SSC) project. The project is being conducted following comprehensive standards to ensure quality and regulatory defensibility. It is in its final phase and is expected to be publicly released in the fall of 2011. The project manager is Larry Salamone (Lawrence.salamone@srs.gov, 803-645-9195) and the technical lead on the project is Dr. Kevin Coppersmith (925-974-3335, kcoppersmith@earthlink.net). Additional information on this project can be found at: http://mydocs.epri.com/docs/ANT/2008-04.pdf, and http://my.epri.com/portal/server.pt?open=512&objID=319&&PageID=218833&mode=2&in_hi_userid=2&cached=true.

**Additional, technical, non-public information:** None

**92) What is the timetable now for consideration of any regulatory changes from the GI-199 research?**

**Public Response:** The NRC is working on developing a Generic Letter (GL) to request information from affected licensees. The GL will likely be issued in a draft form within the next 2 months to stimulate discussions with industry in a public meeting. After that it has to be approved by the Committee to Review Generic Requirements, presented to the Advisory Committee on Reactor Safeguards and issued as a draft for formal public comments (60 days). After evaluation of the public comments it can then be finalized for issuance. We expect to issue the GL by the end of this calendar year, as the new consensus seismic hazard estimates become available. The information from licensees will likely require 3 to 6 months to complete. Staff's review will commence after receiving licensees' responses. Based on staff's review, a determination can be made regarding cost beneficial backfits where it can be justified.

**Additional, technical, non-public information:** None

1. Please explain in plain language how the NRC determined plants are safe with regard to the results of our GI199 assessment report..

2. The GI199 Safety/Risk Assessment states 24 plants "lie in the continue zone" (pg 23) These plants "need more assessment." What are these 24 plants? Why are these plants that require further evaluation safe? (pg 23 and Figure 8)

3. Why is the list of plants identified by the NRC for further evaluation under GI199 different than those identified by MSNBC as the "top 10" likely to fail due to seismic event?

4. Why are plants safe when MSNBC calculations indicate several hundred percent increases in the risk of a seismic event that damages the core?

5. Why do Indian Point 2 and Indian Point 3 plants have different probabilities of failing due to a seismic event when the plants are located next to each other? Is IP3 calculated to be the most likely to fail due to a seismic event? Why? Why is IP2 different? Aren't these plant at the same location and very similar design?

6. Why is Pilgrim not in the NRC "continue to evaluate zone" but second on the MSNBC list as moist likely to fail due to a seismic event?

## Seismic Probabilistic Risk Assessment (SPRA)

**93) The NRC increasingly uses risk-information in regulatory decisions. Are risk-informed PRAs useful in assessing an event such as this?**

**Public response:** Nilesh Chokshi to provide Q&As on SPRA

**Additional, technical, non-public information:** None

## State-of-the-art Reactor Consequence Analysis (SOARCA)

### 94) What severe accident research is the U.S. Nuclear Regulatory Commission (NRC) doing?

**Public Answer:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The NRC and its contractor presently are completing a research project entitled "State-of-the-Art Reactor Consequence Analysis" (SOARCA). This research project develops best estimates of the potential public health effects from a nuclear power plant accident where low-likelihood scenarios could release radioactive material into the environment and potentially cause offsite consequences. The project also evaluates and improves, as appropriate, methods and models for evaluating outcomes of such severe accidents. In addition, research is being conducted to develop advanced risk assessment modeling techniques (e.g., dynamic probabilistic risk assessment (PRA) using simulation based methods) to improve the state-of-the practice in PRA severe accident modeling. Key goals of this research include increased analysis realism, reduced reliance on modeling simplification, and improved the treatment of human interactions with the reactor plant system.

### 95) Why is the NRC performing the SOARCA study?

**Public Answer:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** NRC is doing this study to develop the most realistic evaluations for the potential consequences of severe nuclear accidents. Over the years, NRC, industry, and international nuclear safety organizations have completed substantial research on plant response to hypothetical accidents that could damage the core and containment. The results have significantly improved NRC's ability to analyze and predict how nuclear plant systems and operators would respond to severe accidents. Also, plant owners have improved the plant design, emergency procedures, maintenance programs, and operator training, all of which have improved plant safety. Emergency preparedness measures also have been refined and improved to further protect the public in the highly unlikely event of a severe accident. Combining all of this new information and analysis will improve the realism of accident consequence evaluations.

### 96) Does the NRC intend to revisit previous risk studies?

**Public Answer:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The last NRC-sponsored Level 3 probabilistic risk assessment (PRA) studies to estimate the integrated risk to the public from severe nuclear reactor accidents were conducted in the late 1980s with the results published in a collection of reports and a corresponding summary document, NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants." Based on advances in both nuclear power plant safety and PRA technology since NUREG-1150 was published, the NRC staff is considering conducting new Level 3 PRA studies to update its understanding of the integrated risk to the public from accidents involving nuclear power plant sites. The NRC staff is currently conducting a scoping study to develop various options for proceeding with Level 3 PRA activities, and plans to provide the Commission with these potential options and a specific recommendation for proceeding by July 2011.

97) **How will the SOARCA study be different from earlier studies?**

**Public Answer:** The below is from the internal Q&As for the 3/21 briefing. This needs to be cleared before it can be used.

**Additional, technical, non-public information:** The SOARCA project will:

- Use an improved understanding of source terms and severe accident phenomenology.
- Credit the use of severe accident mitigation strategies and procedures.
- Use updated emergency preparedness modeling.
- Account for plant improvements.
- Use modern computer resources and advanced software to yield more accurate results.

In addition, the SOARCA project is designed to be a more realistic estimate. Some of the earlier studies also were designed to be best estimates; however, because they were limited by the available knowledge of accident phenomenology, these older studies were conservative (particularly the very improbable severe accidents) in their estimates of off-site releases and early fatalities. The SOARCA project will provide the latest basis from which the public and decision makers can assess the consequences of severe reactor accidents.

## Defense-in-Depth and Severe Accident Management

This is not exactly related to seismic questions. I read these with great interest. I believe there are many staff who would like to be more informed about this topic. So, I have included it.

### 99) Although there undoubtedly will be many lessons learned about severe accidents from the tragic events at Fukushima, have you identified any early lessons?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** There will undoubtedly be many lessons learned in the months and years to come as we learn more about the tragic events at the Fukushima Daiichi plant in Japan. However, one of the early lessons is this: You can't anticipate — either in the deterministic design basis of the plant or through probabilistic risk assessment models — everything that could happen. That is why the NRC's defense-in-depth philosophy is fundamental to ensuring that safety is achieved, even under extreme circumstances, such as those experienced at the Fukushima Daiichi plant. This NRC focus on defense-in-depth has led to a number of improvements in the design and operation of U.S. Nuclear Power Plants:

- Studies of severe accident prevention and mitigation in the 1980s led to a number of improvements at plants, such as installation of hardened vents at BWRs with Mark I containments. (See "fact sheet" for more detail.)
- Also, in the 1980s (specifically in 1988) the NRC concluded that additional regulatory requirements were justified in order to provide further assurance that a loss of both offsite and onsite emergency ac power systems would not adversely affect public health and safety and the station blackout rule was enacted. Studies conducted by the NRC since this rule has been in effect confirms that the hardware and procedures that have been implemented to meet the station blackout requirements have resulted in significant risk reduction and have further enhanced defense-in-depth. However, we plan to carefully evaluate the lessons learned from the events in Japan to determine if enhancements to the station blackout rule are warranted. (See "fact sheet" on station black-out.)
- Operator procedures that are symptom-based and ensure that operators primary focus is maintaining the critical safety functions such as ensuring the core is cooled and covered.
- Addition procedures for operators to use in the event of a severe accident (Severe Accident Mitigation Guidelines (SAMG)).
- Provisions in 10 CFR 50.54hh that require licensees to develop and implement guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities in situations involving loss of large areas of the plant due to explosions or fire.

### 100) What procedures do U.S. plants have for responding to an unexpected event like the events in Japan.

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** One of the most significant lessons learned from the Three Mile Island Accident in 1979 was that operating procedures need to be symptom based and less prescriptive. Procedures that previously directed operators to take a series of actions based on a preestablished accident were replaced with procedures that directed operators to maintain the critical safety functions, such as keeping the core covered and cooled. Operators routinely practice these procedures on a plant specific simulator to ensure that they can be implemented for a wide range of accident scenarios, including a station blackout scenario, or other events caused by an earthquake or a flood.

### 101) What are Severe Accident Management Guidelines

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** SAMGs are the set of guidelines employed to manage the in-plant response following a severe accident (i.e., Beyond design basis events that are expected to have resulted in significant core damage).

The *ultimate objective* of SAMGs is to protect the health and safety of the public from the hazards associated with the uncontrolled release of radioactive materials

The *operational objective* of SAMGs is to protect or restore, if possible, the integrity of the three physical barriers (fuel, reactor coolant system, and containment) to contain fission products.

Some important aspects of the guidelines are as follows:

- SAMGs go beyond the Emergency Operating Procedures (EOPs)
- SAMGs identify all possible means of achieving the operational objective, including the use of non-safety-related equipment and capabilities on site (including capabilities from other units)
- plant-specific SAMGs identify the various safety functions and list the capabilities to achieve that function, with some high-level procedure-like guidance.

## Spent Fuel Pools and Independent Spent Fuel Storage Installations

### 102) Are Independent Spent Fuel Storage Installations (ISFSIs) required to withstand the same ground shaking as the reactor?

**Public Response:** Nuclear plant licensees use the same Safe Shutdown Earthquake (SSE) ground motion developed for the nuclear plant site for the design basis ground motion for the spent fuel dry cask storage facilities (also known as independent spent fuel storage installations, or ISFSIs) located at that site. Some reactor licensees have ISFSIs under a site-specific 10 CFR Part 72 license, and these licensees are required to use the same Part 50 reactor SSE for their design basis earthquake, in accordance with 10 CFR 72.102(f)(1). Other reactor licensees have onsite ISFSIs under the general license provisions of 10 CFR 72.210; they are similarly required to apply the same seismic design bases for the Part 50 license to the ISFSI design, in accordance with 10 CFR 72.212(b)(3).

**Additional, technical, non-public information:** none.

### 103) What do we know about the potential for and consequences of a zirconium fire in the spent fuel pool?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Spent fuel pools contain large amounts of water to keep the fuel cooled, and no fire can result as long as the water covers the fuel. Should the pool not be cooled for a substantial amount of time (on the order of days), the water in the pool may boil off. Should that continue and the fuel be exposed, the fuel could overheat. In the worst case, the zirconium cladding could oxidize and burn. The result of such a fire would be significant damage to the fuel, also the fire has the potential to propagate to the other assemblies, as well as release of hydrogen gas and volatile radioactive materials.

### 104) Can a zirconium fuel fire be prevented by wide spacing of spent fuel assemblies in the spent fuel pool?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Wider spacing would help in preventing a fire. Preventing a fire requires coolability in absence of water submersion. This depends on the heat and the assembly arrangement in the pool. A checkerboard arrangement (no two assemblies in adjacent locations) is coolable in about one third the time needed for a fully loaded (no open locations) pool. Other arrangements can also mitigate the potential of the onset of zirconium fires.

### 105) Are the implications of new seismic hazard estimates being considered for the storage of spent fuel?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes, while the GI-199 Safety/Risk Assessment focused solely on operating power reactors in the Central and Eastern U.S., spent fuel storage has been considered by NRC.

The NRC Office of Nuclear Materials Safety and Safeguards (NMSS) was informed of GI-199 and a preliminary screening review was performed in November, 2008 by the NMSS Division of Spent Fuel Storage and Transportation. There is a total of 40 operating independent spent fuel storage installations (ISFSIs) in the Central and Eastern U.S. (CEUS). Except for a wet storage facility at G. E. Morris located in Illinois, the ISFSIs are co-located at the operating and permanently shutdown reactor sites. A review of design earthquakes (DE) used at the existing ISFSI locations in CEUS indicated that the safety margin (defined for ISFSIs as the ratio of DE/SSE, where SSE is the safe shutdown earthquake discussed in answer A8) for the cask designs were in the range of 1.20 ~ 3.90.

Therefore, NMSS considers that there is significant margin built into the existing designs and has confidence that the ISFSIs can continue to operate safely while the licensees' investigate this issue using their site specific information. Even so, holders of operating license for ISFSIs are included among addressees in the Information Notice on GI-199. Spent fuel pools (SFPs) were not specifically evaluated as part of GI-199. However, based on their design attributes (as follows), SFPs remain safe. SFPs are constructed of reinforced concrete, several feet thick, with a stainless steel liner to prevent leakage and maintain water quality. Due to their configuration, SFPs are inherently structurally-rugged and are designed to the same seismic requirements as the nuclear plant.

Note: Typically, SFPs are about 40 feet deep and vary in width and length. The fuel is stored in stainless steel racks and submerged with approximately 23 feet of water above the top of the stored fuel. Each plant has a preferred SFP make-up water source (the refueling water storage tank for pressurized water reactors and the condensate storage tank for boiling water reactors). SFPs have alternate means of make-up such as service water systems and the fire water system. SFPs are also typically designed (e.g. with anti-siphon check valves) and instrumented such that leakage is minimized and promptly detected.

### 106) What are the design acceptance criteria for cooling systems for the spent fuel pools?

**Public Response:** The Standard Review Plan (NUREGO-800) acceptance Criteria for SP Cooling includes the following aspects:

General Design Criterion (GDC) 2 contained in Appendix A to 10 CFR Part 50, as related to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, and hurricanes. Acceptance for meeting this criterion is based on conformance to positions C.1, C.2, C.6, and C.8 of RG 1.13 and position C.1 of RG 1.29 for safety-related and position C.2 of RG 1.29 for nonsafety-related portions of the system.

This criterion does not apply to the cleanup portion of the system and need not apply to the cooling system if the fuel pool makeup water system and its source meet this criterion, the fuel pool building and its ventilation and filtration system meet this criterion, and the ventilation and filtration system meets the guidelines of RG 1.52.

The cooling and makeup system should be designed to Quality Group C requirements in accordance with RG 1.26. However, when the cooling system is not designated Category I it need not meet the requirements of ASME Section XI for in-service inspection of nuclear plant components.

### 107) How does B.5.b apply to spent fuel pools?

**Public Response:** The answer below is a compilation of two questions contained in the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Section B.5.b of the ICM Order required licensees to "Develop specific guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities using existing or readily available resources (equipment and personnel) that can be effectively implemented under the circumstances associated with loss of large areas of the plant due to explosions or fire." Phase 1 was part of a larger NRC effort to enhance the safety and security of the nation's nuclear power plants. In Phase 2, the NRC independently looked at additional ways to protect the spent fuel pools at nuclear power plants. The NRC's plant-specific assessments identified both "readily available" and other resources that could be used to mitigate damage to spent fuel pools and the surrounding areas. The assessments considered damage that could have been caused by land, water, or air attacks.

## Station Blackout

This is not exactly related to seismic questions. But, similar to the above topics, I read these with great interest. I believe there are many staff who would like to be more informed about this topic and this is an excellent summary. So, I have included it here.

A Factsheet related to station blackout has been added (see pg XX).

### 108) What is the definition of station blackout?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Station blackout (SBO) means the complete loss of alternating current (ac) electric power to the essential and nonessential switchgear buses in a nuclear power plant (i.e., loss of offsite electric power system concurrent with turbine trip and unavailability of the onsite emergency ac power system). Station blackout does not include the loss of available ac power to buses fed by station batteries through inverters or by alternate ac sources as defined in this section, nor does it assume a concurrent single failure or design basis accident. At single unit sites, any emergency ac power source(s) in excess of the number required to meet minimum redundancy requirements (i.e., single failure) for safe shutdown (non-DBA) is assumed to be available and may be designated as an alternate power source(s) provided the applicable requirements are met. At multi-unit sites, where the combination of emergency ac power sources exceeds the minimum redundancy requirements for safe shutdown (non-DBA) of all units, the remaining emergency ac power sources may be used as alternate ac power sources provided they meet the applicable requirements. If these criteria are not met, station blackout must be assumed on all the units.

### 109) What is the existing regulatory requirement regarding SBO?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Each light-water-cooled nuclear power plant licensed to operate must be able to withstand for a specified duration and recover from a station blackout as defined in Sec. 50.2.

### 110) How many plants have an alternate ac (AAC) source with the existing EDGs

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** 60 plants

### 111) How many plants cope with existing class 1E batteries?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** 44 plants

### 112) What are the coping duration determined for the plants based on the SBO Rule ?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** 4-16 hours (4 hours only with batteries; 4-16 with AAC)

### 113) How is coping duration determined?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The specified station blackout duration shall be based on the following factors:

(i) The redundancy of the onsite emergency ac power sources;

(ii) The reliability of the onsite emergency ac power sources;

(iii) The expected frequency of loss of offsite power; and

(iv) The probable time needed to restore offsite power.

### 114) When does the SBO event start?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The onset of a loss of offsite power and onsite power as verified by the control room indications

### 115) When does the SBO event end?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Either onsite or offsite power is recovered.

### 116) Did the NRC review the licensee's actions to meet the SBO rule?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes. The NRC staff reviewed the responses from each licensee and issued a SER accepting the proposed coping methods. All plants have (1) established SBO coping and recovery procedures; (2) completed training for these procedures; (3) implemented modifications as necessary to cope with an SBO; and (4) ensured a 4-16 hour coping capability. In addition, the staff performed pilot inspections at 8 sites to verify the implementation of the SBO rule implementation. No issues were identified during initial implementation.

### 117) Are all plants designed to mitigate a station blackout event?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes. All plants have the capability to withstand and recover from a SBO event. In 1988, the NRC concluded that additional regulatory requirements were justified in order to provide further assurance that a loss of both offsite and onsite emergency ac power systems—a station blackout condition--would not adversely affect public health and safety. Studies conducted by the NRC have shown that the hardware and procedures that have been implemented to meet the station blackout requirements have resulted in significant risk reduction and have further enhanced defense in depth.

## Emergency Preparedness (Emphasis on B.5.b)

Although this is not strictly seismic, it is often the case that design for mitigation actions taken for one issue have impact on others. It seems apparent that the actions taken for B.5.b are going to have an impact on the assessment of seismic risk at the plants.

### 118) Is the emergency preparedness planning basis for nuclear power plants is valid?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Yes- NRC continues to conduct studies to determine the vulnerability of nuclear power plants and the adequacy of licensee programs to protect public health and safety. Whether the initiating event is a severe earthquake, a terrorist based event, or a nuclear accident, the EP planning basis provides reasonable assurance that the public health and safety will be protected. EP plans have always been based on a range of postulated events that would result in a radiological release, including the most severe.

### 119) What is B.5.b?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** After the terrorist attacks of 9/11, the NRC issued an Interim Compensatory Measures (ICM) Order on February 25, 2002, requiring power reactor licensees to take certain actions to prevent or mitigate terrorist attacks. Section B.5.b of the ICM Order required licensees to "Develop specific guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities using existing or readily available resources (equipment and personnel) that can be effectively implemented under the circumstances associated with loss of large areas of the plant due to explosions or fire."

### 120) What were Phases 1, 2, and 3 of the B.5.b?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:**

**Phase 1:** Phase 1 was part of a larger NRC effort to enhance the safety and security of the nation's nuclear power plants. The Phase 1 effort was initiated as part of the February 2002 ICM Order. The Order, among other things, required licensees to look at what might happen if a nuclear power plant lost large areas due to explosions or fire. The licensees then were required to identify – and later implement – strategies that would maintain or restore cooling for the reactor core, containment building, and spent fuel pool. The requirements listed in Section B.5.b of the ICM Order directed licensees to identify "mitigative strategies" (meaning the measures licensees could take to reduce the potential consequences of a large fire or explosion) that could be implemented with resources already existing or "readily available."

**Phase 2:** In Phase 2, the NRC independently looked at additional ways to protect the spent fuel pools at nuclear power plants. The NRC's plant-specific assessments identified both "readily available" and other resources that could be used to mitigate damage to spent fuel pools and the surrounding areas. The assessments considered damage that could have been caused by land, water, or air attacks.

**Phase 3:** In Phase 3, each nuclear power plant licensee identified ways to improve its ability to protect the reactor core and containment from a terrorist attack. This was done by identifying both "readily available" and other resources that could be used to mitigate loss of large areas of the plant due to fires and explosions. In addition, the NRC independently assessed the plant and audited the licensee's effort to identify additional mitigation strategies.

### 121) Has the NRC inspected full implementation of the mitigating strategies?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** All phases of the B.5.b mitigating strategies were complete and inspected by December 2008.

### 122) What additional action has been taken?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** On March 27, 2009, the NRC amended 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," which added 10 CFR 50.54(hh)(2) in order to impose the same mitigating strategies requirements on new reactor applicants and licensees as those imposed by the ICM Order and associated license conditions. The Statement of Considerations for this rulemaking specifically noted that the requirements described in Section 50.54(hh) are for addressing certain events that are the cause of large fires and explosions an in addition, the rule contemplates that the initiating event for such large fires and explosions could be any number of beyond-design basis events, including natural phenomena such as earthquakes, tornadoes, floods, and tsunami.

### 123) Is more information available about the mitigating strategies and inspections and reviews conducted?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** In general, the B.5.b mitigating strategies are plans, procedures, and pre-staged equipment whose intent is to minimize the effects of adverse events or accidents due to terrorist attacks. The NRC does not publicly release information that could assist terrorists to make nuclear power plants less safe. Since the NRC cannot share the details of the mitigating strategies with the public, we have given briefings to elected officials such as state governors and members of Congress to share sensitive unclassified or classified information, as appropriate. In addition, the NRC

## Other External Hazards

### 124) How many plants are in hurricane zones?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The plants near Gulf of Mexico and East coast as far north as Pilgrim have experienced Hurricane force winds in the past. Approximately 30 plants fall in this category.

### 125) How many plants are susceptible to flooding?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Most nuclear plants are close to large bodies of water and are situated on flat lands. Approximately 80% of the plants fall in this category. There are a few plants that may NOT be vulnerable to flooding such as Palo Verde.

### 126) How many plants are susceptible to blizzard?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** The plants in California, Arizona, South Texas, Louisiana and Florida are not expected to fall in this category. Approximately 80% of the plants are likely to experience blizzard conditions or adverse wintry weather conditions.

### 127) How many plants are susceptible to tornadoes?

**Public Response:** The below comes from the Q&As for the 3/21 commissioner's briefing. Please make sure these are OK to provide to the public before doing so.

**Additional, technical, non-public information:** Majority of the plants in the Midwest and the South have had tornado activity in the area. Approximately 50% of the operating plants

# Plant-Specific Questions

## San Onofre Nuclear Generating Station (SONGS) Questions

### 128) Could an earthquake and tsunami the size of the one in Japan happen at San Onofre?

No. [insert response to "Does the NRC consider earthquakes of magnitude 9"] Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximately 8.25; and that would only occur on the largest fault lines, such as the San Andreas fault, which is 50 miles away onshore.

### 129) What magnitude earthquake are currently operating US nuclear plants such as SONGS designed to?

Each reactor is designed for a different ground motion that is determined on a site-specific basis. Ground motion is a function of both the magnitude of an earthquake and the distance from the fault to the site; and it is ground motion that causes damage. So, Nuclear plants, and in fact all engineered structures, are actually designed based on ground motion levels, not earthquake magnitudes. The existing nuclear plants were designed based on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquakes expected in the area around the plant. The scenario earthquake at SONGS is a magnitude 7 approximately 5 miles from the main plant. This earthquake results in a ground motion that has a peak ground acceleration of 0.67g, that is 67% of the acceleration of gravity.

### 130) Could San Onofre withstand an earthquake of the magnitude of the Japanese earthquake?

It could withstand the ground shaking experienced by the Japanese nuclear plants. As discussed above, it is actually ground motions that structures, systems, and components "feel". We do not have direct recordings of ground motion at the Japanese reactors. However, we do have estimates of shaking that come from a ShakeMap produced by the K-NET system. The ground motion at the Japanese nuclear reactors is believed to be somewhat on the order of the 0.67g, or possibly slightly higher, that San Onofre peak ground acceleration has been analyzed to. However, US nuclear plants have additional seismic margin, as demonstrated by the result of the Individual Plant Examination of External Events program carried out by the NRC in the mid-90s.

It should be noted that, the Fukushima plant also withstood the earthquake. In the hour or so after the earthquake the Fukushima plant's safety systems, including the diesel generators, performed as expected and effectively shut down the reactor. The cause of the problems at the plant stemmed from the loss of emergency power that appears to be the direct result of the subsequent tsunami, which far exceeded the design basis tsunami for the Fukushima plant.

### 131) Is possible to have a tsunami at San Onofre that is capable of damaging the plant?

**Public Information**: The San Onofre Units 2 and 3 plant grade is elevation +30.0 feet MLLW. San Onofre has reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action. The controlling tsunami for San Onofre occurring during simultaneous high tide and storm surge produces a maximum runup to elevation +15.6 feet MLLW at the Unit 2 and 3 seawall. When storm waves are superimposed, the predicted maximum runup is to elevation +27 MLLW. Tsunami protection for the SONGS site is provided by a reinforced concrete seawall constructed to elevation +30.0 MLLW. A tsunami larger than this is extremely unlikely.

**Additional, technical, non-public information:** None

### 132) Has the earthquake hazard at San Onofre been reviewed like Diablo Canyon nuclear power plant is doing? Are they planning on doing an update before relicensing?

Relicensing does not evaluate seismic hazard or other siting issues. Seismic safety is part of NRC's ongoing licensing activities. If an immediate safety concern immerged, the issue would be addressed as part of NRC's response, regardless of relicensing status.

The closest active fault is approximately five miles offshore from San Onofre, a system of folds and faults exist called the offshore zone of deformation (OZD). The OZD includes the Newport-Inglewood-Rose Canyon fault system. The Cristianitos fault is ½ mile southeast, but is an inactive fault. Other faults such as the San Andreas and San Jacinto, which can generate a larger magnitude earthquake, are far enough away that they would produce ground motions much less severe than earthquakes in the OZD for San Onofre.

Notwithstanding the above, the NRC is considering extending the Generic Issue 199 program to all operating reactors. This would require a reassessment of hazard for San Onofre using the latest probabilistic seismic hazard assessment approaches. Based on a preliminary assessment using the source model developed by the USGS for the national seismic hazard maps, the annual probability of occurrence of a 0.67g ground motion at the San Onofre site is only slightly higher than is than the annual probability of occurrence that is recommended for new nuclear plants.

**Additional, technical, non-public information:** Past history relative to nearby major quakes have been of no consequences to San Onofre. In fact, three major earthquakes from 1992 to 1994 (Big Bear, Landers and Northridge), ranging in distance from 70-90 miles away and registering approximately 6.5 to 7.3 magnitude, did not disrupt power production at San Onofre. The plant is expected to safely shutdown if a major earthquake occurs nearby. Safety related structures, systems and components have been designed and qualified to remain functional and not fail during and after an earthquake.

### 133) How do we know that the emergency diesel generators in San Onofre will not fail to operate like in Japan?

[See response to same question in earlier section]

### 134) Was there any damage to San Onofre from either the earthquake or the resulting tsunami?

There was no damage at the San Onofre nuclear plant from either the earthquake or tsunami.

### 135) What about emergency planning for San Onofre. Does it consider tsunami?

**Public Response**: FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at San Onofre. The next such exercise is planned for April 12, 2011.

The San Onofre emergency plan initiates the emergency response organization and results in declaration of emergency conditions via their Emergency Action Levels. The facility would then make protective action recommendations to the Governor, who would then decide on what protective actions would be ordered for the residents around San Onofre. The consideration of tsunami would be contained in the State and local (City, County) emergency plans, which are reviewed by FEMA.

**Additional, technical, non-public information:** None

**136) SONGS received a white finding in 2008 for 125VDC battery issue related to the EDGs that went undetected for 4 years. NRC issued the white finding as there was increased risk that one EDG may not have started due to a low voltage condition on the battery on one Unit (Unit 2). Aren't all plants susceptible to the unknown? Is there any assurance the emergency cooling systems will function as desired in a Japan-like emergency?**

**Public response:** The low voltage condition was caused by a failure to properly tighten bolts on a electrical breaker that connected the battery to the electrical bus that would be relied on to start the EDG in case of a loss of off-site power. This was corrected immediately on identification and actions taken to prevent its reoccurrence. The 3 other EDGs at SONGS were not affected.

**Additional, technical, non-public information:** None

**137) What is the height of water that SONGS is designed to withstand?**

**Public Response:** 30 feet (9.1 meters). Information for all plants can be found in the "Additional Information' section of this document.

**Additional, technical, non-public information:** None

**138) What about drawdown and debris?**

**Public Response:** *Good question...can HQ answer? Goutam, Henry, or Rich...can you help with this one?*

**Additional, technical, non-public information:** None

**139) Will this be reviewed in light of the Japan earthquake.**

**Public Response:** The NRC will do a thorough assessment of the lessons learned from this event and will review all potential issues at US nuclear plants as a result.

**Additional, technical, non-public information:** None

**140) Could all onsite and offsite power be disrupted from SONGS in the event of a tsunami, and if that happened, could the plant be safely cooled down if power wasn't restored for days after?**

**Public Response:** Seismic Category I equipment is equipment that is essential to the safe shutdown and isolation of the reactor or whose failure or damage could result in significant release of radioactive material. All Seismic Category I equipment at SONGS is designed to function following a DBE with ground acceleration of 0.67g.

The operating basis earthquake (1/2 of the DBE) is characterized by maximum ground shaking of 0.33g. Historically, even this level of ground shaking has not been observed at the site. Based on expert analysis, the average recurrence interval for 0.33g ground shaking at the San Onofre site would be in excess of 1000 years and, thus, the probability of occurrence in the 40-year design life of the plant would be less than 1 in 25. The frequency of the DBE would be much more infrequent, and very unlikely to occur during the life of the plant. Even if an earthquake resulted in greater than the DBE movement/acceleration at SONGS, the containment structure would ultimately protect the public from harmful radiation release, in the event significant damage occurred to Seismic category 1 equipment.

**Additional, technical, non-public information:** None

### 141) Are there any faults nearby SONGS that could generate a significant tsunami?

**Public Response:** Current expert evaluations estimate a magnitude 7 earthquake about 4 miles (6.4 km) from SONGS. This is significantly less than the Japan earthquake, and SONGS has been designed to withstand this size earthquake without incident. Should discuss the different tectonic nature (not a subduction zone like Japan)?

**Additional, technical, non-public information:** None

### 142) What magnitude or shaking level is SONGS designed to withstand? How likely is an earthquake of that magnitude for the SONGS site?

**Public Response:** The design basis earthquake (DBE) is defined as that earthquake producing the maximum vibratory ground motion that the nuclear power generating station is designed to withstand without functional impairment of those features necessary to shut down the reactor, maintain the station in a safe condition, and prevent undue risk to the health and safety of the public. The DBE for SONGS was assessed during the construction permit phase of the project. The DBE is postulated to occur near the site (5 miles (8km)), and the ground accelerations are postulated to be quite high (0.67g), when compared to other nuclear plant sites in the U.S (0.25g or less is typical for plants in the eastern US). Based on the unique seismic characteristics of the SONGS site, the site tends to amplify long-period motions, and to attenuate short-period motions. These site-specific characteristics were accounted for in the SONGS site-specific seismic analyses.

**Additional, technical, non-public information:** None

### 143) Could SONGS withstand an earthquake of the magnitude of the Japanese earthquake?

**Public Response:** We do not have current information on the ground motion at the Japanese reactors. SONGS was designed for approximately a 7.0 magnitude earthquake 4 miles (6.4 km) away. The Japanese earthquake was much larger (8.9), but was also almost 9 miles (14.5 km) away. The local ground motion at a particular plant is significantly affected by the local soil and bedrock conditions. SONGS was designed (0.67g) to withstand more than 2 times the design motion at average US plants.

**Additional, technical, non-public information:** None

### 144) What about the evacuation routes at SONGS? How do we know they are reasonable?

**Public Response:** FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at SONGS. The next such exercise is planned for April 12, 2011.

**Additional, technical, non-public information:** None

### 145) Regarding tsunami at DCNPP and SONGS, is the tsunami considered separately from flooding in licensing? And from the design perspective, is the flood still the controlling event for those plants rather than the tsunami?

Public response: See below

**146) What is the design level flooding for San Onofre? Can a tsunami be larger?**

**Public response:** San Onofre is located above the flood level associated with tsunami. San Onofre has reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action

**Additional, technical, non-public information:** None

**147) Is there potential linkage between the South Coast Offshore fault near SONGS and the Newport-Inglewood Fault system and/or the Rose Canyon fault? Does this potential linkage impact the maximum magnitude that would be assigned to the South Coast Offshore fault and ultimately to the design basis ground motions for this facility?**

**Public response:** Stephanie and Jon to answer (you may want to change the question) based on the discussions in the articles sent by Lara U.

**Additional, technical, non-public information:** Proposed action is to check the FSAR for San Onofre and read the discussion on characterization of the offshore fault. A quick look at discussion of the Newport Ingelwood from other sources suggest this is part of the "system". It would be helpful to check the basis for segmenting the fault in the FSAR. Probably have to dig on this a bit, may need to look at the USGS/SCEC/ model for this area.

## Diablo Canyon Nuclear Power Plant (DCNPP) Questions

### 148) Could an earthquake and tsunami the size of the one in Japan happen at Diablo Canyon?

[use same response as "Could an earthquake and tsunami the size of the one in Japan happen at San Onofre?"]

### 149) What magnitude earthquake are currently operating US nuclear plants such as Diablo Canyon designed to?

[use response to same question for SONG, but substitute the following: "The scenario earthquake at Diablo is a magnitude 7.5 on the Hosgri Fault 3 miles from the main plant. This earthquake results in a ground motion that has a peak ground acceleration of 0.75g, that is 75% of the acceleration of gravity.]

### 150) Could the newly discovered Shoreline Fault produce a larger "Scenario Earthquake"?

The NRC's preliminary analyses indicate that the ground motions from the largest earthquakes expected on the smaller Shoreline Fault do not exceed the ground motions from the Hosgri Fault, for which the plant has already been analyzed and been found to be safe. NRC is currently reviewing the Final Report on the Shoreline Fault that was submitted to the NRC earlier this year. The NRC is performing an independent analysis of potential ground motions based the data contained in the report and other information. Much of the data on the Shoreline Fault comes from the USGS in Menlo Park.

### 151) Could Diablo Canyon withstand an earthquake of the magnitude of the Japanese earthquake?

It could withstand the ground shaking experienced by the Japanese nuclear plants. As discussed above, it is actually ground motions that structures, systems, and components "feel". We do not have direct recordings of ground motion at the Japanese reactors. However, we do have estimates of shaking that come from a ShakeMap produced by the the K-NET system. The ground motion at the Japanese nuclear reactors is believed to be somewhat smaller than the 0.75g peak ground acceleration that Diablo Canyon has been analyzed to. Do, Diablo Canyon could withstand the ground shaking experienced by the Fukushima plant.

In fact, the Fukushima plant also withstood the earthquake. In the hour or so after the earthquake the Fukushima plant's safety systems, including the diesel generators, performed as expected and effectively shut down the reactor. The cause of the problems at the plant stemmed from the loss of emergency power that appears to be the direct result of the subsequent tsunami, which far exceeded the design basis tsunami for the Fukushima plant.

### 152) Is Diablo Canyon's equipment vulnerable to tsunami?

Nuclear plants are designed to withstand protection against natural phenomena such as tsunami, earthquakes. Diablo Canyon's main plant is located above the flood level associated with tsunami. The intake structures and Auxiliary Sea Water System at Diablo canyon are designed for combination of tsunami and storm wave activity.

### 153) How do we know that the emergency diesel generators in Diablo Canyon will not fail to operate like in Japan?

[see same question in earlier section]

**154) Was there any damage to Diablo Canyon from either the earthquake or the resulting tsunami?**

A small tsunami did hit the region around Diablo Canyon. There was no damage at the nuclear plant.

155) <u>How do we know the evacuation routes in the region around Diablo Canyon are realistic?</u>

FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at DCNPP.

**156) Now after the Japan tragedy, will the NRC finally hear us (A4NR) and postpone DC license renewal until seismic studies are complete? How can you be sure that what happened there is not going to happen at Diablo with a worse cast earthquake and tsunami?**

**Public response:** ADD

**Additional, technical, non-public information:** ADD

**157) The evacuation routes at DCNPP see are not realistic. Highway 101 is small...and can you imagine what it will be like with 40K people on it? Has the evacuation plan been updated w/ all the population growth?**

**Public Response:** FEMA reviews off-site evacuation plans formally every 2 years during a biennial emergency preparedness exercise. NRC evaluates on-site evacuation plans during the same exercise. Population studies are formally done every 10 years, and evacuation time estimates are re-evaluated at that time. FEMA reviews these evacuation plans, and will conclude their acceptability through a finding of "reasonable assurance" that the off-site facilities and infrastructure is capable of protecting public health and safety in the event of an emergency at DCNPP.

**Additional, technical, non-public information:** None

**158) Are there local offshore fault sources capable of producing a tsunami with very short warning times?**

**Public Response:** ADD- question forwarded to region

**Additional, technical, non-public information:** ADD

**159) Are there other seismically induced failure modes (other than tsunami) that would yield LTSBO? Flooding due to dam failure or widespread liquefaction are examples.**

**Public Response:** ADD question forwarded to region

**Additional, technical, non-public information:** ADD

**160) Ramifications of beyond design basis events (seismic and tsunami) and potential LTSBO on spent fuel storage facilities?**

**Public Response:** ADD question forwarded to region

**Additional, technical, non-public information:** ADD

161) **Why did the Emergency Warning go out for a 'tsunami' that was only 6 ft (1.8 m) high? Do these guys really know what they're doing? Would they know it if a big one was really coming? Crying wolf all the time doesn't instill a lot of confidence.**

**Public Response:** The warning system performed well. The 6 foot (1.8 meters) wave was predicted many hours before and arrived at the time it was predicted. Federal officials to accurately predicted the tsunami arrival time and size; allowing local official to take appropriate measures as they saw necessary to warn and protect the public. It should be understood that even a 6 foot tsunami is very dangerous. Tsunamis have far more energy and power than wind-driven waves.

**Additional, technical, non-public information:** ADD

**The Japanese were supposed to have one of the best tsunami warning systems around. What went wrong last week?**

**Public Response:** ADD can HQ answer?

**Additional, technical, non-public information:** ADD

*NOTE: need to add to SONGS and DCNPP... Canyon and San Onofre IPEEEs - based on the Technical Evaluation Reports, Diablo did consider a locally induced tsunami in a limited way (the aux service water pumps were assumed to become flooded following a seismic event) while SONGS did not consider a coupled seismic/tsunami event.*

162) **Shouldn't the NRC make licensees consider a Tsunami coincident with a seismic event that triggers the Tsunami?**

ADD

163) **Given that SSCs get fatigued over time, shouldn't the NRC consider after-shocks in seismic hazard analyses?**

ADD

164) **Did the Japanese also consider an 8.9 magnitude earthquake and resulting tsunami "way too low a probability for consideration"?**

ADD

165) **GI-199 shows that the scientific community doesn't know everything about the seismicity of CEUS. And isn't there a prediction that the West coast is likely to get hit with some huge earthquake in the next 30 years or so? Why does the NRC continue to license plants on the west coast?**

Work the following into Q&As as time permits.

After an earthquake, in order to restart, In practice a licensee needs to determine from engineering analysis that the stresses on the plant did not exceed their licensed limits. That would be a very tall order for a plant that experienced a beyond design basis earthquake, and probably is why it had taken Japan so long to restore the KK plants following the earlier earthquake.

**166) Has anyone done work to look at the effect of many cycles of low amplitude acceleration following a larger event. How do we know a plant would be fit to start back up after an event? We cannot possibly do NDE on everything to determine if flaws have propagated to the point where they need to be replaced.**

### 167) Aren't the California plants right on the San Andreas fault?

No. Both plants are approximately 50 miles from the San Andreas Fault. However, both are closer to other active fault zones. Diablo Canyon is closer to the Hosgri fault zone and has been retrofit to be safe in ground motions from a magnitude 7.5 earthquake on the Hosgri, which is 3 miles away. Recently there was a new fault, called the Shoreline fault discovered, about a 1/2 mile from the plant. But it is smaller and only capable of about a 6.5 earthquake at the most. The ground motions from the Hosgri's 7.5 earthquake would be larger than an 6.5 on the Shoreline fault. San Onofre is closes to the Newport-Inglewood fault which is about 5 miles away and capable of a magnitude 7. San Onofre was built to withstand the ground motions from that earthquake.

## Indian Point Questions

### 168) Why is Indian Point safe if there is a fault line so close to it?

**Public Response**: The Ramapo fault system, located near the Indian Point Nuclear Power Plant, is an example of an old fault system that, based on geologic field evidence, has not been active in the last 65.5 million years. The Ramapo fault system extends primarily from southeastern New York to northern New Jersey and is made up of a series of northeast- oriented faults. Even though there is minor earthquake activity in the vicinity of the Ramapo faults, this earthquake activity cannot be directly correlated with any individual fault within the Ramapo fault system.

US nuclear power plants are designed and built to withstand the largest expected earthquake in the site region, based on observed historical seismicity and field evidence for prehistoric earthquakes, and are also designed to incorporate seismic safety margins. A potential earthquake in and around the vicinity of the Ramapo fault system was taken into account during the NRC licensing process for the Indian Point plants, and the plant design incorporated the largest expected earthquake in the site region. In summary, the Ramapo fault system exhibits no definitive evidence for recent fault displacement (i.e., no evidence for fault activity in the last 65.5 million years) and the Indian Point nuclear power plant was designed and built to safely shutdown in the event of an earthquake having the highest magnitude observed in the site region. Therefore, the NRC concluded that the risk of significant damage to the Indian Point reactors due to a potential earthquake is acceptable.

**Additional, technical, non-public information:** The information above and following is consistent with the literature and the UFSAR for IP related to the Ramapo fault. The Ramapo fault system, which passes through the Indian Point area, is a group of Mesozoic age faults, extending from southeastern New York to northern New Jersey, as well as further southwest. The fault system is composed of a series of southeast-dipping, northeast-striking faults. Various faults of the system contain evidence of repeated slip in various directions since Proterozoic time, including Mesozoic extensional reactivation. However, the USGS staff, who reviewed 31 geologic features in the Appalachian Mountains and Coastal Plain and compiled a National Database on Quaternary Faulting (Crone and Wheeler, 2000), listed the Ramapo fault system as low risk because the fault system lacks evidence for Quaternary slip. They further pointed out that the Ramapo fault system, and 17 other geologic features, "have little or no published geologic evidence of Quaternary tectonic faulting that could indicate the likely occurrence of earthquakes larger than those observed historically" (Wheeler and Crone, 2004). Among these faults, the Ramapo fault system is one of the three that underwent a paleoseismological study. In two trenches excavated across the Ramapo fault, no evidence of Quaternary tectonic faulting was found (Wheeler and Crone, 2000). Because the Ramapo fault system is relatively inactive, , and because the plants are designed to safely shutdown in the event of an earthquake of the highest intensity ever recorded in that area, the NRC has concluded that the risk of significant damage to the reactors due to a probable earthquake in the area is extremely small.

The letter that was sent to the NRC from Rep Lowey refers to the Ramapo seismic zone (RSZ) and the Dobbs Ferry fault. The letter incorrectly states that the Dobbs Ferry fault is located within the Ramapo seismic zone. Based on the literature, it is not. It is close, but it is considered to be in the Manhattan Prong more to the east (more like 10-15 miles away) while the Ramapo fault system is considered to be in the Reading Prong (a couple of miles away from IP). Also for clarification, the seismicity is considered to be within the Precambrian/Paleozoic basement at depths greater than the Mesozoic Newark Basin where the RSZ is situated.

## Pending and Unanswered Questions from Members of Congress

The below questions are gleaned from the congressional letters coming into the NRC. Because they generally cover different topics, they are being kept together as sets to assist the office assigned with response. Once a formal response is developed and sent, the questions will be moved to the appropriate sections.

### 169) Received 3/16/11 from Congresswoman Lowey

The key elements of the congresswoman's letter are as follows:

The Ramapo Seismic Zone is a particular threat because the zone passes within two miles of Indian Point. The Ramapo Seismic zone includes the Dobbs Ferry fault in Westchester, which generated a 4.1 magnitude earthquake in 19S5. The Columbia University study suggests that this pattern of subtle but active faults increases the risk to the New York City area and that an earthquake with a magnitude of 7.0 on the Richter scale is within reach. Disturbingly, Entergy measures the risk of an earthquake near Indian Point to be between 1.0 and 3.0 on the Richter scale, despite evidence to the contrary.

The NRC should study Indian Point's risk of, and ability to sustain a disaster, including the impact of earthquakes and hurricanes, as well as collateral impacts such as loss of power, inability to cool reactors and emergency evacuation routes. The NRC should evaluate how a similar incident in the New York metropolitan area could be further complicated due to a dramatically higher population and the effectiveness of the proposed evacuation routes.

**Public Response**: Please see response in the Indian Point section.

**Additional, technical, non-public information:** None.

### 170) From 3/16/11 Press Release from Senators Boxer and Feinstein

**Plant Design and Operations**

1. What changes to the design or operation of the Diablo Canyon and SONGS facilities have improved safety at the plants since they began operating in the mid-1980s?

   **Public Response**: NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

2. What emergency notification systems have been installed at California nuclear power plants? Has there ever been a lapse of these systems during previous earthquakes or emergencies?

   **Public Response**: NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

3. What safety measures are in place to ensure continued power to California reactors in the event of an extended power failure?

   **Public Response**: NRR/DORL developing response

   **Additional, technical, non-public information:** ADD

**Type of Reactor**

4. What are the differences and similarities between the reactors being used in California (pressurized water reactors) and those in Japan (boiling water reactors), as well as the

facilities used to house the reactors, including the standards to which they were built and their ability to withstand natural and manmade disasters?

**Public Response:** NRR/DORL developing response

**Additional, technical, non-public information:** ADD

**Earthquakes and Tsunamis**

5. We have been told that both Diablo Canyon and San Onofre Nuclear Generating Station are designed to withstand the maximum credible threat at both plants, which we understand to be much less than the 9.0 earthquake that hit Japan. What assumptions have you made about the ability of both plants to withstand an earthquake or tsunami? Given the disaster in Japan, what are our options to provide these plants with a greater margin for safety?

    **Public Response:** Annie and Kamal developing response

    **Additional, technical, non-public information:** ADD

6. Have new faults been discovered near Diablo Canyon or San Onofre Nuclear Generating Station since those plants began operations? If so, how have the plants been modified to account for the increased risk of an earthquake? How will the NRC consider information on ways to address risks posed by faults near these plants that is produced pursuant to state law or recommendations by state agencies during the NRC relicensing process?

    **Public Response:** Annie and Kamal developing response

    **Additional, technical, non-public information:** ADD

7. What are the evacuation plans for both plants in the event of an emergency? We understand that Highway 1 is the main route out of San Luis Obispo, what is the plan for evacuation of the nearby population if an earthquake takes out portions of the highway and a nuclear emergency occurs simultaneously?

    **Public Response:** NRR/DORL developing response

    **Additional, technical, non-public information:** ADD

8. What is the NRC's role in monitoring radiation in the event of a nuclear accident both here and abroad? What is the role of EPA and other federal agencies?

    **Public Response:** NRR/DORL developing response

    **Additional, technical, non-public information:** ADD

9. What monitoring systems currently are in place to track potential impacts on the US, including California, associated with the events in Japan?

    **Public Response:** NRR/DORL developing response

    **Additional, technical, non-public information:** ADD

10. 6. Which federal agency is leading the monitoring effort and which agencies have responsibility for assessing human health impacts? What impacts have occurred to date on the health or environment of the US or are currently projected or modeled in connection with the events in Japan?

    **Public Response:** NRR/DORL developing response

    **Additional, technical, non-public information:** ADD

11. What contingency plans are in place to ensure that the American public is notified in the event that hazardous materials associated with the events in Japan pose an imminent threat to the US?

    **Public Response:** NRR/DORL developing response

    **Additional, technical, non-public information:** ADD

### 171) From 3/15/11 Press Release from Congresspeople Markey and Capps

Note that these are only the seismic questions. There are other questions that are structural

1. Provide the Richter or moment magnitude scale rating for each operating nuclear reactor in the United States. If no such information exists, on what basis can such an assertion be made regarding the design of any single nuclear power plant?

**Public Response:** US nuclear power plants are designed for different ground motions determined on a site-specific basis, which are called the Safe Shutdown Earthquake ground motions (SSE). Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location. Ground motion, or shaking, is a function of both earthquake magnitude and distance from the fault to the site. The magnitude alone cannot be used to predict ground motions. Currently operating nuclear power plants developed their SSEs based on a "deterministic" or "scenario earthquake" basis that account for the largest earthquake expected in the area around the plant.

Please see the available table of Design Basis Ground Motions for US Plants in the Additional Information: Useful Tables.

**Additional, technical, non-public information:** ADD

2. The San Onofre reactor is reportedly designed to withstand a 7.0 earthquake, and the Diablo Canyon reactor is designed to withstand a 7.5 magnitude. According to the Southern California Earthquake Center (SCEC), there is an 82% probability of an earthquake 7.0 magnitude in the next 30 years, and a 37 percent probability that an earthquake of 7.5 magnitude will occur. Shouldn't these reactors be retrofitted to ensure that they can withstand a stronger earthquake than a 7.5? If not, why not?

**Public Response:** This needs to be edited and enhanced. The noted SCEC magnitudes and probabilities are sourced from Uniform California Earthquake Rupture Forecast (UCERF) Figure 2 (http://www.scec.org/core/public/sceccontext.php/3935/13662). The value quoted describes the probability that an earthquake of that magnitude will occur somewhere in Southern California. The probability that earthquakes of those magnitudes occur near the plants is far smaller. Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location.

**Additional, technical, non-public information:** The colors in UCERF Figure 2 represent the probabilities of having a nearby earthquake rupture (within 3 or 4 miles) of magnitude 6.7 or larger in the next 30 years. Therefore, reading the colors off of Figure 2, the San Onofre and Diablo Canyon NPPs have a ≤10% probability of having a ≥M6.7 earthquake rupture within 3 to 4 miles in the next 30 years. Therefore, retrofitting these reactors to withstand earthquakes of M7.5 or stronger based on the UCERF study would put an unnecessary burden on the licensees.

3. Provide specific information regarding the differences in safety-significant structures between a nuclear power plant that is located in a seismically active area and one that is not. Provide, for each operating nuclear reactor in a seismically active area, a full list and description of the safety-

significant design features that are included that are not included in similar models that are not located in seismically active areas.

**Public Response:** This is a rough draft. We need to get some reviews of this. Assumed NRR will have ultimate responsibility for the response.

There are no differences in safety requirements for nuclear power plants located in seismically active areas and ones that are not. Regardless of site seismicity, Appendix S to 10 CFR Part 50 requires for site-specific SSE ground motions, structures, systems, and components will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motions. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation elevation of structures must be an appropriate response spectrum with peak ground acceleration (PGA) of at least 0.10g. Design basis loads for nuclear power plant structures, important to safety, include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Institute of Concrete (ACI-349) and the American Institute of Steel Construction (AISC N690), are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads. In addition to the nominal seismic design, all new generation reactors have to demonstrate a seismic margin of 1.67 relative to the site-specific seismic demands.

For the current operating fleet of nuclear power reactors, site-to-site differences in structural design can result from differences in external site hazards such as seismic, wind, tornado, and tsunami. For a low-seismicity region, wind or tornado loads may control the design. Conversely, for a high-seismicity region, seismic loads will likely control. Structures in high-seismicity regions have robust designs with typically higher capacity shear walls, as an example. Systems and components will also be more robust and are designed and tested to higher levels of acceleration.

**Additional, technical, non-public information:** ADD

4. In your opinion, can any operating nuclear reactors in the United States withstand an earthquake of the magnitude experience in Japan?

**Public Response**: The March 11, 2011, magnitude 9 earthquake that recently affected Japan is different than earthquakes that could affect US nuclear plants. Each US nuclear plant is designed to a ground-shaking level that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. The Japan earthquake was caused by a "subduction zone" event, which is the type of mechanism that produces the largest possible magnitude earthquakes. In the continental US, the only subduction zone is the Cascadia subduction zone which lies off the coast of northern California, Oregon and Washington, so an earthquake this large could only happen in that region. The only plant in that area is Columbia Generating Station, which is approximately 225 miles (363 km) from the coast and the subduction zone. Outside of the Cascadia subduction zone, earthquakes are not expected to exceed a magnitude of approximate 8, which has 31 times less energy than a magnitude 9.

**Additional, technical, non-public information:** ADD

## Additional Information: Useful Tables

### Table of Design Basis Ground Motions for US Plants

| Design Basis Earthquake Information | | | | | |
|---|---|---|---|---|---|
| **Nuclear Plant By State/Location** | **Maximum Observed Or Inferred Intensity (MMI Scale)** | **Relative Distance Of Seismic Source** | **Design SSE Peak Acceleration, *g*** | **OBE Peak Acceleration, *g*** | **Soil Condition** |
| **New York** | | | | | |
| Fitzpatrick | VI | Near | 0.15 | 0.08 | Soil |
| Ginna 1 | VIII/IX | >60 miles | 0.2 | 0.08 | Rock |
| Indian Point 2, 3 | VII | Near | 0.15 | 0.1 | Rock |
| Nine Mile Point 1 | IX-X | >60 miles | 0.11 | 0.06 | Rock |
| Nine Mile Point 2 | VI | Near | 0.15 | 0.075 | Rock |
| **New Jersey** | | | | | |
| Salem 1,2 | VII-VIII | Near | 0.2 | 0.1 | Deep Soil |
| **Connecticut** | | | | | |
| Millstone 1, 2, 3 | VII | Near | 0.17 | 0.07 | Rock |
| **Vermont** | | | | | |
| Vermont Yankee | VI | Near | 0.14 | 0.07 | Rock |
| **Ohio** | | | | | |
| Davis Besse 1 | VII | Near | 0.15 | 0.08 | Rock |
| Perry 1 | VII | Near | 0.15 | 0.08 | Rock |
| **Georgia** | | | | | |
| Hatch 1, 2 | VII | Near | 0.15 | 0.08 | Deep Soil |
| Vogtle 1, 2 | VII-VIII | Near | 0.2 | 0.12 | Deep Soil |
| **Tennessee** | | | | | |
| Seqouyah 1, 2 | VIII | Near | 0.18 | 0.09 | Rock |
| Watts Bar 1 | VIII | Near | 0.18 | 0.09 | Rock |
| **California** | | | | | |
| San Onofre 2, 3 | IX-X | Near | 0.67 | 0.34 | Soil |
| Diablo Canyon 1, 2 | X-XI | Near | 0.75 | 0.20 | Rock |
| **Florida** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Crystal River 3 | V | Near | 0.10 | 0.05 | Rock |
| St. Lucie 1, 2 | VI | Near | 0.10 | 0.05 | Soil |
| Turkey Point 3, 4 | VII | Near | 0.15 | 0.05 | Rock |

**NOTES:**

MMI=Modified Mercalli Intensity, a measure of observed/reported damage and severity of shaking.
Relative distance measure used in FSAR to develop SSE acceleration, "Near" indicates distance less than 10 miles.
SSE=Safe Shutdown Earthquake ground motion, for horizontal acceleration, in units of earth's gravity, *g*.
OBE=Operating Basis Earthquake ground motion, level of horizontal acceleration, which if exceeded requires plant shutdown.

## Table of SSE, OBE and Tsunami Water Levels

| Nuclear Plant Name<br>By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Alabama | | | |
| Browns Ferry | 0.200 | 0.100 | N/A (Non-Coastal) |
| Farley | 0.100 | 0.050 | N/A (Non-Coastal) |
| Arkansas | | | |
| Arkansas Nuclear | 0.200 | | N/A (Non-Coastal) |
| Arizona | | | |
| Palo Verde | 0.200 | 0.100 | N/A (Non-Coastal) |
| California | | | |
| Diablo Canyon | 0.400 | 0.200 | The design basis maximum combined wave runup is the greater of that determined for near-shore or distantly-generated tsunamis, and results from near-shore tsunamis. For distantly-generated tsunamis, the combined runup is 30 feet. For near-shore tsunamis, the combined wave runup is 34.6 feet, as determined by hydraulic model testing. The safety-related equipment is installed in watertight compartments to protect it from adverse sea wave events to elevation +48 feet above mean lower low water line (MLLWL). |
| San Onofre | 0.670 | 0.340 | The controlling tsunami occurs during simultaneous high tide and storm surge produces a maximum runup to elevation +15.6 feet mean lower low water line (MLLWL) at the Unit 2 and 3 seawall. When storm waves are superimposed, the predicted maximum runup is to elevation +27 MLLWL. Tsunami protection for the SONGS site is provided by a reinforced concrete seawall constructed to elevation +30.0 MLLWL. |
| Connecticut | | | |
| Millstone | 0.170 | 0.090 | 18 ft SWL |
| Florida | | | |
| Crystal River | 0.050 | 0.025 | N/A (Non-Coastal) |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| St. Lucie | 0.100 | 0.050 | No maximum tsunami level, bounded by PMH surge of +18 MLW wave runup, with plant openings at +19.5 MLW |
| Turkey Point | 0.150 | 0.050 | No maximum tsunami level, bounded by PMH surge of +18.3 MLW water level, site protected to +20 MLW with vital equipment protected to +22 MLW |
| Georgia | | | |
| Hatch | 0.150 | 0.080 | N/A (Non-Coastal) |
| Vogtle | 0.200 | 0.120 | N/A (Non-Coastal) |
| Illinois | | | |
| Braidwood | 0.200 | 0.090 | N/A (Non-Coastal) |
| Byron | 0.200 | 0.090 | N/A (Non-Coastal) |
| Clinton | 0.250 | 0.100 | N/A (Non-Coastal) |
| Dresden | 0.200 | 0.100 | N/A (Non-Coastal) |
| LaSalle | 0.200 | 0.100 | N/A (Non-Coastal) |
| Quad Cities | 0.240 | 0.120 | N/A (Non-Coastal) |
| Iowa | | | |
| Duane Arnold | 0.120 | 0.060 | N/A (Non-Coastal) |
| Kansas | | | |
| Wolf Creek | 0.120 | 0.060 | N/A (Non-Coastal) |
| Louisiana | | | |
| River Bend | 0.100 | 0.050 | |
| Waterford | 0.100 | | Floods – 30 feet MSL |
| Maryland | | | |
| Calvert Cliffs | 0.150 | 0.080 | 14 ft design wave |
| Massachusetts | | | |
| Pilgrim | 0.150 | 0.080 | *Storm flooding design basis - 18.3ft |
| Michigan | | | |
| D.C. Cook | 0.200 | 0.100 | N/A |
| Fermi | 0.150 | 0.080 | N/A |
| Palisades | 0.200 | 0.100 | N/A |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Missouri | | | |
| Callaway | 0.200 | | N/A (Non-Coastal) |
| Mississippi | | | |
| Grand Gulf | 0.150 | 0.075 | N/A |
| Minnesota | | | |
| Monticello | 0.120 | 0.060 | N/A (Non-Coastal) |
| Prarie Island | 0.120 | 0.060 | N/A (Non-Coastal) |
| Nebraska | | | |
| Cooper | 0.200 | 0.100 | N/A (Non-Coastal) |
| Fort Calhoun | 0.170 | 0.080 | N/A (Non-Coastal) |
| New York | | | |
| Fitzpatrick | 0.150 | 0.080 | N/A (Non-Coastal) |
| Ginna | 0.200 | 0.080 | N/A |
| Indian Point | 0.150 | 0.100 | 15 ft msl |
| Nine Mile Point, Unit 1 | 0.110 | 0.060 | N/A |
| Nine Mile Point, Unit 2 | 0.150 | 0.075 | N/A |
| New Hampshire | | | |
| Seabrook | 0.250 | 0.125 | (+) 15.6' MSL Still Water Level (Tsunami Flooding -Such activity is extremely rare on the US Atlantic coast and would result in only minor wave action inside the harbor.) |
| New Jersey | | | |
| Hope Creek | 0.200 | 0.100 | 35.4 MSL The maximum probable tsunami produces relatively minor water level changes at the site. The maximum runup height reaches an elevation of 18.1 feet MSL with coincident 10 percent exceedance high tide) |
| Oyster Creek | 0.184 | 0.092 | (+) 23.5' MSL Still Water Level (Probable Maximum Tsunami - Tsunami events are not typical of the eastern coast of the United States and have not, therefore, been addressed.) |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Salem | 0.200 | 0.100 | 21.9 MSL (There is no evidence of surface rupture in East Coast earthquakes and no history of significant tsunami activity in the region) |
| North Carolina | | | |
| Brunswick | 0.160 | 0.030 | N/A |
| McGuire | 0.150 | 0.080 | N/A (Non-Coastal) |
| Shearon Harris | 0.150 | | N/A (Non-Coastal) |
| Ohio | | | |
| Davis-Besse | 0.150 | 0.080 | N/A |
| Perry | 0.150 | 0.080 | N/A |
| Pennsylvania | | | |
| Beaver Valley | 0.130 | 0.060 | N/A (Non-Coastal) |
| Limerick | 0.150 | 0.075 | N/A (Non-Coastal) |
| Peach Bottom | 0.120 | 0.050 | N/A (Non-Coastal) |
| Three Mile Island | 0.120 | 0.060 | N/A (Non-Coastal) |
| Susquehanna | 0.150 | 0.080 | N/A (Non-Coastal) |
| South Carolina | | | |
| Catawba | 0.150 | 0.080 | N/A (Non-Coastal) |
| Oconee | 0.150 | 0.050 | N/A (Non-Coastal) |
| Robinson | 0.200 | 0.100 | N/A (Non-Coastal) |
| V.C. Summer | 0.250 | 0.150 | N/A (Non-Coastal) |
| Tennessee | | | |
| Sequoyah | 0.180 | 0.090 | N/A (Non-Coastal) |
| Watts Bar, Unit 1 | 0.180 | 0.090 | N/A (Non-Coastal) |
| Texas | | | |
| Comanche Peak | 0.120 | 0.060 | N/A |
| South Texas Project | 0.100 | 0.050 | N/A |
| Vermont | | | |

| Nuclear Plant Name By State/ Location | Safe Shutdown Earthquake (SSE) Peak Acceleration (g) | Operating Basis Earthquake (OBE) Peak Acceleration, (g) | Probable Maximum Tsunami OR Maximum Tsunami Water Level |
|---|---|---|---|
| Vermont Yankee | 0.140 | 0.070 | N/A |
| Virginia | | | |
| North Anna | 0.180 | | N/A |
| Surry | 0.150 | 0.080 | N/A |
| Washington | | | |
| Columbia | 0.250 | | N/A (Non-Coastal) |
| Wisconsin | | | |
| Kawaunee | 0.120 | 0.060 | N/A |
| Point Beach | 0.120 | | N/A |
| **Definition of Safe Shutdown Earthquake** | The safe-shutdown earthquake (SSE) for the site is the ground motion response spectra (GMRS), which also satisfies the minimum requirement of paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Code of Federal Regulations (10 CFR Part 50). | | |
| **Definition of Operating Basis Earthquake:** | To satisfy the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE) ground motion is defined as follows:<br>(i) For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.<br>(ii) For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in design control document (DCD).<br>(iii) The spectrum ordinate criterion to be used in conjunction with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," issued March 1997, is the lowest of (i) and (ii). | | |

## Table of Plants Near Known Active Faults or in High or Moderate Seismicity Zones

It should be noted that in much of the Central and Eastern US, the seismicity comes from "background" seismicity. Background seismicity is earthquake activity, where the earthquakes cannot be tied to known faults.

| Plant (state) | Nearest Active Fault or Seismic Zone | Distance to Fault or Range of Distances to Zones | Type of Faulting Mechanism | Range of Maximum Magnitude ($M_w$) | OBE (g) | SSE (g) |
|---|---|---|---|---|---|---|
| Diablo Canyon (CA) | Hosgri Fault | 5 miles | Predominantly Strike Slip | 7.5 | | |
| | Shoreline Fault | 0.5 miles | Strike Slip | 6.25 to 6.75 best estimate by NRC staff in RIL 09-001. Final report on the fault in review by NRC staff | | |
| San Onofre (CA) | | | | | | |
| Comanche Peak | | | | | | |

| Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes (RLE), and Seismic Core Damage Frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|
| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
| Arkansas 1 | 05000313 | 0.2 | 2.8E-04 | 0.3 | 4.1E-06 | 0.3g full-scope EPRI SMA | GI-199 |
| Arkansas 2 | 05000368 | 0.2 | 9.7E-05 | 0.3 | 4.1E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Beaver Valley 1 | 05000334 | 0.12 | 3.3E-04 | n/a | 4.8E-05 | seismic PRA | GI-199 |
| Beaver Valley 2 | 05000412 | 0.12 | 2.7E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Braidwood 1 | 05000456 | 0.2 | 6.7E-05 | 0.3 | 7.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Braidwood 2 | 05000457 | 0.2 | 6.7E-05 | 0.3 | 7.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 1 | 05000259 | 0.2 | 2.5E-04 | 0.3 | 3.7E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 2 | 05000260 | 0.2 | 2.5E-04 | 0.26 | 5.4E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Browns Ferry 3 | 05000296 | 0.2 | 2.5E-04 | 0.26 | 5.4E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Brunswick 1 | 05000325 | 0.16 | 7.3E-04 | 0.3 | 1.5E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Brunswick 2 | 05000324 | 0.16 | 7.3E-04 | 0.3 | 1.5E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Byron 1 | 05000454 | 0.2 | 5.2E-05 | 0.3 | 5.8E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Byron 2 | 05000455 | 0.2 | 5.2E-05 | 0.3 | 5.8E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Callaway | 05000483 | 0.2 | 3.8E-05 | 0.3 | 2.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Calvert Cliffs 1 | 05000317 | 0.15 | 1.9E-04 | n/a | 1.0E-05 | seismic PRA | GI-199 |
| Calvert Cliffs 2 | 05000318 | 0.15 | 1.9E-04 | n/a | 1.2E-05 | seismic PRA | GI-199 |
| Catawba 1 | 05000413 | 0.15 | 1.4E-04 | n/a | 3.7E-05 | seismic PRA | GI-199 |
| Catawba 2 | 05000414 | 0.15 | 1.4E-04 | n/a | 3.7E-05 | seismic PRA | GI-199 |
| Clinton | 05000461 | 0.25 | 5.8E-05 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Columbia | 05000397 | 0.25 | 1.7E-04 | n/a | 2.1E-05 | seismic PRA | IPEEE |
| Comanche Peak 1 | 05000445 | 0.12 | 1.6E-05 | 0.12 | 4.0E-06 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |

| Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes (RLE), and Seismic Core Damage Frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Plant** | **Docket** | **SSE (g's)** | **Frequency of Exceeding the SSE (per year)** | **RLE (HCLPF) (g's)** | **Seismic Core Damage Frequency (per year)** | **IPEEE Method** | **Source** |
| Comanche Peak 2 | 05000446 | 0.12 | 1.6E-05 | 0.12 | 4.0E-06 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |
| Cooper | 05000298 | 0.2 | 1.5E-04 | 0.3 | 7.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Crystal River 3 | 05000302 | 0.1 | 8.9E-05 | 0.1 | 2.2E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| D.C. Cook 1 | 05000315 | 0.2 | 2.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| D.C. Cook 2 | 05000316 | 0.2 | 2.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Davis Besse | 05000346 | 0.15 | 6.3E-05 | 0.26 | 6.7E-06 | reduced-scope EPRI SMA | GI-199 |
| Diablo Canyon 1 | 05000275 | 0.75 | 2.0E-04 | n/a | 4.1E-05 | seismic PRA | IPEEE |
| Diablo Canyon 2 | 05000323 | 0.75 | 2.0E-04 | n/a | 4.1E-05 | seismic PRA | IPEEE |
| Dresden 2 | 05000237 | 0.2 | 9.7E-05 | 0.26 | 1.9E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Dresden 3 | 05000249 | 0.2 | 9.7E-05 | 0.26 | 1.9E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Duane Arnold | 05000331 | 0.12 | 2.3E-04 | 0.12 | 3.2E-05 | reduced-scope EPRI SMA; SSE = 0.12g | GI-199 |
| Farley 1 | 05000348 | 0.1 | 1.0E-04 | 0.1 | 2.8E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Farley 2 | 05000364 | 0.1 | 1.0E-04 | 0.1 | 2.8E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Fermi 2 | 05000341 | 0.15 | 1.0E-04 | 0.3 | 4.2E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Fitzpatrick | 05000333 | 0.15 | 3.2E-04 | 0.22 | 6.1E-06 | 0.3g focused-scope NRC SMA | GI-199 |
| Fort Calhoun 1 | 05000285 | 0.17 | 3.7E-04 | 0.25 | 5.4E-06 | 0.3g focused-scope NRC SMA | GI-199 |
| Ginna | 05000244 | 0.2 | 1.0E-04 | 0.2 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Grand Gulf | 05000416 | 0.15 | 1.0E-04 | 0.15 | 1.2E-05 | reduced-scope EPRI SMA; SSE = | GI-199 |

| Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes (RLE), and Seismic Core Damage Frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|
| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
| | | | | | | 0.15g | |
| Hatch 1 | 05000400 | 0.148 | 3.9E-04 | 0.29 | 2.3E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Hatch 2 | 05000321 | 0.15 | 2.7E-04 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Hope Creek | 05000366 | 0.2 | 9.7E-05 | 0.3 | 2.5E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Indian Point 2 | 05000354 | 0.15 | 4.9E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Indian Point 3 | 05000247 | 0.15 | 4.9E-04 | n/a | 3.3E-05 | seismic PRA | GI-199 |
| Kewaunee | 05000286 | 0.12 | 2.8E-04 | n/a | 1.0E-04 | seismic PRA | GI-199 |
| LaSalle 1 | 05000305 | 0.2 | 1.7E-04 | n/a | 5.1E-06 | seismic PRA | GI-199 |
| LaSalle 2 | 05000373 | 0.2 | 1.7E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Limerick 1 | 05000374 | 0.15 | 1.8E-04 | n/a | 2.8E-06 | seismic PRA | GI-199 |
| Limerick 2 | 05000352 | 0.15 | 1.8E-04 | 0.15 | 5.3E-05 | reduced-scope EPRI SMA | GI-199 |
| McGuire 1 | 05000353 | 0.15 | 9.5E-05 | 0.15 | 5.3E-05 | reduced-scope EPRI SMA | GI-199 |
| McGuire 2 | 05000369 | 0.15 | 9.5E-05 | n/a | 3.1E-05 | seismic PRA | GI-199 |
| Millstone 1 | 05000370 | 0.254 | 9.3E-05 | n/a | 3.1E-05 | seismic PRA | GI-199 |
| Millstone 2 | 05000336 | 0.17 | 8.3E-05 | 0.25 | 1.1E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Millstone 3 | 05000423 | 0.17 | 8.3E-05 | n/a | 1.5E-05 | seismic PRA | GI-199 |
| Monticello | 05000263 | 0.12 | 9.3E-05 | 0.12 | 1.9E-05 | modified focused/expended reduced-scope EPRI SMA | GI-199 |
| Nine Mile Point 1 | 05000220 | 0.11 | 1.5E-04 | 0.27 | 4.2E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Nine Mile Point 2 | 05000410 | 0.15 | 4.8E-05 | 0.23 | 5.6E-06 | SPRA and focused-scope EPRI SMA | GI-199 |
| North Anna 1 | 05000338 | 0.12 | 2.1E-04 | 0.16 | 4.4E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| North Anna 2 | 05000339 | 0.12 | 2.1E-04 | 0.16 | 4.4E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Oconee 1 | 05000269 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |

| Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes (RLE), and Seismic Core Damage Frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Plant** | **Docket** | **SSE (g's)** | **Frequency of Exceeding the SSE (per year)** | **RLE (HCLPF) (g's)** | **Seismic Core Damage Frequency (per year)** | **IPEEE Method** | **Source** |
| Oconee 2 | 05000270 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oconee 3 | 05000287 | 0.1 | 9.7E-04 | n/a | 4.3E-05 | seismic PRA | GI-199 |
| Oyster Creek | 05000219 | 0.17 | 1.5E-04 | n/a | 1.4E-05 | seismic PRA | GI-199 |
| Palisades | 05000255 | 0.2 | 1.4E-04 | n/a | 6.4E-06 | seismic PRA | GI-199 |
| Palo Verde 1 | 05000528 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Palo Verde 2 | 05000529 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Palo Verde 3 | 05000530 | 0.258 | 3.5E-05 | 0.3 | 3.8E-05 | 0.3g full-scope EPRI SMA | IPEEE |
| Peach Bottom 2 | 05000277 | 0.12 | 2.0E-04 | 0.2 | 2.4E-05 | modified focused-scope EPRI SMA | GI-199 |
| Peach Bottom 3 | 05000278 | 0.12 | 2.0E-04 | 0.2 | 2.4E-05 | modified focused-scope EPRI SMA | GI-199 |
| Perry | 05000440 | 0.15 | 2.2E-04 | 0.3 | 2.1E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Pilgrim 1 | 05000293 | 0.15 | 8.1E-04 | n/a | 6.9E-05 | seismic PRA | GI-199 |
| Point Beach 1 | 05000266 | 0.12 | 2.0E-04 | n/a | 1.1E-05 | seismic PRA | GI-199 |
| Point Beach 2 | 05000301 | 0.12 | 2.0E-04 | n/a | 1.1E-05 | seismic PRA | GI-199 |
| Prairie Island 1 | 05000282 | 0.12 | 2.0E-04 | 0.28 | 3.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Prairie Island 2 | 05000306 | 0.12 | 2.0E-04 | 0.28 | 3.0E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Quad Cities 1 | 05000254 | 0.24 | 8.2E-04 | 0.09 | 2.7E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Quad Cities 2 | 05000265 | 0.24 | 8.2E-04 | 0.09 | 2.7E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| River Bend | 05000458 | 0.1 | 2.4E-04 | 0.1 | 2.5E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Robinson (HR) | 05000261 | 0.2 | 1.1E-03 | 0.28 | 1.5E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| Saint Lucie | 05000335 | 0.1 | 1.4E-04 | 0.1 | 4.6E-05 | reduced-scope EPRI SMA; SSE = 0.1g | GI-199 |
| Salem 1 | 05000389 | 0.2 | 2.6E-04 | 0.1 | 4.6E-05 | reduced-scope EPRI SMA; SSE = | GI-199 |

| Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes (RLE), and Seismic Core Damage Frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Plant** | **Docket** | **SSE (g's)** | **Frequency of Exceeding the SSE (per year)** | **RLE (HCLPF) (g's)** | **Seismic Core Damage Frequency (per year)** | **IPEEE Method** | **Source** |
| | | | | | | 0.1g | |
| Salem 2 | 05000272 | 0.2 | 2.6E-04 | n/a | 9.3E-06 | seismic PRA | GI-199 |
| San Onofre 2 | 05000361 | 0.67 | 1.2E-04 | n/a | 1.7E-05 | seismic PRA | IPEEE |
| San Onofre 3 | 05000362 | 0.67 | 1.2E-04 | n/a | 1.7E-05 | seismic PRA | IPEEE |
| Seabrook | 05000311 | 0.25 | 1.3E-04 | n/a | 9.3E-06 | seismic PRA | GI-199 |
| Sequoyah 1 | 05000443 | 0.18 | 7.1E-04 | n/a | 2.2E-05 | seismic PRA | GI-199 |
| Sequoyah 2 | 05000327 | 0.18 | 7.1E-04 | 0.27 | 5.1E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| Shearon Harris 1 | 05000328 | 0.15 | 4.6E-05 | 0.27 | 5.1E-05 | 0.3g full-scope EPRI SMA | GI-199 |
| South Texas 1 | 05000498 | 0.1 | 3.0E-05 | n/a | 6.2E-06 | seismic PRA | GI-199 |
| South Texas 2 | 05000499 | 0.1 | 3.0E-05 | n/a | 6.2E-06 | seismic PRA | GI-199 |
| Summer | 05000395 | 0.15 | 3.9E-04 | 0.22 | 3.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Surry 1 | 05000280 | 0.15 | 2.2E-04 | n/a | 5.7E-06 | seismic PRA | GI-199 |
| Surry 2 | 05000281 | 0.15 | 2.2E-04 | n/a | 5.7E-06 | seismic PRA | GI-199 |
| Susquehanna 1 | 05000387 | 0.1 | 1.9E-04 | 0.21 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Susquehanna 2 | 05000388 | 0.1 | 1.9E-04 | 0.21 | 1.3E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Three Mile Island 1 | 05000289 | 0.12 | 1.0E-04 | n/a | 4.0E-05 | seismic PRA | GI-199 |
| Turkey Point 3 | 05000250 | 0.15 | 3.8E-05 | 0.15 | 1.0E-05 | site-specific approach; SSE=0.15g | GI-199 |
| Turkey Point 4 | 05000251 | 0.15 | 3.8E-05 | 0.15 | 1.0E-05 | site-specific approach; SSE=0.15g | GI-199 |
| Vermont Yankee | 05000271 | 0.14 | 1.2E-04 | 0.25 | 8.1E-06 | 0.3g focused-scope EPRI SMA | GI-199 |
| Vogtle 1 | 05000424 | 0.2 | 1.5E-04 | 0.3 | 1.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Vogtle 2 | 05000425 | 0.2 | 1.5E-04 | 0.3 | 1.8E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Waterford 3 | 05000382 | 0.1 | 1.1E-04 | 0.1 | 2.0E-05 | reduced-scope EPRI SMA; SSE = | GI-199 |

| Table From GI-199 Program Containing SSE, SSE Exceedance Frequencies, Review Level Earthquakes (RLE), and Seismic Core Damage Frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|
| Plant | Docket | SSE (g's) | Frequency of Exceeding the SSE (per year) | RLE (HCLPF) (g's) | Seismic Core Damage Frequency (per year) | IPEEE Method | Source |
| | | | | | | 0.1g | |
| Watts Bar | 05000390 | 0.18 | 2.9E-04 | 0.3 | 3.6E-05 | 0.3g focused-scope EPRI SMA | GI-199 |
| Wolf Creek | 05000482 | 0.12 | 3.7E-05 | 0.2 | 1.8E-05 | reduced-scope EPRI SMA | GI-199 |
| | | 25th percentile | 9.6E-05 | | 6.0E-06 | | |
| | | min | 1.6E-05 | | 2.0E-06 | | |
| | | median | 1.7E-04 | | 1.5E-05 | | |
| | | mean | 3.1E-04 | | 2.1E-05 | | |
| | | max | 3.9E-03 | | 1.0E-04 | | |
| | | 75th percentile | 2.6E-04 | | 3.2E-05 | | |

**Table: Design Basis Ground Motions and New Review Level Ground Motions Used for Review of Japanese Plants**

| Plant sites | Contributing earthquakes | New DBGM $S_s$ | Original DBGM $S_2$ |
|---|---|---|---|
| Tomari | Earthquakes undefined specifically | 550 Gal | 370 Gal |
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 | 375 |
| Higashidoori | Earthquakes undefined specifically | 450 | 375 |
| Fukushima | Earthquake near the site (M7.1) | 600 | 370 |
| Tokai | Earthquakes undefined specifically | 600 | 380 |
| Hamaoka | Assumed Tokai (M8.0), etc. | 800 | 600 |
| Shika | Sasanami-oki Fault (M7.6) | 600 | 490 |
| Tsuruga | Urazoko-Uchiikemi Fault (M6.9), etc. →Mera-Kareizaki - Kaburagi(M7.8), Shelf edge+B+Nosaka (M7.7) | 800 | 532 |
| Mihama | C, Fo-A Fault (M6.9)→ Shelf edge+B+Nosaka(M7.7) | 750 | 405 |

| | | | |
|---|---|---|---|
| Ohi | C, Fo-A Fault (M6.9)→Fo-A+Fo-B （M7.4) | 700 | 405 |
| Takahama | Fo-A Fault (M6.9) →Fo-A+Fo-B(M7.4) | 550 | 370 |
| Shimane | Shinji Fault (M7.1) | 600 | 456 |
| Ikata | Central Tectonic Structure (M7.6) | 570 | 473 |
| Genkai | Takekoba F. （M6.9) → Enhanced uncertainty consideration | 540 | 370 |
| Sendai | Gotandagawa F.(M6.9), F-A(M6.9) | 540 | 372 |
| Kashiwazaki-Kariwa | F-B Fault (M7.0), Nagaoka-plain-west Fault (M8.1) | 2300 (R1 side)<br>1209 (R5 side) | 450 |
| Monjyu (Proto Type FBR) | Shiraki-Niu F.(M6.9) , C F.(M6.9)→Shelf edge+B+Nosaka(M7.7), Small Damping | 760 | 408 |
| Shimokita Reprocessing F. | Deto-Seiho F.(M6.8), Yokohama F.(M6.8) | 450 | 320 |

Table: Status of Review of Japanese NPPs to New Earthquake Levels Based on 2006 Guidance

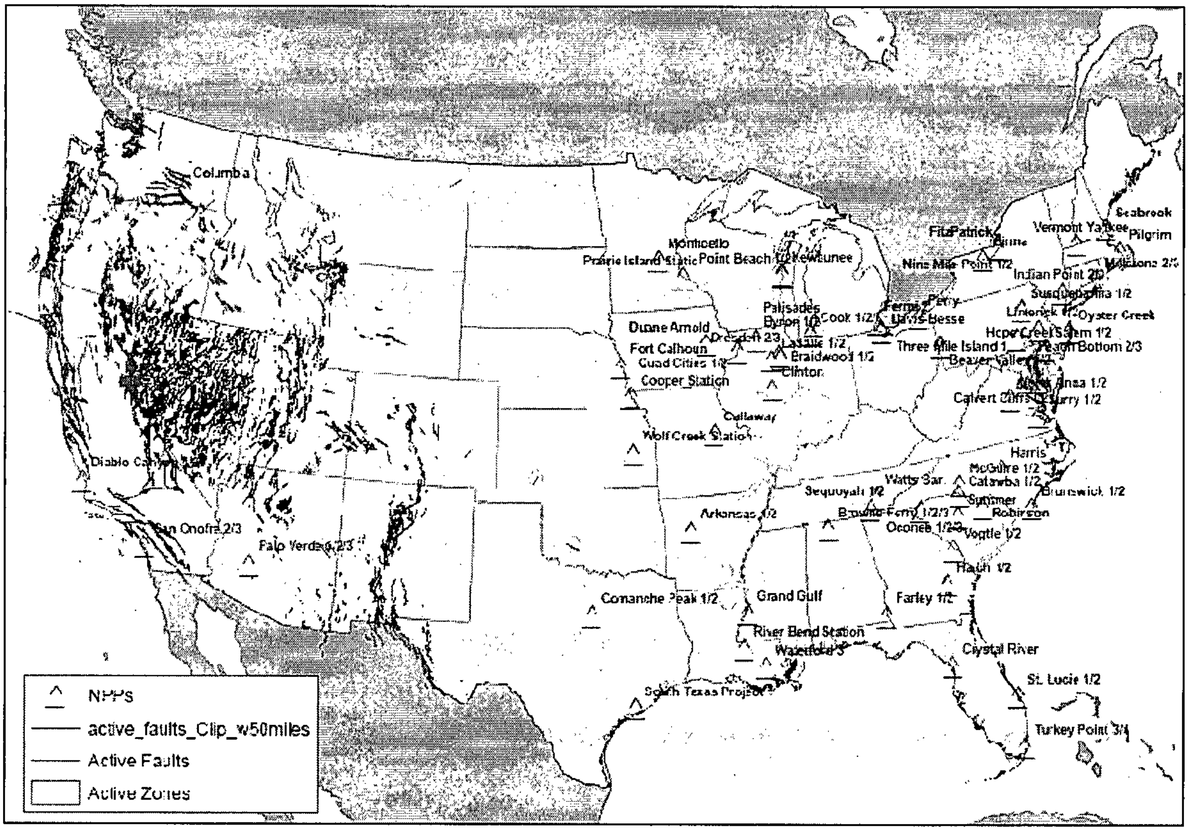
| Utility | Site (Unit) | Type | Dec.2010 |
|---|---|---|---|
| Hokkaido | Tomari | PWR | △ |
| Tohoku | Onagawa (Unit1) | BWR | ◎ |
| | Higashi-dori | BWR | △ |
| Tokyo | Kashiwazaki-Kariwa | BWR | Unit 1,5,6,7 ◎ |
| | Fukushima-No1 | BWR | Unit 3 ◇, 5 ◎ |
| | Fukushima-No2 | BWR | Unit 4,5 ◎ |
| Chubu | Hamaoka | BWR | △ |
| Hokuriku | Shika (Unit 2) | BWR | ◎ |
| Kansai | Mihama(Unit 1) | PWR | ◎ |
| | Ohi(Unit 3,4) | PWR | ◎ |
| | Takahama (Unit 3,4) | PWR | ◎ |
| Chugoku | Shimane (Unit 1, 2) | BWR | ◎ |
| Shikoku | Ikata (Unit 3) | PWR | ◎ |
| Kyushu | Genkai (Unit 3 ) | PWR | ◎ |
| | Sendai (Unit 1) | PWR | ◎ |
| Japan Atomic Power | Tokai-Daini | BWR | ○ |
| | Tsuruga | BWR/PWR | △ |
| JAEA | Monjyu | Proto Type FBR | ◎ |
| Japan Nuc. Fuel | Rokkasyo | Reprocessing | ◎ |

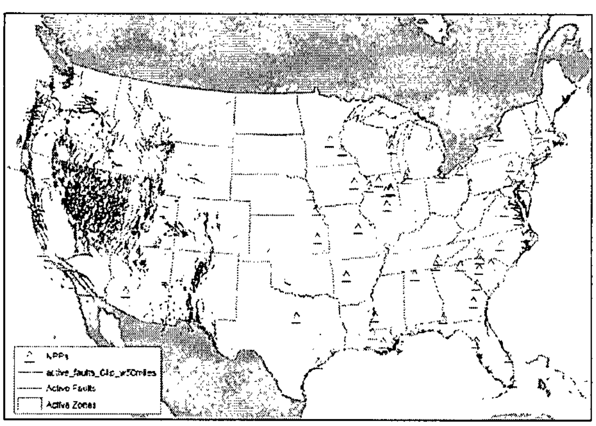
◎: NSC review finished, ○: NISA review finished and in NSC review, △: Under review by NISA

# Additional Information: Useful Plots

## Plot of Mapped Active Quaternary Faults and Nuclear Plants in the US

It is important to note that this plot somewhat misleading as faults in the central and eastern US are not well characterized. For example, the faults responsible for very large historic events, such as the 1811 and 1812 New Madrid Earthquakes, and the 1886 Charleston Earthquakes have not been conclusively located.



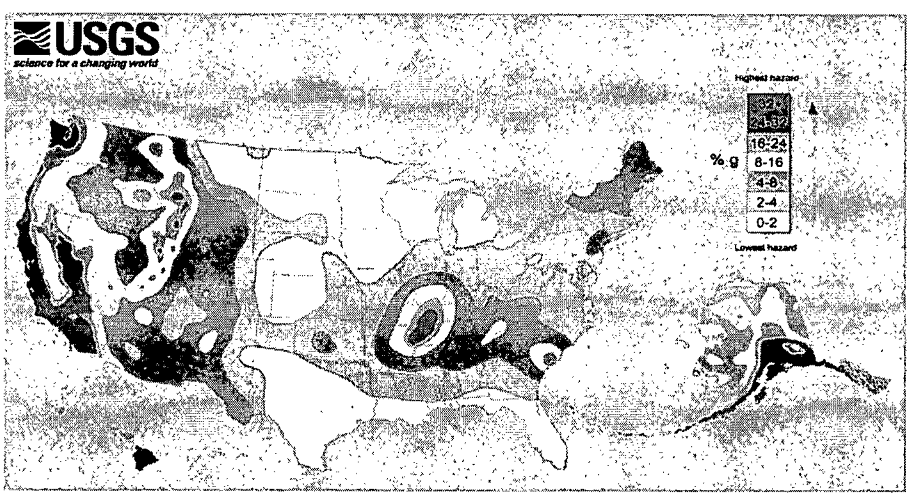
## Nuclear Plants in the US Compared to the USGS National Seismic Hazard Maps


Figure 1: US Nuclear Plants overlain on the USGS National Seismic Hazard Map

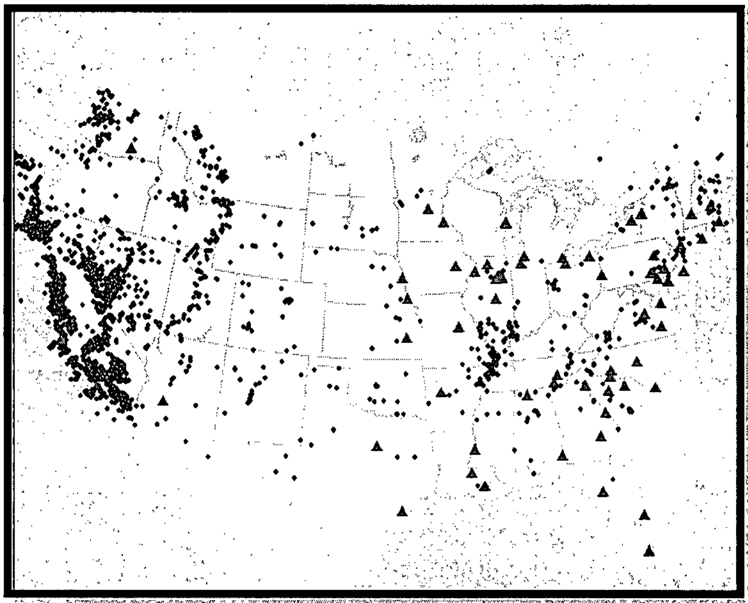
As you can see the seismic source regions in the central and eastern east are not well defined. So to state a specific number of plants that are in the moderate seismicity zones is challenging and open to interpretation. This is just one interpretation, which is provided by the USGS.

## USGS US National Seismic Hazard Maps

Many version of this map are available at the USGS website at http://earthquake.usgs.gov/hazards/

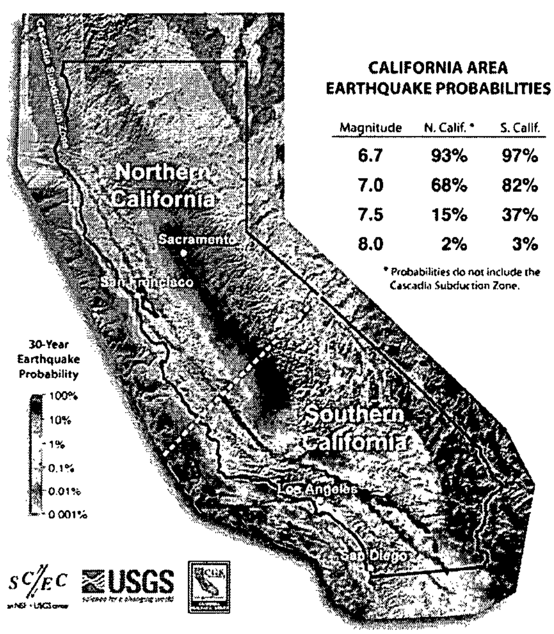


## Plot of Nuclear Plants in the US Compared to Recent Earthquakes

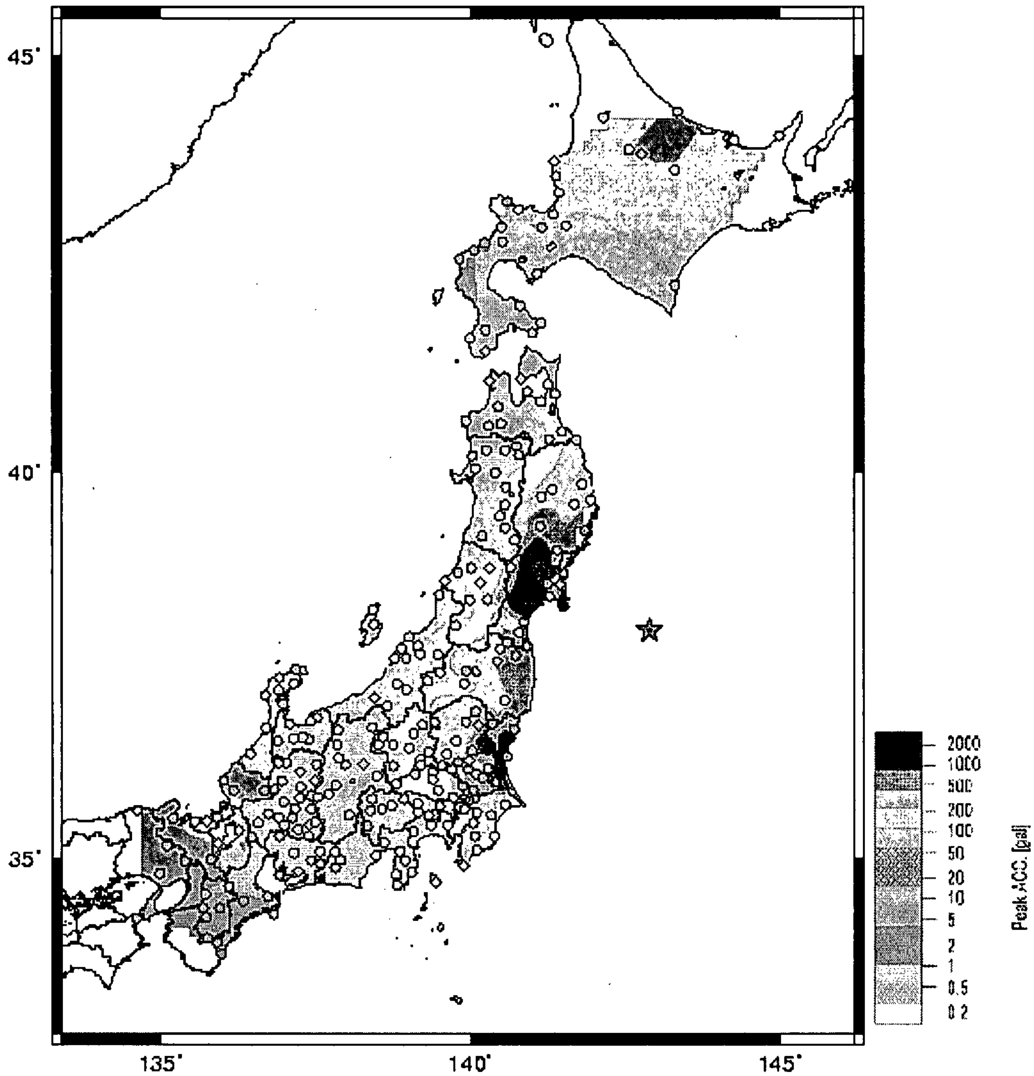


## UCERF Map of California Earthquake Probabilities for Northern versus Southern California

This is included in this document as Markey (inaccurately) used the below statistics to say that the probability of a magnitude 7 at SONGS was 82%. The dashed line of this California map is the boundary between northern and southern California used in the UCERF study. As shown in the table, the 30-year probability of an earthquake of magnitude 7.5 or larger is higher in the southern half of the state (37%) than in the northern half (15%).



## Plot of ground motion acceleration (PGA) from Japanese earthquake




2011/03/11–14:46 38.0N 142.9E 24km M9.0

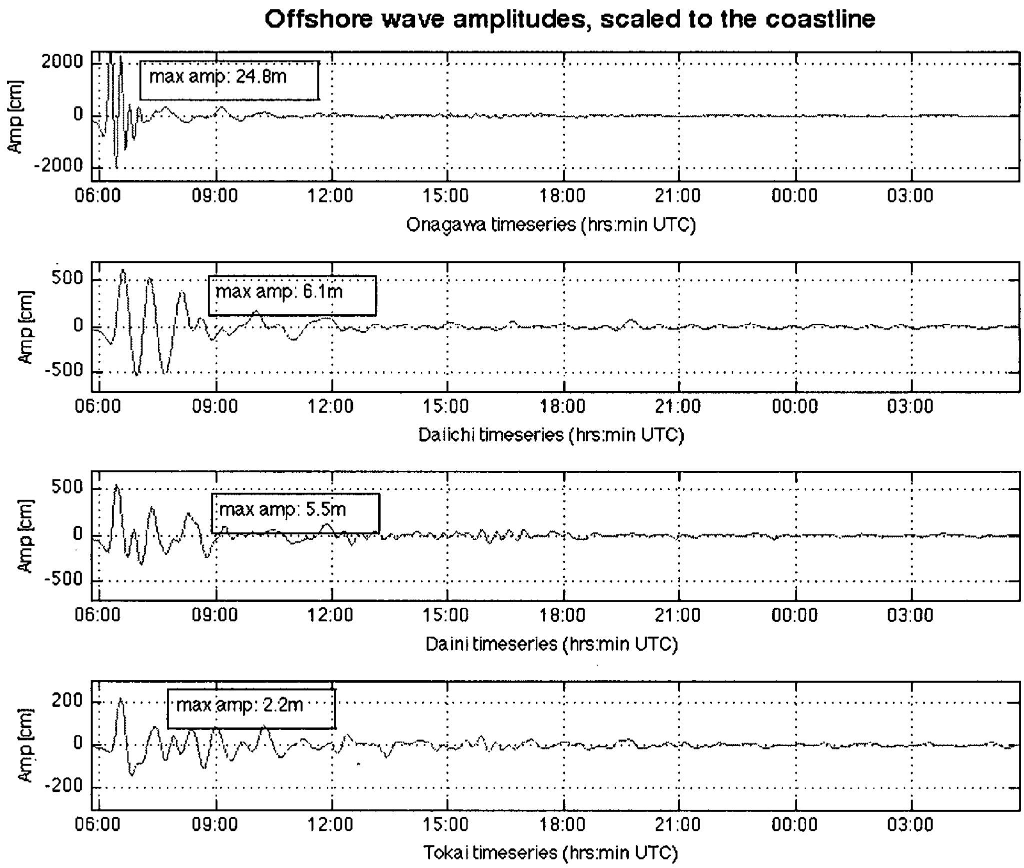
Peak Acceleration Map from K-NET NEID

Table of Nuclear Plant Design and Review Ground Motions for the Plants that Automatically Tripped (JNES)

| Plant sites | Contributing earthquakes used for determination of hazard | New DBGM $S_s$ | Original DBGM $S_1$ |
|---|---|---|---|
| Onagawa | Soutei Miyagiken-oki (M8.2) | 580 gal (0.59g) | 375 gal (0.38g) |
| Fukushima (both) | Earthquake near the site (M7.1) | 600 gal (0.62g) | 370 gal (0.37g) |
| Tokai | Earthquakes specifically undefined | 600 gal (0.62g) | 380 gal (0.39g) |

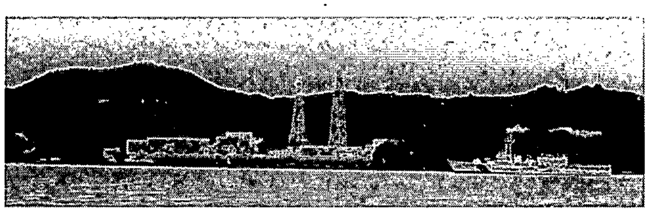
## Plot of Tsunami Wave Heights at 5 Meter Bathymetry Offshore at the Japanese Plants (NOAA)

These are results from high-resolution models run by PMEL NOAA staff, who do modeling for the tsunami warning system. While the available bathymetry and topography data used in the model are not of the highest quality at that location, NOAA has confidence in the results, which show good comparisons between model flooding estimates and inundation observations inferred from satellite images. DART measurements are used in the modeling. The images show model time series very close to a shoreline, at about 5m depth. The runup heights (maximum elevation of flooded area) may be different from these amplitudes at shoreline (can be higher or lower, depending on the topographic profile). According to TEPCO, the wave height onshore at the Fukushima plant was 14 meters high.



## Plot of Tsunami Wave Heights in the Pacific (NOAA)


This shows the effect on the US coastline.



I found the numbers at the Onagawa plant unimaginable, so I found a side view picture. It's hard to tell the elevation of the plant.

# Fact Sheets

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (High level overview)

The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations: 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part, which describes the general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that that the structures and components in nuclear power plants be designed to withstand the effects of natural phenomena, including earthquakes and tsunamis, without loss of capability to perform their intended safety functions. GDC 2 also requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The earthquake which could cause the maximum vibratory ground motion at the site is designated as the **Safe Shutdown Earthquake (SSE)**. Under SSE ground motions, nuclear power plant structures and components must remain functional and within applicable stress, strain, and deformation limits. Each plant must also have seismic instrumentation to determine if the **Operating Basis Earthquake (OBE)**, typically one-half or one-third the level of the SSE, has been exceeded. If the OBE is exceeded or significant plant damage has occurred, then the nuclear power plant must be shutdown.

Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of the earthquake, the distance of the earthquake to the site, and the local geology. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant. This required an assessment of earthquakes that had occurred in the region around each plant site.

Design basis loads for nuclear power plant structures include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Society of Mechanical Engineers, the American Concrete Institute, and the American Institute of Steel Construction, are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

In the mid to late 1990s, NRC staff reviewed the potential consequences of severe earthquakes (earthquakes beyond the safety margin included in each plant's design basis), as part of the Individual Plant Examination of External Events (or IPEEE) program. From this review, the staff determined that seismic designs of operating plants in the United States have adequate safety margins, for withstanding earthquakes, built into the designs. Currently, the NRC staff is reassessing the seismic designs of operating plants through our Generic Issues program. The initial results of this assessment found that: 1) seismic hazard estimates have increased at some operating plants in the central and eastern US; 2) there is no immediate safety concern, plants have significant safety margin and overall seismic risk estimates remain small; and 3) assessment of updated seismic hazards and plant performance should continue.

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (The policy wonk version)

(Jon to clean up upon his return from vaca) NRC's regulatory framework for seismic safety of nuclear reactors and facilities is based on: reactor site suitability with respect to geological, seismological, hydrological and other site specific hazards; classification of structures, systems and componenets (SSCs) as Seismic Category I, seismic design of Seismic Category I SSCs, seismic and environmental qualification of Category I SSCs; and maintenance and in-service inspection of equipment and structures, including the containment structure. The NRC's regulatory framework with respect to seismic issues has evolved through time.

**Currently Operating Reactors (licensed prior to 1997):**

The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations: 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part which describes general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.

General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that that the SSCs important to safety be designed to withstand the effects of natural phenomena, including earthquakes, tsunamis, and seiches without loss of capability to perform their intended safety functions. GDC 2 requires that the design bases shall include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, and shall consider appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena. The earthquake which could cause the maximum vibratory ground motion at the site is designated the **Safe Shutdown Earthquake (SSE)**.

Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of an earthquake and the distance from the fault to the site. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant based on an assessment of earthquakes that had occurred in the region historically. There is no specification of frequency of occurrence in the deterministic approach. There is no requirement for a periodic reassessment of the seismic design basis.

Paragraph VI(a)(3) of Appendix A requires that suitable seismic instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be determined promptly after an earthquake to permit comparison of such response to that used as the design basis. Such a comparison is needed to decide whether the plant can continue to be operated safely and to permit appropriate action in a timely manner. Appendix A requires thatin addition to seismic loads, including aftershocks, applicable concurrent functional and accident induced loads shall be taken into account in the design of safety-related SSCs. Paragraph VI(c) requires that seismically induced flood, water waves from either locally or distantly generated seismic activity and other design conditions shall be taken into account in nuclear power plant design.

**Proposed New Reactors (submitted after 1997):**

In 1997 new rules governing reactor siting were established. 10 CFR Part 50 Appendix A (GDC 2), 100.23 and Appendix S establish the seismic design basis for plants licensed after January 10,1997. Similar to

pre-1997, Appendix S defines the SSE as *"the Safe-shutdown earthquake ground motion* is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional." 10 CFR Part 100.23 "Geologic and Seismic Siting Criteria" requires that the applicant determine the SSE **and its uncertainty**, the potential for surface tectonic and nontectonic deformations. Regulatory Guide 1.165 (and subsequently Regulatory Guide 1.208) provides guidance on satisfying 10 CFR Part 100.23, one of which is performing a probabilistic seismic hazard assessment (**PSHA**).

Appendix S to 10 CFR Part 50 requires for SSE ground motions, SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motions. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation elevation of structures must be an appropriate response spectrum with a peak ground acceleration (PGA) of at least 0.10g. Design basis loads for nuclear power plant structures, important to safety, include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the ASME B&PV Code, the American ~~Institute of~~ Concrete Institute (ACI-359/ASME Section III Division 2, ACI-349) and the American Institute of Steel Construction (AISC N690), are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

In contrast to the deterministic approach used prior to 1997, the probabilistic method is used and explicitly accounts for possible earthquakes of various magnitudes that come from all plausible potential sources (including background seismicity) and the likelihood that each particular hypothetical earthquake occurs. The PSHA process provides a complete characterization of the ground motion and comprehensively addresses uncertainties in nuclear power plant seismic demands. The PSHA results are major input to seismic risk evaluation using either SPRA or SMA approaches. As for plants licensed prior-to 1997, there is no requirement for a periodic reassessment of the seismic design basis.

In addition to the nominal seismic design, all new generation reactors have to demonstrate a **Seismic margin of 1.67** relative to the site-specific seismic demands. These designs are required to perform a Probabilistic Risk Assessment (PRA) based seismic margins analysis (SMA) to identify the vulnerabilities of their design to seismic events. The minimum high confidence, low probability of failure (HCLPF) for the plant should be at least 1.67 times the ground motion acceleration of the design basis safe-shutdown earthquake (SSE).

The Standard Review Plan (NUREG-0800), Regulatory Guides and Interim Staff Guidance provide the basis for staff reviews of existing reactors and new license applications. Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. Paragraph 10 CFR 50.54(ff) and Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) occurs. The OBE is typically one-half or one-third the level of the SSE. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after occurrence of the OBE, the licensee must consult with the NRC and must propose a plan for the timely, safe shutdown of the nuclear power plant. Paragraph IV(c) requires that seismically induced flood, water waves from either locally or distantly generated seismic activity and other design conditions shall be taken into account in nuclear power plant design so as to prevent undue risk to health and safety of the public.

## Fact Sheet: Summarization of the NRC's Regulatory Framework for Seismic Safety (The cliff notes)

NRC Regulations and Guidelines for Seismic Safety:

- The seismic regulatory basis for licensing of the currently operating nuclear power reactors is contained in the following regulations:
  - 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," including the "General Design Criteria for Nuclear Power Plants," and
  - 10 CFR Part 100 ("Seismic and Geologic Siting Criteria For Nuclear Power Plants") and Appendix A to that Part, which describes the general criteria that guide the evaluation of the suitability of proposed sites for nuclear power plants.
- In addition, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A requires that:
  - The structures and components in nuclear power plants be designed to withstand the effects of natural phenomena, including earthquakes and tsunamis, without loss of capability to perform their intended safety functions.
  - GDC 2 also requires that the design bases include sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
    - The earthquake which could cause the maximum vibratory ground motion at the site is designated as the **Safe Shutdown Earthquake (SSE)**. Under SSE ground motions, nuclear power plant structures and components must remain functional and within applicable stress, strain, and deformation limits.
    - Each plant must also have seismic instrumentation to determine if the **Operating Basis Earthquake (OBE)**, typically one-half or one-third the level of the SSE, has been exceeded. If the OBE is exceeded or significant plant damage has occurred, then the nuclear power plant must be shutdown.

Plant Design /Design Basis (Seismic):

- Each plant is designed to a ground-shaking level (the SSE) that is appropriate for its location, given the possible earthquake sources that may affect the site and its tectonic environment. Ground shaking is a function of both the magnitude of the earthquake, the distance of the earthquake to the site, and the local geology. The magnitude alone cannot be used to predict ground motions. The existing plants were designed on a "deterministic" or "scenario earthquake" basis that accounted for the largest earthquake expected in the area around the plant. This required an assessment of earthquakes that had occurred in the region around each plant site.
- Design basis loads for nuclear power plant structures include combined loads for seismic, wind, tornado, normal operating conditions (pressure and thermal), and accident conditions. Codes and standards, such as the American Society of Mechanical Engineers, the American Concrete Institute, and the American Institute of Steel Construction, are used in the design of nuclear power plant structures to ensure a conservative, safe design under design basis loads.

# Fact Sheet: Summarization of the NRC's Regulatory Framework for Tsunami

**Review Guidance and Guidelines Related to Tsunami:**

1. General Design Criterion 2 (GDC 2), 10CFR50, requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Design bases for these SSCs are also required to reflect:
2. 10 CFR 100.23, requires, in part, that the size of seismically induced floods and water waves that could affect a site from either locally or distantly generated seismic activity must be determined.
3. RG 1.102 – Flood Protection for Nuclear Power Plants, describes types of flood protection acceptable to the NRC staff
    a. Exterior Barriers (e.g.)
        i. Levee – embankment to protect land from inundation
        ii. Seawall or floodwall - a structure separating land and water areas, primarily to prevent erosion and other damages due to wave action
        iii. Bulkhead – similar to seawall, purpose is to restrain the land area
    b. Incorporated Barriers
        i. Protection provided by specially designed walls and penetration closures. Walls are usually reinforced concrete designed to resist static and dynamic forces of a Design Basis Flood Level of a Probable Maximum Flood.
4. RG 1.59 – Design Basis Floods for Nuclear Power Plants
    a. The most severe seismically induced floods reasonably possible should be considered for each site.
    b. Tsunami requires consideration of seismic events of the severity of the Safe Shutdown Earthquake occurring at the location that would produce the worst such flood at the nuclear power plant site.
5. US NRC, Standard Review Plan, "Probable Maximum Tsunami Flooding," Section 2.4.6, Rev. 2
    a. Areas of Review
        i. Probable maximum tsunami postulated for a site should include wave runup and drawdown
        ii. Hydrologic characteristics of maximum locally and distantly generated tsunami (e.g., volcanoes, landslides)
        iii. Geological and seismic characteristics of potential tsunami faults (e.g., magnitude, focal depth, source dimensions, fault orientation, and vertical displacement)

## Fact Sheet: Tsunami Assessment Method for Nuclear Power Plants in Japan

[This section is a placeholder and needs to be expanded]

- An overview of the tsunami assessment method for NPP in Japan is available in ADAMs: ML110770010
- Information is also available at: http://www.jsce.or.jp/committee/ceofnp/Tsunami/eng/tsunami_eng.html
- The Japan Society of Civil Engineers is currently finalizing guidance PTHA = probabilistic tsunami hazard analysis

# Fact Sheet: Summarization of the NRC's Regulatory Framework for Flooding

**Flooding Issues:**

1. General Design Criterion 2 (GDC 2), 10CFR50, requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Design bases for these SSCs are also required to reflect:

   b. Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding region, with sufficient margin for the limited accuracy and quantity of the historical data and the period of time in which the data have been accumulated.

   c. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

   d. The importance of the safety functions to be performed.

6. Design basis floods for most of the present fleet of operating reactors were calculated using deterministic methods to determine the maximum credible flood levels at the site. These deterministic methods include the site specific calculation of parameters such as the probable maximum precipitation, which is defined as the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin. Other potential flooding hazards such as flooding due to storm surge, river flooding, coastal flooding including tsunamis, are evaluated at each site using maximum credible levels from each hazard. Over the life of the operating reactor, if new information becomes available that could affect the design basis, licensees are required to evaluate the new information. Based on this review, if needed, licensees are required to take appropriate mitigation measures, update their final safety analysis report and submit it to the NRC for review and approval.

7. In order to impose new requirements on existing plants, the NRC must be able to justify the new requirements in accordance with the "Backfit Rule" (10 CFR 50.109).

**Questions and Answers for Flooding Issues**

### 172) Does the NRC consider severe floods in the design of nuclear power plants?

Yes. NRC regulations require that nuclear power plants are, at all times, capable of safely shutting down and maintaining a safe shutdown condition under severe flooding situations. Safety-related Structures, Systems and Components (SSCs) of Nuclear reactors in the U.S. are required to withstand the design basis flood (DBF). The design basis flood may be caused by the following natural Phenomena:

1) Intense rainfall occurring at the site (known as local intense precipitation).
2) Intense rainfall (known as the Probable Maximum Precipitation) occurring on other areas of the watershed leading to riverine or coastal flooding (known as Probable Maximum Flood" or "PMF".
3) Floods from upstream dam failure or a combination of upstream dam failures.
4) Failure of On-site Water Control or Storage Structures (i.e. tanks).
5) Storm Surge, Seiche and Tsunami including wave effects.(**See Tsunami Q&A Sheet**)
6) Flooding caused by ice effects (i.e. ice dams both upstream and downstream).
7) Floods caused by diversions of stream channels toward the site.

8) Other potential site specific flood hazard(s).

**173) What about droughts and conditions which lead to low water? Are these considered?**

Yes. Impacts to the plant from low water conditions brought about by ice effects, downstream dam breach, tsunamis, hurricanes and channel diversions away from the site are reviewed to ensure the plant remains safe under these scenerios.

**174) Periods of long rainfall can cause the groundwater elevation to rise which can cause structures such as deeply embedded tanks to fail due to buoyancy. Are nuclear power plants designed to withstand this effect?**

Yes. Worst-case groundwater levels are estimated for each site and the impacts of these levels are considered in the design of the plant to ensure the plant remains safe under these conditions. During the safety review, impacts due to groundwater levels and other hydrodynamic effects on the design bases of plant foundations and other safety-related structures systems and components (SSCs) are evaluated. Impacts to a safety-related structure such as a deeply embedded tank or a structure containing a deeply embedded tank are considered in the safety review.

**175) Some of the Reports from the National Weather Service used to estimate the design precipitation are 30-40 years old. Are these estimates still valid?**

The NRC has funded research by the U.S. Bureau of Reclamation to review the information and methods developed by the National Weather Service and the U.S. Army Corps of Engineers (HMR 51), focusing on South and North Carolina. To date, reviews of precipitation records from extreme storm events (e.g., tropical storms, hurricanes) since the publication of HMR 51 does not indicate any exceedance or potential for exceedance of those precipitation (PMP) estimates in this region. We have not seen any information or data that would indicate that HMR precipitation (PMP) estimates for the U.S. have been exceeded. As expected, individual point rainfall gauges have recorded rainfall amounts that have exceeded these areal estimates.

## Fact Sheet: Summarization of Seismological Information from Regional Instrumentation

Placeholder: to be developed.

## Fact Sheet: Regulatory Framework for Protection of Nuclear Power Plants against Tsunami Flooding

Nuclear power plants are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The word tsunami literally means harbor wave. Tsunamis can be generated by large offshore earthquakes (usually greater than magnitude 6.5), submarine or on shore land slides or volcanoes. Some large onshore earthquakes close to the shoreline can generate tsunami. The Nuclear Regulatory Commission (NRC) requires all nuclear power plants to be protected against earthquakes, tsunamis and other natural hazards.

**Background**

Protection against tsunami effects was required for all operating plants and is required for all new reactors. Following the Indian Ocean tsunami on December 26, 2004, the President moved to protect lives and property by launching an initiative to improve domestic tsunami warning capabilities. This plan was placed under the auspices of the National Science and Technology Council through the President's initiative in July 2005 in the context of a broad national effort of tsunami risk reduction, and United States participated in international efforts to reduce tsunami risk worldwide. In response to the president's initiative, the NRC reviewed its licensing criteria and conducted independent studies and participated in international forums under the auspices of the International Atomic Energy Agency with many participating countries including India and Japan. The final report of the study was published in April 2009 as NUREG/CR 6966, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America," ADAMS Accession # ML0915901933. NRC revised its Standard Review Plan for conducting safety reviews of nuclear power plants in 2007. Section 2.4.6 specifically addresses tsunamis. The Office of Nuclear Regulatory Research is conducting tsunami studies in collaboration with the United States Geological Survey and has published a report on tsunami hazard in the Atlantic, Gulf and Pacific coastal areas. Selected nuclear power plants now get tsunami warning notification. The agency requires plant designs to withstand the effects of natural phenomena including effects of tsunamis. The agency's requirements, including General Design Criteria for licensing a plant, are described in Title 10 of the *Code of Federal Regulations* (10 CFR). These license requirements consist of incorporating margins in the initiating hazard and additional margins are due to traditional engineering practices such as "safety factors." Practices such as these add an extra element of safety into design, construction, and operations.

The NRC has always required licensees to design, operate, and maintain safety-significant structures, systems, and components to withstand the effects of natural hazards and to maintain the capability to perform their intended safety functions. The agency ensures these requirements are satisfied through the licensing, reactor oversight, and enforcement processes.

**Tsunami Hazard Evaluation**

Tsunami hazard evaluation is one component of the complete hydrological review requirements provided in the Standard Review Plan under Chapter 2.4. The safety determination of reactor sites requires consideration of major flood causing events, including consideration of combined flood causing conditions. These conditions include Probable Maximum Flood (PMF) on Streams and Rivers, Potential Dam Failures, Probable Maximum Surge and Seiche Flooding and Probable Maximum Tsunami Hazards, among others. The most significant flooding event is called the design basis flood and flooding protection requirements are correlated to this flood level in 2.4.10.

The Probable Maximum Tsunami (PMT) is defined as that tsunami for which the impact at the site is derived from the use of best available scientific information to arrive at a set of scenarios reasonably expected to affect the nuclear power plant site taking into account (a) appropriate consideration of the most severe of the natural phenomena that have been historically reported or determine from geological and physical data for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (b) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (c) the importance of the safety functions to be performed.

Site-specific tsunami data are collected from historical tsunami records, paleotsunami evidence, regional tsunami assessments, site-specific tsunami mechanisms, site-specific data, such as submarine survey of sea bed and approach channel geometry. Effects of tsunami on a nuclear power plant can be flooding due to water run up, hydro-dynamic pressure on exterior walls of structures, impact of floating debris, and foundation scouring. In addition, tsunami can draw down water from the intake source of plant cooling water.

The tsunami database is available for interactive search and downloads on the internet at http://www.ngdc.noaa.gov/hazard/tsu.shtml.

**Tsunami Safety Assessment**

The licensing bases for existing nuclear power plants are based on historical data at each site. This data is used to determine probable maximum tsunami and the tsunami effects are evaluated for each site with potential for tsunami flooding. The potential for tsunami hazard is determined on a hierarchical analysis process that can identify tsunami potential based primarily on distance from tsunami source and site elevation. The NRC also required existing plants to assess their potential vulnerability to external events, as part of the Individual Plant Examination of External Events Program. This process ensured that existing plants are not vulnerable to tsunami hazard, and they continue to provide adequate public health and safety.

Today, the NRC utilizes a risk-informed regulatory approach, including insights from probabilistic assessments and traditional deterministic engineering methods to make regulatory decisions about existing plants (e.g., licensing amendment decisions). Any new nuclear plant the NRC licenses will use a probabilistic, performance-based approach to establish the plant's seismic hazard and the seismic loads for the plant's design basis.

**Operating Plants**

The NRC is fully engaged in national international tsunami hazard mitigation programs, and is conducting active research to refine the tsunami sources in the Atlantic, Gulf Coast and Pacific Coast areas. Diablo Canyon (DC) and San Onofre (SONGS) are two nuclear plant sites that have potential for tsunami hazard. Both the DC (main plant) and SONGS are located above the flood level associated with tsunami. However, the intake structures and Auxiliary Sea Water System at DC are designed for combination of tsunami-storm wave activity to 45 ft msl. SONGS has a reinforced concrete cantilevered retaining seawall and screen well perimeter wall designed to withstand the design basis earthquake, followed by the maximum predicted tsunami with coincident storm wave action, designed to protect at approximately 27 ft msl. These reactors are adequately protected against tsunami effects. Distant tsunami sources for DC include the Aleutian area, Kuril-Kamchatka region, and the South American coast (for Songs the Aleutian area). Distant sources for SONGS is limited by the presence of a broad continental shelf. Local or near sources for DC include the Santa Lucia Bank and Santa Maria Basin Faults (for Songs the Santa Ana wind).

**Additional Information**

To read more about risk-related NRC policy, see the fact sheets on Probabilistic Risk Assessment (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/probabilistic-risk-asses.html) and Nuclear Reactor Risk (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/reactor-risk.html). Each provides more information on the use of probability in evaluating hazards (including earthquakes) and their potential impact on plant safety margins. Other regulatory framework includes General Design Criterion 2, 10 CFR Part 100.23, Regulatory Guide 1.102 "Flood Protection for Nuclear Power Plants", Rev. 1 1976, Regulatory Guide 1.59 "Design Basis for Nuclear Power Plants" Rev. 2 1977 (update in progress), and USNRC Standard Review Plan "Probable Maximum Tsunami Flooding" Section 2.4.6, Rev. 2.

March 2011

## Fact Sheet: Seismic Zones and US Plants

Note: This is some basic information...staff is developing this into a fact sheet

Some Key Points:

- Although we often think of the US as having "active" and "non-active" earthquake zones, earthquakes can actually happen almost anywhere. Seismologists typically separate the US into low, moderate, and high seismicity zones; not into "active" and "inactive".
- The boundaries of the low, medium and high zones are not hard, are not well constrained, and are open to interpretation. Below we've pulled together a list based on our judgment and based on multiple interpretations in the technical community. But this is just for guidance; it is subjective.
- Faults are often well mapped and characterized in active zones, such as the west. But there are very few mapped faults in the east, which doesn't mean that there aren't earthquakes. For example, the most widely felt historical earthquakes in the US occurred in the New Madrid seismic zone in 1811 and 1812. The zones is (clearly shown on figure 1, the hazard map. However, the fault has never been identified and so is only shown as an area source on figure 2. In fact, most CEUS earthquakes are not tied to a known fault.
- The NRC has a seismic research program which has—with DOE and EPRI—sponsored and undertaken a ground breaking project to create a new state of the art seismic source model for the central and eastern US. This project, the Central and Eastern US Seismic Source Characterization for Nuclear Facilities project, is expected to finish at the end of this year.
- The NRC is also undertaking the Generic Issue 199 program to reassess seismic risk in light of the potential for higher seismic hazard (ground shaking) in the CEUS. This shows an ongoing dedication to seismic safety.
- The NRC requires that every nuclear plant be designed for site-specific ground motions that are appropriate for their locations. In addition, the NRC has specified a minimum ground motion level to which nuclear plants must be designed.

**This is a preliminary (and subjective) list from seismic staff: Please consider this sensitive information**

**High Seismicity:**

- Diablo Canyon
- SONGS

**Moderate Seismicity:**

**Charleston Seismic Zone**

- Brunswick
- Robinson
- Summer
- Vogtle
- Hatch (maybe depends on interpretation)

**Wabash Valley Seismic Zone**

- Clinton

**East Tennessee Seismic Zone (a real point of contention)**

- Watts Bar

- Sequoya

**Central Virginia Seismic Zone**

- North Anna

Notes:

Also minimum standard on shaking

Note that new Madrid has several subzones.

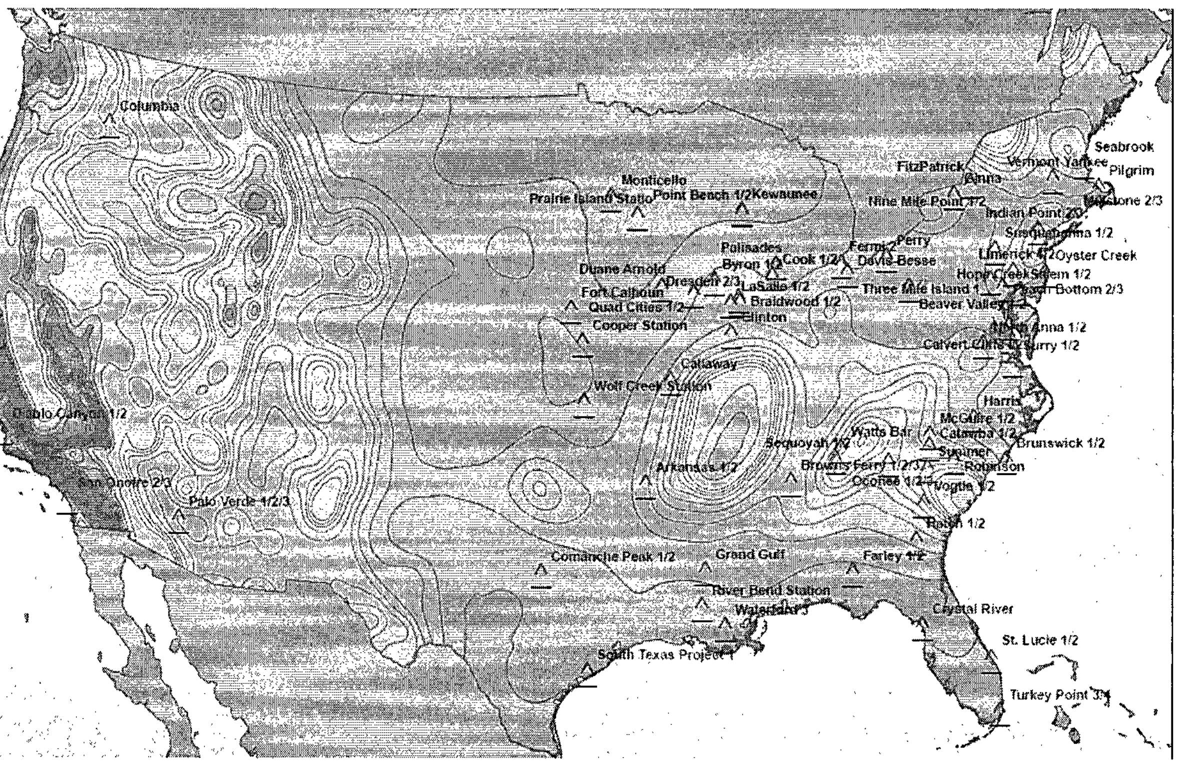



Figure 1: US Nuclear Plants overlain on the USGS National Seismic Hazard Map

As you can see the seismic source regions in the central and eastern east are not well defined. So to state a specific number of plants that are in the moderate seismicity zones is challenging and open to interpretation. This is just one interpretation, which is provided by the USGS.

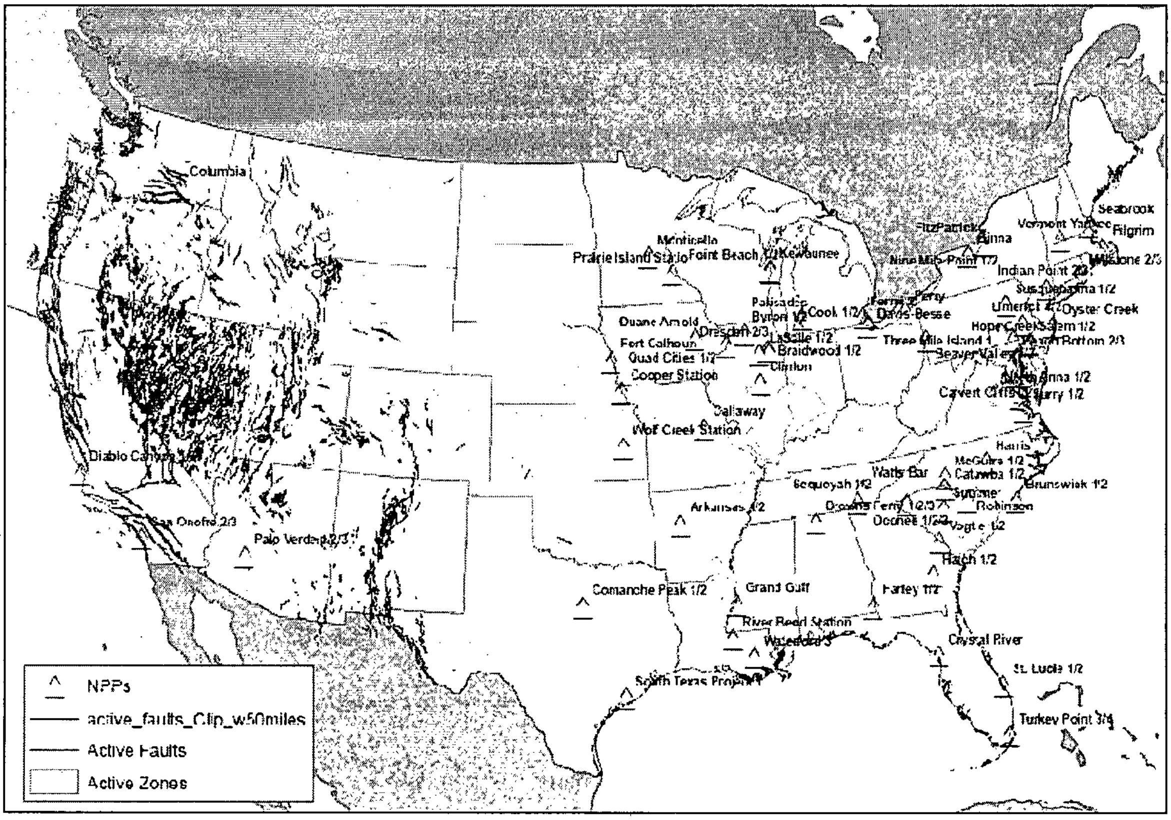



Figure 2: This figure shows mapped active faults and US Nuclear plants

As you can see, there are very few mapped active faults in the east, which doesn't mean that there aren't earthquakes. The most widely felt historical earthquakes in the US happened in the New Madrid seismic zone (clearly shown on figure 1, the hazard map). However, the fault is not shown here because we can't find it under all that Mississippi sand! You can (faintly) see the source one interpretation of a source zone on the figure. However, this is just the interpretation that was in the GIS map we were working with. We will likely put nested "blobs" onto this figure to the widest and narrowest zone interpretations.

If someone asks about plants being very near *mapped* active faults, there are two…but that doesn't mean that there isn't hazard elsewhere because in the central and eastern US the seismicity comes from "seismic zones" not faults. It's a hard balance between saying things that make it seem that we have a lot of problems and saying things that make it seem we are underestimate the hazard or not taking it seriously.

Figure 3: Earthquakes Plotted with US Nuclear Plants

We are remaking a plot like this with a more complete set of earthquake (we're not sure that the time frame of the quakes is), this speaks to the fact that earthquakes occur everywhere, even where we don't have mapped faults.

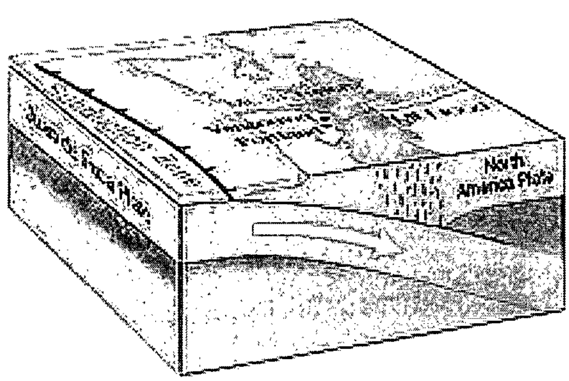
## Fact Sheet: Seismicity of the Central and Eastern US (In-depth technical information)

**Key Points**:

- To date, very large earthquakes (Magnitudes greater than 8.25) have only occurred in specific geological settings, in particular the interfaces between tectonic plates in major **subduction zones**. The only subduction zone that potentially impacts the continental US is the Cascadia zone off the coast of northern California, Oregon and Washington.
- Recent analyses of the magnitudes of the largest earthquakes **not associated** with subduction zones indicates magnitudes are less than ~8.25.
- The size (magnitude) of earthquakes is proportional to the fault area that slips in a given earthquake. The prediction of earthquake magnitudes for a specific fault considers the dimensions of the fault. Extremely large earthquakes do not occur on small faults.
- Nuclear power plants are licensed based on vibratory ground shaking, not earthquake magnitude. The ground shaking (accelerations) are used to estimate forces which are used in the seismic design process. In many cases smaller magnitude earthquakes closer to a site produce more severe ground shaking than larger, more distant earthquakes. Hence it is important to consider all potential earthquake sources regardless of magnitude.

**Discussion:** Earthquakes with very large magnitudes such as the March 2011 earthquake off the northeast coast of the Japanese island of Honshu occur within subduction zones, which are locations where one of the earth's tectonic plates is subducting beneath (being thrust under) another. The fault that defines the Japan Trench plate boundary dips to the west, i.e., becomes deeper towards the coast of Honshu. Large offshore earthquakes have historically occurred in the same subduction zone (in 1611, 1896, and 1933) all of which produced significant tsunami waves. The magnitudes of these previous large earthquakes have been estimated to be between 7.6 and 8.6. Prior to March 2011, the Japan Trench subduction zone has produced nine earthquakes with magnitudes greater than 7 just since 1973.

The only subduction zone that is capable of directly impacting the continental US is the Cascadia subduction zone, which lies off of the coast of northern California, Oregon, and Washington. The fault surface defined by this interface dips to the east (becomes deeper) beneath the coast. The Cascadia subduction zone is capable of producing very large earthquakes if all or a large portion of the fault area ruptures in a single event. However, the rate of earthquake occurrence along the Cascadia subduction zone is much less than has been observed along the Japan Trench subduction zone. The only operating nuclear power plant in that area is Columbia, which is far from the coast (~220 miles/350 km) and the Cascadia subduction zone. _The occurrence of earthquakes on the Cascadia subduction zone has been considered in the evaluation of the Columbia NPP._



Schematic Illustration of the Cascadia Subduction Zone

The size (magnitude) of earthquakes is proportional to the surface area of a fault that slips in a given earthquake. Large earthquakes are associated with large (long) faults. Hence, the prediction of earthquake magnitudes for a specific fault considers the dimensions of the fault. Identification of fault size is usually based on geologic mapping or the evaluation of spatial patterns of small earthquakes. To provide **a point of comparison**, the length of the fault that slipped during the March 11, 2011 magnitude 9 Japanese earthquake was >620 km, the length of the fault(s) that slipped during the magnitude 7.3 1992 Landers, CA earthquake was ~90 km and the estimated length of the Hosgi fault near Diablo Canyon NPP is 140 km and a magnitude of 7.5 is assigned to that fault. A number of major crustal faults or fault zones (not associated with the Cascadia subduction zone) have been identified that have produced earthquakes of magnitude 7.5 to 8 in the continental US (including California). ***These fault sources have been identified and characterized in seismic hazard assessments.***

Seismic designs at US nuclear power plants are developed in terms of seismic ground motion spectra, which are called the Safe Shutdown Earthquake ground motion response spectra (SSE). Each nuclear power plant is designed to a ground motion level that is appropriate for the geology and tectonics in the region surrounding the plant location. Currently operating nuclear power plants developed their SSEs based on a "deterministic" or "scenario earthquake" basis that account for the largest earthquake expected in the area around the plant. Seismic activity in the regions surrounding US plants is much lower than that for Japan since **most US plants are located in the interior of the stable continental US** The largest earthquakes within the continental US are the 1811-12 New Madrid sequence and the 1886 Charleston, SC, which were estimated to be between about magnitude 6.8 to 7.5. On the west coast of the US, the two nuclear power plants are designed to specific ground motions from earthquakes of about magnitude 7+ on faults located just offshore of the plants. The earthquakes on these faults are mainly strike-slip (horizontal motion on near vertical planes) type earthquakes, not subduction zone earthquakes. This fault geometry does not produce large tsunamigenic waves. Therefore, the likelihood of a significant tsunami from these faults is very remote.

## Fact Sheet: US Portable Array Information

NOTE: This is provided because IRIS participants let us know that here was a discussion about the NRC's involvement in this program during a meeting with congressional staffers. We have been involved in this for the last couple years.

the IRIS CONSORTIUM

The Incorporated Research Institutions for Seismology is the Consortium of Unites States Universities with Major Research Programs in Seismology and Related Fields.

**The Transportable Array: A Science Investment that Can Be Leveraged**

IRIS is installing the Transportable Array – a set of 400 broadband seismic instruments – in each of more than 1600 sites across the contiguous United States. The instruments operate at each site for two years and then are removed and redeployed further east. Roughly 1100 stations have been installed since 2003, and instruments have been removed from more than 600 of those sites in the western United States.

The National Science Foundation is funding the full cost to "roll" the Transportable Array across the US, more than $90,000,000 over ten years. Comparatively small incremental investments could add significant data that are relevant to the safety of nuclear power plants. These efforts would be uniquely cost effective, since NSF is already funding installation, and they would feed data into an existing, standardized and widely used data management system that already incorporates the vast majority of seismic data from US networks. But these opportunities are time constrained: the array will be fully installed in the contiguous 48 states by late 2013.

**More Value from Longer Term Regional Observations**

A dense, uniform seismic network is necessary for long-term, broad-area seismic monitoring of the central and eastern United States due to low event recurrence rates and the risk of significant earthquakes ($M$>5) anywhere in the region. Monitoring seismicity in the central and eastern US can be improved by turning selected sites into permanent seismic stations. A total of more than 35 Transportable Array stations have already been "adopted" by several organizations, creating a permanent legacy, but only in the western United States.

A strategic "1-in-4" plan would involve "adoption" of systematically selected stations in the central and eastern United States – every other station in both the east-west and north-south directions, creating a uniform grid of some 250 stations. Long-term regional operation could be combined with two optional enhancements to create a unique observatory for the study of seismicity, source characteristics, attenuation, and local ground acceleration.

**Enhancement 1: Acquire Higher Frequency Data**

Crustal rigidity in the central and eastern US makes it desirable to record high frequency characteristics of local and regional earthquakes. The existing instruments could be reconfigured to record high frequencies but doing so would nearly triple the data flow, necessitating improvements to the communications infrastructure.

**Enhancement 2: Add Strong Motion Sensors**

Acquiring strong motion sensors and reconfiguring field computers that record and telemeter the data would help to measure unique effects of severe shaking. The design anticipated this augmentation, and several stations in California and Washington were operated that way. Upgrade would be more efficient at sites that have not yet been installed.

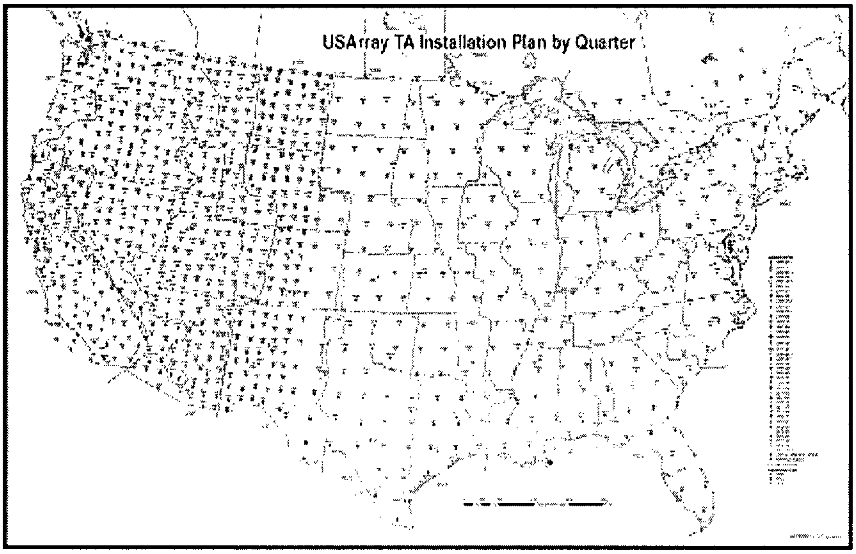
*Estimate of annual acquisition and O&M costs for the 1-in-4, 250-station network in central and eastern US.*

| Year | Stations | Acquisition[1] | O&M[2] | Total |
|---|---|---|---|---|
| 2011 | 50 | $1,800,000 | $ 400,000 | $2,200,000 |
| 2012 | 50 | $1,800,000 | $ 800,000 | $2,600,000 |
| 2013 | 50 | $1,800,000 | $1,200,000 | $3,000,000 |
| 2014 | 50 | $1,800,000 | $1,600,000 | $3,400,000 |
| 2015 | 50 | $1,800,000 | $2,000,000 | $3,800,000 |
| 2016 | – | – | $2,000,000 | $2,000,000 |

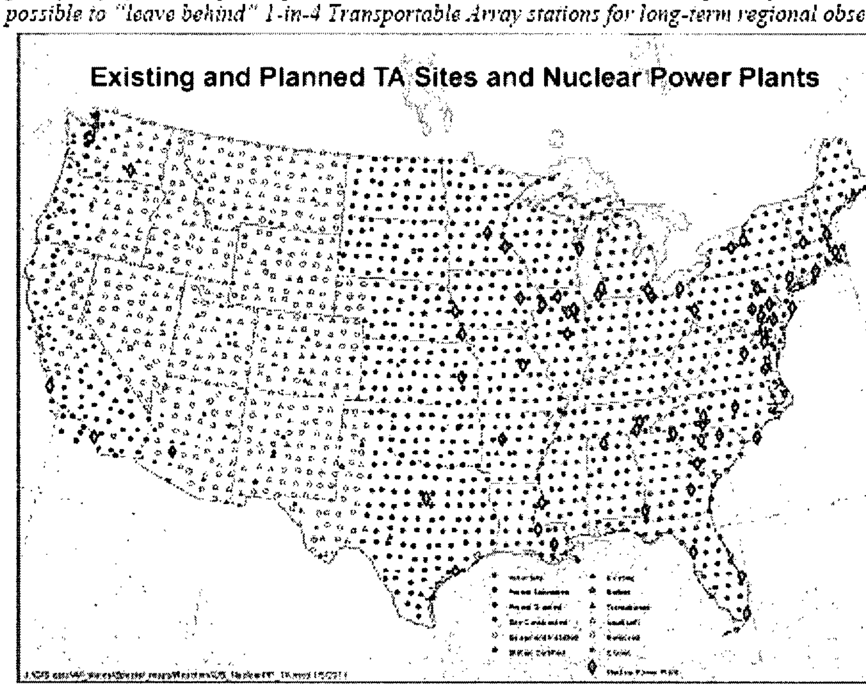
[1] Assumes upgrades to six channel data loggers with strong motion sensors.

[2] Assumes a conservative estimate of $8,000/station/year.

*The 1-in-4, 250-station network that could be created in the central and eastern US by "leaving behind" one out of every four Transportable Array stations during the years 2011 through 2015.*




*A large majority of nuclear power plants are located in the central and eastern parts of the US, where it is still possible to "leave behind" 1-in-4 Transportable Array stations for long-term regional observations.*



## Fact Sheet: The B.5.b Rule (10 CFR 50.54hh/B.5.b)

The following was taken from the Commission Briefing (3/21) notes:

Following the terrorist events of September 11, 2001, the NRC issued EA-02-026, "Order for Interim Safeguards and Security Compensatory Measures" (the ICM Order), February 25, 2002, (designated SGI), which specified interim safeguards and security compensatory measures. Section B.5.b of the ICM Order required licensees to adopt mitigation strategies using readily available resources to maintain or restore core cooling, containment, and SFP cooling capabilities to cope with the loss of large areas of the facility due to large fires and explosions from any cause, including beyond-design-basis aircraft impacts.

In June 2005 the NRC developed a phased approach to implement the B.5.b requirements:

- For Phase 1, the NRC expected licensees to use information from (1) existing programs and equipment and operational know-how, including maintaining capabilities currently in place, (2) industry best practices, and (3) application of generic lessons learned from engineering analyses.
- Phase 2 addressed assessment of SFPs including additional mitigation strategies that use existing or readily available resources to further enhance the plant's effectiveness in maintaining SFP cooling, and identify potential practicable options for the use of generic, deployable, or other backup mitigation capabilities that exceed the NRC's requirements.
- Phase 3 addressed assessment of the reactor and containment mitigation. This change allowed the staff to give priority to the assessment of SFPs before the reactor and containment.

On February 25, 2005, the NRC issued guidance for implementing Section B.5.b of the ICM Order. This included guidance on:

- Actions to Mitigate Fuel damage, which included:
  - Develop procedures to facilitate primary containment to secondary containment venting without AC power as an alternate remove heat from primary containment,
  - Develop/Modify procedures to start safety and or operate equipment to facilitate plant cooldown (Diesel generators, AFPs, RCIC ) without DC power,
  - Identification and use of alternate water sources and pumping sources (such as a site fire pump as an alternate supply water for core cooling and SFP water),
  - Development of strategies for use of portable and offsite equipment to support recovery efforts ( prefabricated and pre-staged cables, adapters, jumpers spool pieces, equipment needed for primary to secondary containment venting),
- Spent Fuel pool mitigation measures, which included:
  - Strategies for dispersing higher decay power (hottest) fuel amongst older low decay power (coolest) fuel to facilitate cooling, enabling air cooling if water level is lost in the reduced timeframes
  - Maintenance of empty space in the SFP to provide for a downcomer effect, facilitating natural circulation within the pool
  - Provide for emergency water makeup sources, and/or emergency repair

By December 2006, the staff had completed Phase 1 inspections at all operating reactor sites. In December 2006, the NRC endorsed NEI 06-12, Revision 2, "B.5.b Phase 2 & 3 Submittal Guideline," which provided specifications for standard mitigative strategies to address the maintenance or restoration of core cooling, containment and spent fuel pool cooling, including the use of some equipment that would have been beyond readily available. The strategies included those listed below:

- Adding make-up water to the SFP,
- Spraying water on the spent fuel,

- Enhanced initial command and control activities for challenges to core cooling and containment, and
- Enhanced response strategies for challenges to core cooling and containment.

The B.5.b Guidance and NEI 06-12, Revision 2, were used by each licensee in preparing information submitted to the NRC that describes a plant specific approach to implementing mitigating strategies and supports each plant specific license condition.

The NRC Performed Section B.5.b Phase 2 Assessments (June – December 2005) to Identify SFP Mitigation Strategies.

The NRC and Industry Performed B.5.b Phase 3 Assessments (October 2005 – June 2006) to Identify Reactor and Containment Mitigation Strategies.

In 2007, the NRC staff completed safety evaluations of licensee commitments submitted using the NEI 06-12 Guideline and imposed license conditions requiring them to provide a regulatory footprint. By December 2008 the NRC staff completed its inspection to verify the implementation of strategies and guidance at each facility.

On March 27, 2009, the NRC amended 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," and Part 73, "Physical Protection of Plants and Materials," with new requirements.

This rulemaking added 10 CFR 50.54(hh)(2) in order to impose the same mitigating strategies requirements on new reactor applicants and licensees as those imposed by the ICM Order and associated license conditions.

This rulemaking also added paragraph (i) to 10 CFR 50.34, "Contents of applications; technical information," to require submittal of a "description and plans for implementation of the guidance and strategies intended to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities under the circumstances associated with the loss of large areas of the plant due to explosions or fire as required by § 50.54(hh)(2) of this chapter." (A parallel requirement was added as paragraph (d) to 10 CFR 52.80 for reactors licensed under 10 CFR Part 52, under the purview of the Office of New Reactors.)

The Statement of Considerations for this rulemaking specifically noted that the requirements described in Section 50.54(hh) are for addressing certain events that are the cause of large fires and explosions that affect a substantial portion of the nuclear power plant contemplates that the initiating event for such large fires and explosions could be any number of beyond-design basis events, including natural phenomena such as those described in General Design Criteria (i.e., earthquakes, tornadoes, floods, tsunami, and seiches).

## Fact Sheet: Generic Issue GI-199, "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants"

The objective of the GI-199 Safety/Risk Assessment was to perform a conservative, screening-level assessment to evaluate if further investigations of seismic safety for operating reactors in the central and eastern U.S. (CEUS) are warranted consistent with NRC directives.

- The results of the GI-199 safety risk assessment should not be interpreted as definitive estimates of plant-specific seismic risk.
- The nature of the information used (both seismic hazard data and plant-level fragility information) make these estimates useful only as a screening tool. The NRC does not rank plants by seismic risk.

**Key Messages from the GI-199 Communications Plan:**

- In August 2010, the Safety/Risk Assessment for GI-199 was completed. That assessment found that operating nuclear power plants are safe: Plants have adequate safety margin for seismic issues. The NRC's Safety/Risk Assessment confirmed that overall seismic risk estimates remain small and that adequate protection is maintained.
- Though still small, some seismic hazard estimates have increased: Updates to seismic data and models indicate increased seismic hazard estimates for some operating nuclear power plant sites in the Central and Eastern United States.
- Assessment of GI-199 will continue: Plants are safe (see key message 1), but the NRC has separate criteria for evaluating whether plant improvements may be imposed.

The NRC's Safety/Risk Assessment used readily available information and found that for about one-quarter of the currently operating plants, the estimated core damage frequency change is large enough to warrant further attention. Action may include obtaining additional, updated information and developing methods to determine if plant improvements to reduce seismic risk are warranted.

**Note**: GI-199 Communication Plan is available in ADAMs: ML081850477.

Status of Operating Plants and Need of Additional Actions due to Japanese Event:

- Currently operating nuclear plants in the United States remain safe, with no need for immediate action.
- This determination is based on NRC staff reviews of updated seismic hazard information and the conclusions of the Generic Issue 199 Screening Panel.
- Existing plants were designed with considerable margin to be able to withstand the ground motions from the "deterministic" or "scenario earthquake" that accounted for the largest earthquake expected in the area around the plant.
- During the mid-to late-1990s, the NRC staff reassessed the margin beyond the design basis as part of the Individual Plant Examination of External Events (IPEEE) program.
- The results of the GI-199 assessment demonstrate that the probability of exceeding the design basis ground motion may have increased at some sites, but only by a relatively small amount. In addition, the Safety/Risk Assessment stage results indicate that the probabilities of seismic core damage are lower than the guidelines for taking immediate action.

- In summary, US plants are designed for appropriate earthquake levels and are safe. As addressed above, the NRC is conducting a program called Generic Issue 199, which is reviewing the adequacy of the earthquake design of US NPPs in central and eastern North America based on the latest data and analysis techniques. The NRC will look closely at all aspects of the response of the plants in Japan to the earthquake and tsunami to determine if any actions need to be taken in US plants and if any changes are necessary to NRC regulations.

Timeline for Preparation and Issuance of GI-199 Generic Letter:

- The NRC is working on developing a Generic Letter (GL) to request information of all affected plants (96 plants that are east of the Rockies).
- The GL is planned to be issued in draft form within the next 2 months to stimulate discussions with industry in a public meeting.
- Process will be followed, i.e., Committee to Review Generic Requirements, Advisory Committee on Reactor Safeguards Meeting and then GL will be issued as a draft for formal public comments (60 days), followed by a second meeting with ACRS.
- We expect to issue the GL by the end of this calendar year, as the new consensus seismic hazard estimates become available. (This effort is being coordinated with US NRC, DOE, EPRI, and USGS).
- The information from licensees will likely require 3 to 6 months to complete. Staff's review will commence after receiving licensees' responses. Based on staff's review, a determination can be made regarding cost beneficial backfits where it can be justified.

## Fact Sheet: Station Blackout Rule

The NRC designated station blackout (SBO), which is a loss of all offsite and onsite ac power concurrent with a turbine trip, as an Unresolved Safety Issue in 1980. In 1988, the Commission concluded that additional SBO regulatory requirements were justified and issued the SBO rule, 10 CFR 50.63, to provide further assurance that a loss of both offsite and onsite emergency AC power systems would not adversely affect public health and safety. As a result of the SBO rule all plants have (1) established SBO coping and recovery procedures; (2) completed training for these procedures; (3) implemented modifications as necessary to cope with an SBO; and (4) ensured a 4-16 hour coping capability. The coping capability was based on the reliability and redundancy of the on-site electrical system, the frequency of a loss of off-site power and the time needed to restore off-site power. The staff also performed pilot inspections at 8 sites to verify proper implementation of the SBO rule.

Based on the outcomes of those inspections the NRC staff concluded that the industry was properly implementing the rule. Each light-water-cooled nuclear power plant licensed to operate must be able to withstand for a specified duration and recover from a station blackout (as defined in 10 CFR 50.2). Forty-four (44) U.S reactors rely on battery power (4-hour coping) and sixty (60) have opted to use an alternate AC source (4 to 16 hour coping) to cope with a SBO. The NRC staff reviewed the responses from every nuclear power plant and issued a SER accepting the proposed coping methods. Studies conducted by the NRC have shown that the hardware and procedures that have been implemented to meet the station blackout requirements have resulted in significant risk reduction and have further enhanced defense in depth. The NRC plans to carefully evaluate the lessons learned from the events in Japan to determine if enhancements to the station blackout rule are warranted.

Staff issued implementation guidance, Regulatory Guide (RG) 1.155, "Station Blackout," issued August 1988. Industry Issued SBO Rule Implementation Guidance NUMARC 87-00. During License renewal of power plants, staff reviewed aging management of SBO SSCs. SBO Rule requires that each light-water-cooled nuclear power plant licensed to operate under this part, each light-water-cooled nuclear power plant must be able to withstand for a specified duration and recover from a station blackout as defined in § 50.2. The specified station blackout duration shall be based on the following factors:

- (i) The redundancy of the onsite emergency ac power sources;
- (ii) The reliability of the onsite emergency ac power sources;
- (iii) The expected frequency of loss of offsite power; and
- (iv) The probable time needed to restore offsite power.

SBO Rule also requires that the reactor core and associated coolant, control, and protection systems, including station batteries and any other necessary support systems, must provide sufficient capacity and capability to ensure that the core is cooled and appropriate containment integrity is maintained in the event of a station blackout for the specified duration. The capability for coping with a station blackout of specified duration shall be determined by an appropriate coping analysis. Licensees are expected to have the baseline assumptions, analyses, and related information used in their coping evaluations available for NRC review. Currently, all plants are in compliance with 50.63, "Loss of all Alternating current Power". **All U.S. plants have the capability, capacity, and operating procedures in place to cope with a station blackout event.**

**Additional reference:** NUREG/CR-6890 (2005), "Reevaluation of Station Blackout Risk at Nuclear Power Plants."

## Terms and Definitions

***Acceptable Method* –** In many places, this standard contains statements indicating that a certain reference provides an "acceptable method" for satisfying the intent of a given requirement. The plain meaning of such a statement is that the referenced method is one way to meet the given requirement. The intent is to be permissive, meaning that the analysis team can use another method, if justified, without prejudice. However, it is important to understand that the intent of the standard goes beyond the plain meaning, as follows: Whenever the phrasing "acceptable method" is used, the intent is that if the analysis uses another method, the other method must satisfy the stated requirement with a comparable level of conservatism considering a similar level of details pertinent to the analysis scope. It is not acceptable to use another method that does not satisfy the requirement at least as well as the acceptable method would satisfy it. Whenever an alternative to the acceptable method is selected, it is understood that the peer review team will pay particular attention to this topic.

***Accident Consequences* –** The extent of plant damage or the radiological release and health effects to the public or the economic costs of a core damage accident.

***Accident Sequence* –** A representation in terms of an initiating event (IE) followed by a sequence of failures or successes of events (such as system, function, or operator performance) that can lead to undesired consequences, with a specified end state (e.g., core damage or large early release).

***Accident Sequence Analysis* –** The process to determine the combinations of IEs, safety functions, and system failures and successes that may lead to core damage or large early release.

***Active or Seismogenic Fault* –** need to add definition of active fault

***Aleatory Variability (or Aleatory Uncertainty)* –** The variability inherent in a nondeterministic (i.e., stochastic, random) phenomenon. Aleatory variability is accounted for by modeling the phenomenon in terms of a probability model. In principle, aleatory uncertainty cannot be reduced by the accumulation of more data or additional information, but the detailed characteristics of the probability model can be improved. Sometimes aleatory variability is called "randomness."

***Annual exceedance frequency (AEF)*** – Number of times per year that a site's ground motion is expected to exceed a specified acceleration.

***Area Source* –** An area at the surface of the earth's crust that is assumed to have experienced relatively uniform earthquake source characteristics for use in the PSHA. (See also "Volumetric Source Zone".)

***At Power* –** Those plant operating states characterized by the reactor being critical and producing power, with automatic actuation of critical safety systems not blocked and with essential support systems aligned in their normal power operation configuration.

***Background Source Zone* –** A part of the earth's crust, usually of large surface area dimension, within which potentially damaging earthquakes could occur that are not associated either with known fault sources or even with the uniform pattern, rate, or style of deformation or seismicity commonly identified with volumetric seismic source zones. In PSHA calculations, earthquakes that cannot be associated with other sources default to a background source zone.

***Basic Event* –** An event in a fault tree model that requires no further development, because the appropriate limit of resolution has been reached.

***Bounding Analysis* –** Analysis that uses assumptions such that the assessed outcome will meet or exceed the maximum severity of all credible outcomes.

***Capable Tectonic Source –*** A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation such as faulting or folding at or near the earth's surface in the present seismotectonic regime. It is described by at least one of the following: characteristics:

(1) presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years or at least once in the last approximately 50,000 years

(2) a reasonable association with one or more moderate to large earthquakes or sustained earthquake activity that are usually accompanied by significant surface deformation

(3) a structural association with a capable tectonic source that has characteristics of either item a or b (above), such that movement on one could be reasonably expected to be accompanied by movement on the other

In some cases, the geological evidence of past activity at or near the ground surface along a potential capable tectonic source may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the structure from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence is to be used in determining whether the structure is a capable tectonic source within this definition. Notwithstanding the foregoing paragraphs, the association of a structure with geological structures that are at least pre-Quaternary, such as many of those found in the central and eastern regions of the United States, in the absence of conflicting evidence, will demonstrate that the structure is not a capable tectonic source within this definition.

***CDFM method –*** Refers to the Conservative Deterministic Failure Margin (CDFM) method as described in EPRI NP-6041-56, Rev. 1 wherein the seismic margin of the component is calculated using a set of deterministic rules that are more realistic than the design procedures.

***Central and Eastern United States (CEUS) –*** That portion of the United States east of the Rocky Mountains (approximately the 104th parallel).

***Certified Seismic Design Response Spectra (CSDRS) –*** Site-independent seismic design response spectra that have been approved under Subpart B of 10 CFR Part 52 as the seismic design response spectra for an approved certified standard design nuclear power plant. The input or control location for the CSDRS is specified in the certified standard design.

***Combined License –*** A combined construction permit and operating license with conditions for a nuclear power facility issued pursuant to Subpart C of 10 CFR Part 52.

***Common-Cause Failure (CCF) –*** A failure of two or more components during a short period of time as a result of a single shared cause.

***Component –*** An item in a nuclear power plant, such as a vessel, pump, valve, or circuit breaker.

***Composite Variability –*** The composite variability includes the aleatory (randomness) uncertainty ($\beta_R$) and the epistemic (modeling and data) uncertainty ($\beta_U$). The logarithmic standard deviation of composite variability, $\beta_c$, is expressed as $(\beta_R^2 + \beta_U^2)^{1/2}$.

***Containment Analysis –*** The process to evaluate the failure thresholds or leakage rates of the containment.

***Containment Failure*** **–** Loss of integrity of the containment pressure boundary from a core damage accident that results in unacceptable leakage of radionuclides to the environment.

***Controlling Earthquakes*** **–** Earthquakes used to determine spectral shapes or to estimate ground motions at the site for some methods of dynamic site response. There may be several controlling earthquakes for a site. As a result of the probabilistic seismic hazard analysis (PSHA), controlling earthquakes are characterized as mean magnitudes and distances derived from a deaggregation analysis of the mean estimate of the PSHA.

***Core Damage Frequency (CDF)*** **–** Expected number of core damage events per unit of time.

***Core damage*** **–** Refers to the uncovery and heat-up of the reactor core, to the point that prolonged oxidation and severe fuel damage are not only anticipated but also involve enough of the core to result in off-site public health effects if released. *Seismic core damage frequency* refers to the component of total CDF that is due to seismic events.

***Cumulative Absolute Velocity (CAV)*** **–** For each component of the free-field ground motion, the CAV should be calculated as follows: (1) the absolute acceleration (g units) time-history is divided into 1-second intervals, (2) each 1-second interval that has at least 1 exceedance of 0.025g is integrated over time, and (3) all the integrated values are summed together to arrive at the CAV. The CAV is exceeded if the calculation is greater than 0.16 g-second. The application of the CAV in siting requires the development of a CAV model because the PSHA calculation does not use time histories directly.

***Deaggregation*** **–** The process for determining the fractional contribution of each magnitude-distance pair to the total seismic hazard. To accomplish this, a set of magnitude and distance bins are selected and the annual probability of exceeding selected ground acceleration parameters from each magnitude-distance pair is computed and divided by the total probability for earthquakes.

***Dependency*** **–** Requirement external to an item and upon which its function depends and is associated with dependent events that are determined by, influenced by, or correlated to other events or occurrences.

***Design basis earthquake (DBE)*** **or** ***safe shutdown earthquake (SSE)*** – A *design basis earthquake* is a commonly employed term for the *safe shutdown earthquake* (*SSE)*; the SSE is the earthquake ground shaking for which certain structures, systems, and components are designed to remain functional. In the past, the SSE has been commonly characterized by a standardized spectral shape associated with a peak *ground acceleration* value.

***Design Factor*** **–** The ratio between the site-specific GMRS and the UHRS. The design factor is aimed at achieving the target annual probability of failure associated with the target performance goals.

***Distribution System*** **–** Piping, raceway, duct, or tubing that carries or conducts fluids, electricity, or signals from one point to another.

***Early Site Permit*** **–** A Commission approval, issued pursuant to Subpart A of 10 CFR Part 52, for a site or sites for one or more nuclear power facilities.

***Earthquake Recurrence*** **–** The frequency of occurrence of earthquakes as a function of magnitude. Recurrence relationships or curves are developed for each seismic source, and they reflect the frequency of occurrence (usually expressed on an annual basis) of magnitudes up to the maximum, including measures of uncertainty.

***Epicenter*** – The point on the earth's surface directly above the focus (i.e., hypocenter) of the earthquake source.

***Epistemic Uncertainty*** – Uncertainty attributable to incomplete knowledge about a phenomenon that affects the ability to model it. Epistemic uncertainty is captured by considering a range of model parameters within a given expert interpretation or multiple expert interpretations and each of which is assigned an associated weight representing statistical confidence in the alternatives. In principle, epistemic uncertainty can be reduced by the accumulation of additional information associated with the phenomenon. The uncertainty in the parameters of the probability distribution of a random phenomenon is epistemic.

***Event Tree*** – A logic diagram that begins with an IE or condition and progresses through a series of branches that represent expected system or operator performance that either succeeds or fails and arrives at either a successful or failed end state.

***External Event*** – An IE originating outside a nuclear power plant that causes safety system failures, operator errors, or both, that in turn may lead to core damage or large early release. Events such as earthquakes, tornadoes, and floods from sources outside the plant and fires from sources inside or outside the plant are considered external events (see also internal event). By convention, LOSP not caused by another external event is considered by convention to be an internal event.

***Failure Mechanism*** – Any of the processes that result in failure modes, including chemical, electrical, mechanical, physical, thermal, and human error.

***Failure Mode*** – 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, leaks).

***Failure Probability*** – The likelihood that an SSC will fail to operate upon demand or fail to operate for a specific mission time.

***Failure Rate*** – Expected number of failures per unit of time, evaluated, for example, by the ratio of the number of failures in a total population of components to the total time observed for that population.

***Fault*** – A fracture in the earth along which blocks of crust on either side have moved with respect to one another.

***Fault Source*** – A fault or zone for which the tectonic features causing earthquakes have been identified. These are usually individual faults, but they may be zones comprising multiple faults or regions of faulting if surface evidence of these faults is lacking but the faults are suspected from seismicity patterns, tectonic interpretations of crustal stress and strain, and other evidence. Regions of blind thrust faults are a good example of the latter.

***Fault Tree*** – A deductive logic diagram that depicts how a particular undesired event can occur as a logical combination of other undesired events.

***Fractile Hazard Curve*** – Epistemic uncertainty is expressed by a distribution of exceedence probability values; a distribution of hazard curves, rather than a single value; or a single curve. In a fractile hazard curve, all the points on the curve correspond to the same fractile of the distribution of the probability of exceedence. A 5% percentile hazard curve indicates that we have a 5% confidence that the calculated hazard would be less than that given by the curve. A 95% percentile hazard curve indicates that we are 95% confident that the hazard is below the hazard given by the hazard curve.

***Fragility*** – 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, Am, bR, and bU, which are, respectively, the median acceleration capacity, the logarithmic standard deviation of the aleatory (randomness) uncertainty in capacity, and the logarithmic standard deviation of the epistemic (modeling and data) uncertainty in the median capacity.

***Frequency of Onset of Significant Inelastic Deformation (FOSID)*** – The annual probability of the onset of significant inelastic deformation (OSID). OSID is just beyond the occurrence of insignificant (or localized) inelastic deformation, and in this way corresponds to "essentially elastic behavior." As such, OSID of a structure, system, or component (SSC) can be expected to occur well before seismically induced core damage, resulting in much larger frequencies of OSID than seismic core damage frequency (SCDF) values. In fact, OSID occurs before SSC "failure," where the term failure refers to impaired functionality.

***Ground acceleration*** – Acceleration produced at the ground surface by seismic waves, typically expressed in units of *g*, the acceleration of gravity at the earth's surface.

***Ground Motion Response Spectra (GMRS)*** – A site-specific ground motion response spectra characterized by horizontal and vertical response spectra determined as free-field motions on the ground surface or as free-field outcrop motions on the uppermost in-situ competent material using performance-based procedures. When the GMRS are determined as free-field outcrop motions on the uppermost in-situ competent material, only the effects of the materials below this elevation are included in the site response analysis.

***Ground Motion Slope Ratio*** – Ratio of the spectral accelerations, frequency by frequency, from a seismic hazard curve corresponding to a 10-fold reduction in hazard exceedance frequency. (See Equation 3 in Regulatory Position 5.1.)

***Hazard*** – The physical effects of a natural phenomenon such as flooding, tornado, or earthquake that can pose potential danger (for example, the physical effects such as ground shaking, faulting, landsliding, and liquefaction that underlie an earthquake's potential danger).

***Hazard (as used in probabilistic hazard assessment)*** – Represents the estimate of expected frequency of exceedance (over some specified time interval) of various levels of some characteristic measure of a natural phenomenon [for example, peak ground acceleration (PGA) to characterize ground shaking from earthquakes]. The time period of interest is often taken as 1 year, in which case the estimate is called the annual frequency of exceedance.

***Hazard Curve*** – A curve that gives the probability of a certain ground motion parameter (usually the PGA, PGV, or response spectral values) being exceeded. Hazard curves are generally generated for periods of exposure of one year, and they give annual probabilities of exceedence.

***HCLPF capacity*** – Refers to the High Confidence of Low Probability of Failure capacity, which is a measure of seismic margin. In seismic PRA, this is defined as the earthquake motion level at which there is a high (95 percent) confidence of a low (at most 5 percent) probability of failure. Using the lognormal fragility model, the HCLPF capacity is expressed as $A_m \exp[-1.65(\beta_R + \beta_U)]$. When the logarithmic standard deviation of composite variability $\beta_C$ is used, the HCLPF capacity could be approximated as the ground motion level at which the composite probability of failure is at most 1 percent. In this case, HCLPF capacity is expressed as $A_m \exp[-2.33\beta_c]$. In deterministic SMAs, the HCLPF capacity is calculated using the CDFM method.

***High confidence of low probability of failure (HCLPF) capacity*** – A measure of *seismic margin*. In *seismic risk* assessment, *HCLPF capacity* is defined as the earthquake motion level, at which there is high confidence (95%) of a low probability (at most 5%) of failure of a structure, system, or component.

***High Winds*** – Tornadoes, hurricanes (or cyclones or typhoons as they are known outside the United States), extratropical (thunderstorm) winds, and other wind phenomena depending on the site location.

***Hypocenter*** – The point of the earth's crust where a rupture initiates, creating an earthquake.

***In-column Motion*** – Motion that is within a soil column, as opposed to the motion at the surface or treated as if it is at the surface.

***Initiating Event (IE)*** – Any event either internal or external to the plant that perturbs the steady-state operation of the plant, if operating, thereby initiating an abnormal event such as a transient or loss-of-coolant accident (LOCA) within the plant. Initiating events trigger sequences of events that challenge plant control and safety systems whose failure could potentially lead to core damage or large early release.

***Intensity*** – The intensity of an earthquake is a qualitative description of the effects of the earthquake at a particular location, as evidenced by observed effects on humans, on human-built structures, and on the earth's surface at a particular location. Commonly used scales to specify intensity are the Rossi-Forel, Mercalli, and Modified Mercalli. The Modified Mercalli Intensity (MMI) scale describes intensities with values ranging from I to XII in the order of severity. MMI of I indicates an earthquake that was not felt except by a very few, whereas MMI of XII indicates total damage of all works of construction, either partially or completely.

***Interfacing Systems LOCA (ISLOCA)*** – A loss-of- coolant accident (LOCA) when a breach occurs in a system that interfaces with the reactor coolant system (RCS), where isolation between the breached system and the RCS fails. An ISLOCA is usually characterized by the overpressurization of a low-pressure system when subjected to RCS pressure and can result in containment bypass.

***Internal Event*** – An event originating within a nuclear power plant that in combination with safety system failures, operator errors, or both, can affect the operability of plant systems and may lead to core damage or large early release. By convention, loss of off-site power not caused by an external event is considered to be an internal event, and internal fire is considered to be an external event.

***Key Assumption*** – An assumption made in response to a key source of uncertainty in the knowledge that a different reasonable alternative assumption would produce different results, or an assumption that results in an approximation made for modeling convenience in the knowledge that a more detailed model would produce different results. For the base PRA, the term "different results" refers to a change in the plant risk profile (e.g., total CDF and total LERF, the set of initiating events and accident sequences that contribute most to CDF and to LERF) and the associated changes in insights derived from the changes in risk profile. A "reasonable alternative" assumption is one that has broad acceptance within the technical community and for which the technical basis for consideration is at least as sound as that of the assumption being challenged.

***Key Source of Uncertainty*** – A source of uncertainty that is related to an issue for which there is no consensus approach or model and where the choice of approach or model is known to have an impact on the risk profile (e.g., total CDF and total LERF, the set of initiating events and accident sequences that contribute most to CDF and LERF) or a decision being made using the PRA. Such an impact might occur, for example, by introducing a new functional accident sequence or a change to the overall CDF or LERF estimates significant enough to affect insights gained from the PRA.

***Large Early Release*** – The rapid, unmitigated release of airborne fission products from the containment to the environment occurring before the effective implementation of off-site emergency response and protective actions, such that there is a potential for early health effects.

***Large Early Release Frequency (LERF)*** – The expected number of large early releases per unit of time. A *large early release* is the rapid, unmitigated release of airborne fission products from the containment building to the environment, occurring before the effective implementation of off-site emergency response and protective actions, such that there is a potential for early health effects. *Seismic large early release frequency* refers to the component of total LERF that is due to seismic events.

***Level 1 Analysis*** – Identification and quantification of the sequences of events leading to the onset of core damage.

***Level 2 Analysis*** – Evaluation of containment response to severe accident challenges and quantification of the mechanisms, amounts, and probabilities of subsequent radioactive material releases from the containment.

***Liquefaction*** – The sudden loss of shear strength and rigidity of saturated, cohesionless soils, due to steady-state groundwater f low or vibratory ground motion. The term "seismic liquefaction" is used in this standard for liquefaction phenomena induced by seismic motions.

***Magnitude*** – An earthquake's magnitude is a measure of the strength of the earthquake as determined from seismographic observations and is an objective, quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, Surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the most commonly used magnitude measurement is the Moment Magnitude, Mw, which is based on the seismic moment computed as the rupture force along the fault multiplied by the average amount of slip, and thus is a direct measure of the energy released during an earthquake.

***Maximum Magnitude*** – The maximum magnitude is the upper bound to earthquake recurrence curves.

***Median Hazard Curve*** – Corresponds to a 50%, or the 50th fractile, hazard curve.

***Mean Hazard Curve*** – Corresponds to the mean of the probability distribution of hazard curves.

***Mean Site Amplification Function*** – The mean amplification function is obtained for each controlling earthquake, by dividing the response spectrum from the computed surface motion by the response spectrum from the input hard rock motion, and computing the arithmetic mean of the individual response spectral ratios.

***Nontectonic Deformation*** – Nontectonic deformation is distortion of surface or near-surface soils or rocks that is not directly attributable to tectonic activity. Such deformation includes features associated with subsidence, karst terrain, glaciation or deglaciation, and growth faulting.

***Operating-Basis Earthquake (OBE)*** – To satisfy the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE) ground motion is defined as follows:

(i) For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.

(ii) For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in design control document (DCD).

(iii) The spectrum ordinate criterion to be used in conjunction with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," issued March 1997, is the lowest of (i) and (ii).

That earthquake ground motion that, when exceeded (along with a CAV value exceedance) requires shutdown of the plant. In the past, the OBE was commonly chosen to be one-half of the safe shutdown earthquake (SSE). However, newer guidance sets the OBE at 1/3 of the SSE unless additional calculations are performed.

***Peak Ground Acceleration (PGA)*** – Maximum absolute value of acceleration displayed on an accelerogram, the largest ground acceleration produced by an earthquake at a site.

***Peak Ground Displacement*** – The largest ground displacements produced by an earthquake at a site.

***Peak Ground Velocity*** – The largest ground velocity produced by an earthquake at a site.

***Plant*** – A general term used to refer to a nuclear power facility (for example, "plant" could be used to refer to a single unit or multiunit site).

***Point Estimate*** – Estimate of a parameter in the form of a single number.

***Probabilistic Risk Assessment (PRA)*** – A qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public [also referred to as a probabilistic safety assessment (PSA)].

***Probability of Exceedence*** – The probability that a specified level of seismic hazard will be exceeded at a site or in a region during a specified exposure time.

***PRA Configuration Control Plan*** – The process and document used by the owner of the PRA to define the PRA technical elements that are to be periodically maintained and0or upgraded and to document the methods and strategies for maintenance and upgrading of those PRA technical elements.

***Randomness (as used in seismic-fragility analysis)*** – The variability in seismic capacity arising from the randomness of the earthquake characteristics for the same acceleration and to the structural response parameters that relate to these characteristics. Also see "Aleatory Variability."

***Response Spectrum*** – A plot of the maximum responses (acceleration, velocity, or displacement) of idealized single-degree-of-freedom oscillators as a function of the natural frequencies of the oscillators for a given damping value. The response spectrum is calculated for a specified vibratory motion input at the oscillators' supports.

***Review Level Earthquake (RLE)*** – An earthquake larger than the plant SSE and is chosen in seismic margin assessment (SMA) for initial screening purposes. Typically, the RLE is defined in terms of a ground motion spectrum. (Note—A majority of plants in the Eastern and Midwestern United States have conducted SMA reviews for an RLE of 0.3g PGA anchored to a median NUREG0CR-0098 spectrum.)

***Ring Area*** – Annular region bounded by radii associated with the distance rings used in hazard deaggregation (RG 1.208, Appendix D, Table D.1, "Recommended Magnitude and Distance Bins").

***Risk*** – Probability and consequences of an event, as expressed by the "risk triplet" that is the answer to the following three questions: (a) What can go wrong? (b) How likely is it? and (c) What are the consequences if it occurs?

***Safe Shutdown Earthquake Ground Motion (SSE)*** – The vibratory ground motion for which certain structures, systems, and components are designed, pursuant to Appendix S to 10 CFR Part 50, to remain functional. The SSE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface. [paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Code of Federal Regulations (10 CFR Part 50).]

Staff's current guidance on SSE is found in Regulatory Guide 1.208 (2007)

***Safe Shutdown Equipment List (SSEL)*** – The list of all SSCs that require evaluation in the seismic-margins-calculation task of an SMA. Note that this list can be different from the seismic equipment list (SEL) used in a seismic PRA.

***Safety Function*** – Function that must be performed to control the sources of energy in the plant and radiation hazards.

***Safety Related*** – SSCs that are relied upon to remain functional during and following design-basis events to ensure (a) the integrity of the reactor coolant pressure boundary, (b) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (c) the capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposures comparable to the applicable exposures established by the regulatory authority.

***Safety Systems*** – Those systems that are designed to prevent or mitigate a design-basis accident.

***Screening Analysis*** – An analysis that eliminates items from further consideration based on their negligible contribution to the frequency of an accident or of its consequences.

***Screening Criteria*** – The values and conditions used to determine whether an item is a negligible contributor to the probability of an accident sequence or its consequences.

***Seismic Design Category (SDC)*** – A category assigned to an SSC that is a function of the severity of adverse radiological and toxicological effects of the hazards that may result from the seismic failure of the SSC on workers, the public, and the environment. SSCs may be assigned to SDCs that range from 1 through 5. For example, a conventional building whose failure may not result in any radiological or toxicological consequences is assigned to SDC-1; a safety-related SSC in a nuclear material processing facility with a large inventory of radioactive material may be placed in SDC-5. In this standard, the term SDC has a different meaning than in the International Building Code. ANSIOANS-2.26-2004 [1] provides guidance on the assignment of SSCs to SDCs.

***Seismic Equipment List (SEL)*** – The list of all SSCs that require evaluation in the seismic-fragilities task of a seismic PRA. Note that this list can be different from the SSEL used in an SMA.

***Seismic Hazard*** – Any physical phenomenon, such as ground motion or ground failure, that is associated with an earthquake and may produce adverse effects on human activities (such as posing a risk to a nuclear facility).

***Seismic margin***– The difference between a plant's capacity and its seismic design basis (*safe shutdown earthquake, or SSE*).

***Seismic Margin Assessment (SMA)*** – The process or activity to estimate the seismic margin of the plant and to identify any seismic vulnerabilities in the plant. This is described further in Appendix C.

***Seismic Risk*** – The risk (frequency of occurrence multiplied by its consequence) of severe earthquake-initiated accidents at a nuclear power plant. A severe accident is an accident that causes core damage, and, possibly, a subsequent release of radioactive materials into the environment. Several risk metrics may be used to express *seismic risk*, such as seismic *core damage frequency* and seismic *large early release frequency*.

***Seismic Source*** – A general term referring to both seismogenic sources and capable tectonic sources. A seismogenic source is a portion of the earth assumed to have a uniform earthquake potential (same expected maximum earthquake and recurrence frequency), distinct from the seismicity of the surrounding regions. A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation such as faulting or folding at or near the earth's surface. In a probabilistic seismic hazard analysis (PSHA), all seismic sources in the site region with a potential to contribute to the frequency of ground motions (i.e., the hazard) are considered.

***Seismic Spatial Interaction*** – An interaction that could cause an equipment item to fail to perform its intended safety function. It is the physical interaction of a structure, pipe, distribution system, or other equipment item with a nearby item of safety equipment caused by relative motions from an earthquake. The interactions of concern are (a) proximity effects, (b) structural failure and falling, and (c) flexibility of attached lines and cables.

***Seismic Source Characteristics (SSC)*** – The parameters that characterize a seismic source for PSHA, including source geometry, probability of activity, maximum magnitude, and earthquake recurrence.

***Seismic Wave Transmission (Site Amplification)*** **–** The amplification (increase or decrease) of earthquake ground motion by rock and soil near the earth's surface in the vicinity of the site of interest. Topographic effects, the effect of the water table, and basin edge wave-propagation effects are sometimes included under site response.

***Seismogenic Crust*** **–** The brittle portion of the earth's crust capable of generating earthquakes.

***Seismogenic Source*** **–** A portion of the earth that is assumed to have a uniform earthquake potential (same expected maximum earthquake and recurrence frequency), distinct from that of surrounding sources. A seismogenic source will generate vibratory ground motion but is assumed to not cause surface displacement. Seismogenic sources cover a wide range of seismotectonic conditions, from a well-defined tectonic structure to simply a large region of diffuse seismicity.

***Seismotectonic*** **–** Rock-deforming processes and resulting structures and seismicity that occur over large sections of the earth's crust and upper mantle.

***Senior Seismic Hazard Analysis Committee (SSHAC)*** **–** A committee sponsored by the NRC, DOE, and EPRI to review the state of the art and improve the overall stability of the PSHA process. SSHAC [4] concluded that most of the differences were consequences of differences in the process of elicitation of the information from experts. SSHAC made recommendations on the process, which are now almost uniformly adopted by analysts worldwide.

***Severe Accident*** **–** An accident that usually involves extensive core damage and fission product release into the reactor vessel, containment, or the environment.

***Shall, Should, and May*** **–** The word "shall" is used to denote a requirement; the word "should" is used to denote a recommendation; and the word "may" is used to denote permission, neither a requirement nor a recommendation.

***Required Plant Shutdown Criteria–*** Appendix S to 10 CFR Part 50 (3) has the following information: Required Plant Shutdown. If vibratory ground motion exceeding that of the Operating Basis Earthquake Ground Motion or if significant plant damage occurs, the licensee must shut down the nuclear power plant. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after the occurrence of the Operating Basis Earthquake Ground Motion, the licensee must consult with the Commission and must propose a plan for the timely, safe shutdown of the nuclear power plant. Prior to resuming operations, the licensee must demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public and the licensing basis is maintained.

***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 that 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*** **–** A basic event that has a Fussell-Vesely importance greater than 0.005 OR a risk-achievement worth greater than 2. significant cutset (relative to sequence): Those cutsets that, when rank ordered by decreasing frequency, comprise 95 percent of the sequence CDF OR that individually contribute more than 1 percent to the sequence CDF.

***Significant Cutset (relative to CDF)*** – Those cutsets that, when rank ordered by decreasing frequency, comprise 95 percent of the CDF OR that individually contribute more than 1 percent to CDF.

***Significant Accident Sequence*** – A significant accident sequence is one of the set of sequences, defined at the functional or systemic level that, when rank ordered by decreasing frequency, comprise 95 percent of the core damage frequency (CDF), OR that individually contribute more than; 1 percent 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 percent of the large early release frequency (LERF), OR that individually contribute more than; 1 percent to the LERF.

***Site Response (Amplification)*** – The amplification (i.e., increase or decrease) of earthquake ground motion by rock and soil near the earth's surface in the vicinity of the site of interest. Topographic effects, the effect of the water table, and basin edge wave-propagation effects are sometimes included under site response.

***Spectral Acceleration*** – Peak acceleration response of an oscillator as a function of period or frequency and damping ratio when subjected to an acceleration time history. It is equal to the peak relative displacement of a linear oscillator of frequency, f, attached to the ground, times the quantity $(2Bf)^2$. It is expressed in units of gravity (g) or cm/second$^2$.

***Stable Continental Region (SCR)*** – An SCR is composed of continental crust, including continental shelves, slopes, and attenuated continental crust, and excludes active plate boundaries and zones of currently active tectonics directly influenced by plate margin processes. It exhibits no significant deformation associated with the major Mesozoic-to-Cenozoic (last 240 million years) orogenic belts. It excludes major zones of Neogene (last 25 million years) rifting, volcanism, or suturing.

***Stationary Poisson Process*** – A probabilistic model of the occurrence of an event over time (or space) that has the following characteristics: (1) the occurrence of the event in small intervals is constant over time (or space), (2) the occurrence of two (or more) events in a small interval is negligible, and (3) the occurrence of the event in non-overlapping intervals is independent.

***Structure, System, or Component*** – A "structure" is an element, or a collection of elements, to provide support or enclosure, such as a building, free-standing tanks, basins, dikes, or stacks. A "system" is a collection of components assembled to perform a function, such as piping; cable trays; conduits; or heating, ventilation, and air-conditioning. A "component" is an item of mechanical or electrical equipment, such as a pump, valve, or relay, or an element of a larger array, such as a length of pipe, elbow, or reducer.

***Support System*** – A system that provides a support function (e.g., electric power, control power, or cooling) for one or more other systems.

***System Failure*** – Loss of the ability of a system to perform a modeled function.

***Systems Analysis*** – That portion of the external events PRA analysis that applies to evaluating the impact of external events within the plant PRA model. In this context, the term "systems analysis" encompasses the tasks related to identification of the SSCs to be included in the analysis, event sequence modeling, analysis of the failure of individual system functions within the sequences, and the integration and quantification of the overall PRA model.

***Target Performance Goal (PF)*** – Target annual probability of exceeding the 1 E-05 frequency of onset of significant inelastic deformation (FOSID) limit state.

***Tectonic Structure*** – A large-scale dislocation or distortion, usually within the earth's crust. Its extent may be on the order of tens of meters (yards) to hundreds of kilometers (miles).

***Uncertainty*** – A representation of the confidence in the state of knowledge about the parameter values and models used in constructing the PRA. Also see "Variability," "Epistemic Uncertainty," and "Aleatory Variability."

***Uncertainty (as used in seismic-fragility analysis)*** – The variability in the median seismic capacity arising from imperfect knowledge about the models and model parameters used to calculate the median capacity.

***Uniform Hazard Response Spectrum (UHRS)*** – A plot of a ground response parameter (for example, spectral acceleration or spectral velocity) that has an equal likelihood of exceedance at different frequencies.

***Up to Date*** – As used in this standard [for example, when the standard speaks of an "up-to-date database" in (HLR-HA-B)], the concept is that a reasonable attempt should be made to use all available data at the time of the application. However, routine updating of the data is not required if the data used reasonably represent what is needed for the application.

***Variability*** – See "Epistemic Uncertainty" and "Aleatory Variability."

***Verify*** – To determine that a particular action has been performed in accordance with the rules and requirements of this standard, either by witnessing the action or by reviewing records.

***Volumetric Source Zone*** – A volume of the earth's crust within which future seismicity is assumed to have distributions of source properties and locations of energy release that do not vary in time and space.

***Walkdown*** – Inspection of local areas in a nuclear power plant where SSCs are physically located in order to ensure accuracy of procedures and drawings, equipment location, operating status, and environmental effects or system interaction effects on the equipment that could occur during accident conditions. For seismic-PRA and SMA reviews, the walkdown is explicitly used to confirm preliminary screening and to collect additional information for fragility or margin calculations.

***Within Motion*** – An earthquake record modified for use in a site response model. Within motions are developed through deconvolution of a surface recording to account for the properties of the overburden material at the level at which the record is to be applied. The within motion can also be called the "bedrock motion" if it occurs at a high-impedance boundary where rock is first encountered.

## List of Questions