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DECEMBER 3, 2014

NRC'S IMPLEMENTATION OF THE FUKUSHIMA NEAR-TERM TASK FORCE RECOMMENDATIONS AND OTHER ACTIONS TO ENHANCE AND MAINTAIN NUCLEAR SAFETY"

UNITED STATES SENATE, COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ONE HUNDRED THIRTEENTH CONGRESS, SECOND SESSION

HEARING CONTENTS:

OPENING STATEMENTS:

Committee Chairwoman Barbara Boxer [PDF unavailable}

WITNESSES:

Panel I:

Allison M. Macfarlane *[view PDF]*

Chairman, Nuclear Regulatory Commission

Kristine L. Svinicki [PDF unavailable]

Commissioner, Nuclear Regulatory Commission

William C. Ostendorff [PDF unavailable]

Commissioner, Nuclear Regulatory Commission

Jeff Baran [PDF unavailable]

Commissioner, Nuclear Regulatory Commission

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Stephen G. Burns [PDF unavailable]

Commissioner, Nuclear Regulatory Commission

Panel II:

Sam Blakeslee, Ph.D. *[view PDF]*

Former State Senator, State of California and Former Commissioner, California Seismic Safety Commission

Daniel Hirsch *[view PDF]*

Lecturer, University of California, Santa Cruz

Anthony R. Peitrangelo *[view PDF]*

Senior Vice President and Chief Nuclear Officer, Nuclear Energy Institute

AVAILABLE WEBCAST(S):*

- Archived Webcast: *http://www.epw.senate.gov/public/index.cfm?FuseAction=Hearings.LiveStream&Hearing_id=e00b7db3-aae3-b792-852a-bee992bb2be7*

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WRITTEN STATEMENT

BY ALLISON M. MACFARLANE, CHAIRMAN

UNITED STATES NUCLEAR REGULATORY COMMISSION

TO THE

SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

DECEMBER 3, 2014

Chairman Boxer, Ranking Member Vitter, Chairman Whitehouse, Ranking Member Sessions, and Members of the Committee, my colleagues and I appreciate the opportunity to appear before you today on behalf of the U.S. Nuclear Regulatory Commission (NRC).

The NRC remains deeply engaged in activities to oversee the operational safety of nuclear reactors, fuel cycle plants and other materials facilities on a daily basis. We are successfully meeting a variety of challenges we face while also seeking to continuously improve our processes to remain a strong and effective regulator. Today, I'd like to highlight some of the NRC's accomplishments and challenges and address the agency's efforts to ensure it is operating efficiently and effectively.

THE COMMISSION

As the Committee is aware, the Commission is once again operating as a full group of five members with the arrival of Commissioners Jeff Baran and Stephen Burns. We are working well together and I am confident that the Commission will continue to operate collegially and effectively after my departure.

FUKUSHIMA

The NRC and the industry continue to make significant progress in implementing post-Fukushima safety enhancements at nuclear facilities across the United States. The agency

remains committed to completing this work. We have seen the first reactors come into compliance with the Mitigating Strategies and the Spent Fuel Pool Instrumentation Orders. Reactors that are required to come into compliance with these orders during their upcoming spring outages are preparing to make safety system modifications that will enable them to complete their required safety enhancements on time. The NRC continues to monitor licensees' progress and conduct thorough inspections to ensure that licensees are in compliance with NRC requirements.

Enhanced Capabilities to Mitigate Beyond-Design-Basis Accidents

The NRC's Mitigating Strategies Order required licensees to ensure that they are prepared to respond to beyond-design-basis accidents. These requirements include procuring additional equipment to maintain or restore core cooling, containment integrity, and spent fuel pool cooling for all units at a site.

Nuclear power plant licensees also continue to make plant modifications and procure additional equipment for their individual sites to support full implementation of the Mitigating Strategies Order by their established due dates. In October of this year, North Anna Unit 2 became the first plant to complete implementation of all mitigating strategies requirements. Many sites are scheduled to achieve full implementation by the end of 2015, with the remaining sites to be completed by 2016. These dates were established to align with refueling outage schedules. The one exception to this schedule is that some boiling water reactors are requesting schedule extensions for those parts of the mitigating strategies affected by the NRC's revision to the order on containment venting, which I will discuss further in a moment. During and after implementation, the NRC will conduct inspections to verify that nuclear power plants have put appropriate strategies in place to mitigate beyond-design-basis accidents.

In the past six months, both of the industry's National Response Centers – one in Phoenix, Arizona and one in Memphis, Tennessee – opened their doors. Both centers contain emergency diesel generators, pumps, hoses, and other backup equipment that can be delivered to any site within 24 hours. The centers are being managed by an industry group, the Strategic Alliance for FLEX Emergency Response (SAFER), which also maintains two control centers to coordinate equipment deliveries. Last summer, the NRC observed and evaluated two simulated exercises SAFER conducted to demonstrate that the centers could meet their commitments to deliver equipment quickly and safely. In one exercise, emergency equipment was sent by truck from Memphis to the Three Mile Island Nuclear Station in Pennsylvania. In the other, equipment was airlifted from Phoenix to the Surry Power Station in Virginia. SAFER has secured a contract with Federal Express for truck and aircraft shipments, and is coordinating with the Federal Aviation Administration to ensure that aircraft can have access to otherwise restricted airspace in an emergency. Thus far, the NRC is satisfied that SAFER has used the information gained from these exercises to ensure that the industry's approach would be effective if called upon.

This additional capability to address beyond-design-basis events, such as large earthquakes or floods, provides the most significant safety improvement that the NRC has required as a result of the lessons learned from Fukushima.

Consistent with our regulatory practices, the NRC is conducting a rulemaking that will adopt the requirements already imposed in the March 2012 Order. The NRC staff has consolidated into a single effort the mitigating strategies rulemaking, the Emergency Response Capabilities rulemaking, and codification of portions of other Japan Near-Term Task Force (NTTF) recommendations that are already being addressed as part of the Mitigating Strategies Order. Also included are implementation of other NTTF recommendations related to on-site emergency actions, and other actions already being implemented by industry. These rulemaking efforts were consolidated into a single Mitigation of Beyond-Design-Basis Events

rulemaking due to the interrelated nature of the activities. The NRC staff is on track to provide its proposed rule to the Commission for review by early 2015. After that review is completed, it will then be issued for public comment. The rulemaking remains on schedule to be completed by 2016.

Seismic and Flooding Reevaluations

The NRC continues to make good progress in reviewing seismic hazard reports for licensees in the central and eastern United States. Through this process, we have identified approximately 35 sites with new seismic hazard estimates that exceed the previously evaluated hazard and for which further seismic risk analysis may be necessary. As we had previously informed this Committee, in order to ensure a coordinated and efficient staff review of the reports, the NRC categorized plants according to the size of their estimated hazard risk increase. The staff also is preparing to review "expedited approach" submittals due later this month from licensees whose hazard estimate required further seismic analysis. These licensees are required to inform the NRC about interim steps they have taken to identify and implement seismic-related upgrades to certain safety-significant equipment at their sites by 2016.

The three licensees located west of the Rocky Mountains are required to complete their seismic hazard reevaluations by March 2015, and the NRC staff is prepared to thoroughly review them when they are submitted.

It is important to emphasize that all nuclear power plants in the United States continue to operate safely. All plants have been designed and constructed with safety margins to withstand ground motion associated with a potential earthquake exceeding their original design bases. The seismic hazard reevaluations will enable both the NRC and licensees to better understand seismic issues associated with individual nuclear power plant sites based on the most up-to-

date scientific information available. The NRC will require safety enhancements as appropriate to address seismic risks that are higher than previously estimated.

The NRC is also continuing its review of reevaluated flooding hazards, for which plants were divided into three categories based on the complexity of the analysis and other factors. The staff is reviewing the reevaluated flooding hazards for plants that the new seismic hazard estimates exceed the previously evaluated hazard, and began issuing assessments of the licensees' reports in July. Other licensees are required to submit their reevaluated hazard assessments by March 2015. I should note that the NRC granted extensions to certain licensees that needed data from the U.S. Army Corps of Engineers regarding upstream dam failures or that needed to analyze complex watersheds.

Similar to the seismic hazard reevaluations, the NRC is working with those licensees whose site flooding hazard reevaluation results exceeded their current design basis and is conducting inspections to ensure that they are implementing appropriate interim safety enhancements. These licensees must perform an integrated assessment to reassess their flood protection and mitigation capabilities within two years of submitting the hazard reevaluation results to identify whether any further enhancements are necessary.

The NRC is also performing on-site inspections to ensure that the interim actions that licensees have taken are appropriate. Some of the on-site inspections have been completed while others are ongoing. The NRC will continue to review the interim actions as flood hazard reevaluation reports are received.

Emergency Preparedness Communication and Staffing

In addition to the on-site emergency response capabilities rulemaking, which, as described above, has been combined with the mitigation strategies rulemaking into the Mitigation of Beyond-Design-Basis Events rulemaking, the staff issued a letter to licensees

addressing prolonged station blackout conditions affecting multiple units. The NRC's work to assess licensees' substantial progress in addressing this issue is ongoing.

Spent Fuel Pool Instrumentation

The Enhanced Spent Fuel Pool Instrumentation Order required licensees to install enhanced instrumentation to monitor the water levels in spent fuel pools. This work is closely related to licensees' efforts to implement the Mitigating Strategies Order. Licensees are currently in the process of meeting this requirement in accordance with their refueling outage schedules. They had previously submitted plans to the NRC detailing how they intended to address the order, and the NRC's input on these plans has informed their implementation. The NRC is inspecting licensees' progress, and some reactors are already in compliance. The NRC staff will be conducting inspections and issuing safety evaluations for each licensee, and will conduct thorough post-compliance inspections after all licensees are in full compliance with the order.

Reliable Hardened Vents

The NRC ordered licensees with boiling water reactors with Mark I and II containment types to install reliable hardened vents. This order was subsequently revised to require that licensees ensure these vents are severe accident-capable. As a result of this new requirement, certain licensees requested, and were granted, extensions for the aspects of their work on the Mitigating Strategies Order that related to containment venting. The NRC is currently reviewing integrated plans and conducting audits of licensee progress towards compliance with the first phase of the order. By June 2015, the NRC staff plans to issue interim staff evaluations to all applicable licensees. Licensees must then submit their integrated plans for the second phase – design and installation of venting capability from the containment drywell under severe accident conditions, or, alternatively, developing and implementing a reliable containment venting

strategy that makes it unlikely that a licensee would need to vent from the drywell during a severe accident - by the end of 2015 in compliance with interim staff guidance.

The Commission also directed the NRC staff to undertake a rulemaking to consider additional filtration strategies for boiling water reactors with Mark I and II containments to enhance their ability to vent containment without releasing radioactive material during an accident. The staff is currently developing the regulatory basis for a rulemaking in this area.

National Academy of Sciences Study

As directed by Congress, the NRC issued a grant to the National Academies of Science (NAS) to assess the causes of the Fukushima accident and lessons learned that could enhance nuclear safety and security at U.S. facilities. The NRC staff is currently reviewing the report, which NAS issued in July 2014, and will inform the Commission of its assessment of the study's findings and its plans to address them in the near future.

Longer-Term Actions Associated with Fukushima Lessons Learned

Our primary focus is on the highest-priority, most safety-significant enhancements to maximize the safety impact to the nuclear power plants. The agency will complete the most safety-significant enhancements on or ahead of the five-year goal.

Over the coming months and years, we will gain additional insights from implementation of the highest-priority actions, and the decommissioning activities at the Fukushima Dai-ichi site. As NRC staff with critical skills are freed up from the highest-priority and most safety-significant Fukushima work, we will focus our efforts on the remaining lessons learned activities, and we will disposition the remaining recommendations from the Near-Term Task Force.

The NRC continues to interact with our licensees and interested members of the public as we move forward to implement these Fukushima safety enhancements. We have held more than 150 public meetings over the past three years to keep the public apprised of our activities.

The NRC is mindful that we must take a careful and deliberate approach to this work to prevent these regulatory actions from distracting us or the industry from day-to-day nuclear safety and security priorities, and to avoid unintended consequences. As with the NRC's response to previous events, such as the September 11, 2001 terrorist attacks, we remain cognizant that a change in one system has the potential to adversely affect another system if not considered holistically.

The NRC continues to receive regular reports on the efforts to remediate the Fukushima site and makes use of this information to help identify potential lessons learned for U.S. reactors. The NRC is also maintaining an awareness of the activities of other federal and state agencies in monitoring and sharing information with the public about the very low levels of radioactive materials that scientists have now identified off the coast of the western U.S.

DECOMMISSIONING

The NRC has shifted its oversight at San Onofre Nuclear Generating Station (SONGS) Units 2 and 3, Kewaunee, and Crystal River Unit 3, to focus on decommissioning. In the past few months, the NRC and these licensees have taken a number of important steps in this direction. For example, Southern California Edison submitted its Post-Shutdown Decommissioning Activities Report (PSDAR) for the SONGS facility in September. The report included information about the estimated cost associated with decommissioning the two units and a plan for managing spent fuel. In October, as required by our regulations, the NRC held a public meeting in California to hear from interested parties about the PSDAR and answer questions. The staff also accepted written comments from the public.

The SONGS PSDAR indicated that the licensee intends to pursue the DECON method for decommissioning the facility; that is, promptly removing or decontaminating all components and structures contaminated by radioactive material.

Southern California Edison has formed a Community Engagement Panel with members of local government, public interest groups, the business community, and academia to advise the licensee on the ongoing decommissioning process. NRC supports this type of community engagement and has participated in some meetings to communicate the NRC's regulatory role to the Panel.

All of the plants undergoing decommissioning have requested certain amendments to their licenses and certain exemptions from the NRC's regulations – which were written primarily for operating reactors – that reflect the impending reduction in risk that will occur when fuel is permanently removed from these reactors. For example, Dominion Energy Kewaunee has requested, and been granted, exemptions from NRC requirements to maintain a 10-mile emergency planning zone and offsite radiological emergency plans. However, the NRC denied a separate request from Kewaunee for exemptions from certain NRC physical security regulations because the licensee had not adequately justified the reductions. Similar requests from SONGS and Crystal River, as well as Vermont Yankee, which will soon permanently cease operations, are still being evaluated by the NRC. The NRC staff reviews each request with a careful focus on individual circumstances at each site and whether the exemption would provide an adequate level of protection.

Though there has been significant attention paid to the sites that have most recently begun the decommissioning process, 17 other nuclear power reactors are in various stages of the decommissioning process. Since 2000, ten power reactors have been successfully decommissioned. The NRC remains committed to maintaining rigorous oversight at all of these facilities as they move through the decommissioning process.

NEW CONSTRUCTION

Construction of the new reactor units at Plant Vogtle in Georgia and V.C. Summer in South Carolina continues to progress under NRC oversight. Major sections of the primary

containment vessels at Summer Unit 2 and Vogtle Unit 3 are being set in place. Construction and installation of structural modules continues. A significant milestone was recently reached at Vogtle Unit 3 when the module that includes the chemical and volume control system and the passive core cooling system was placed in containment.

The NRC staff continues to provide oversight of module fabrication and other construction activities at the sites to ensure that all identified quality issues are corrected and that the plants are being constructed in accordance with the approved design.

The NRC also continues to oversee construction at Watts Bar Unit 2 in Tennessee. The NRC staff's review of the Tennessee Valley Authority's (TVA) Operating License Application for Watts Bar Nuclear Plant Unit 2, while mostly complete, is still in progress. Construction inspections and inspections of operational readiness remain on-track to support upcoming licensing decisions. The NRC staff continues to document its findings in supplements to the safety evaluation report, and construction inspection reports to ensure that TVA has met applicable regulatory requirements. Currently, the staff is working toward issuing a decision on an operating license in mid-2015.

In October, the agency issued the final rule to certify the Economic Simplified Boiling Water Reactor (ESBWR) design. That brings to five the number of new reactor designs that have been certified by the NRC, including the ABWR, System 80+, AP 600, and AP 1000.[1] The NRC is currently reviewing two combined license applications referencing the ESBWR design. The NRC also continues to review other design certification, combined license, and early site permit applications. Additionally, we anticipate the submission of the first design certification applications for small modular reactors in 2016.

[1] System 80+ is no longer valid as of June 20, 2012; and AP600 will not be valid after January 24, 2015.

CONTINUED STORAGE RULE AND GENERIC ENVIRONMENTAL IMPACT STATEMENT

In August 2014, after a two year rulemaking process that included extensive public engagement, the Commission approved the NRC final rule on the environmental effects of continued storage of spent nuclear fuel and its supporting generic environmental impact statement (GEIS), which became effective in October, 2014. The rulemaking took into consideration more than 33,000 public comments.

The rule adopts the findings of the GEIS, which analyzes the environmental impact of storing spent fuel beyond the licensed operating life of nuclear reactors over a short-term timeframe of 60 years, a long-term timeframe of 100 years after the initial 60 years, and indefinitely. The GEIS found no significant impacts for any of these time periods.

The implementation of the Continued Storage rule enables the NRC to complete several reactor licensing actions that had been suspended pending the outcome of this rulemaking.

YUCCA MOUNTAIN

In keeping with the Commission's direction, the NRC staff continues its work on the Safety Evaluation Report (SER) on the proposed repository at Yucca Mountain. In October 2014, the staff issued Volume 3 of the report, which is its technical analysis of the period after a repository at Yucca Mountain – if licensed and ultimately constructed – would be permanently sealed. The staff is scheduled to issue the remaining volumes - Volume 2 (Repository Safety Before Permanent Closure), Volume 4 (Administrative and Programmatic Requirements), and Volume 5 (License Specifications) -- by January 2015; they will be released as they are completed. The Commission will provide further direction to staff on completing the tasks of making documents from the Licensing Support Network publicly-available, and issuing a Yucca Mountain environmental impact statement using the agency's remaining Nuclear Waste Funds.

Completion of the SER is the next important step in a long and complex licensing process. Many other steps would remain if the licensing process were to continue. Among

other things, the adjudicatory proceeding associated with the construction authorization would recommence sometime after issuance of the SER. The adjudication would involve the reinstatement and maintenance of the Licensing Support Network (or its functional equivalent), resolution of approximately 300 pending contentions challenging the license application, resolution of any new contentions, Commission appellate activities, and completion of the Commission's supervisory review of the application.

SOURCE SECURITY

Radioactive source security has been, and continues to be, a top priority for the NRC. The NRC collaborates with the 37 Agreement States and domestic and international agencies on a variety of initiatives to make risk-significant radioactive sources even more secure and less vulnerable to malevolent use.

Immediately following the events of September 11, 2001, the NRC, working with other Federal and State agencies, prioritized actions to enhance the security of radioactive sources and facilities. At that time, the NRC disseminated a number of security advisories to NRC and Agreement State licensees, recommended specific actions to enhance security, addressed potential threats, and communicated general threat information. The urgency revealed by the threat and facility security assessments made it essential for the NRC to remove any security gaps by issuing immediately-effective Orders, rather than undertaking a more time-consuming rulemaking process.

In 2005, the Energy Policy Act expanded the NRC's authority to ensure the security and control of additional risk-significant materials, and mandated the development of a national registry of radioactive sources. Accordingly, in 2007, the NRC and Agreement States issued additional security Orders to comply with the Act.

The Energy Policy Act also established an interagency task force on radiation source protection and security under the lead of the NRC to provide recommendations to the President

and the Congress relating to the security of domestic radiation sources. This task force has to date submitted reports to the President and Congress in 2006, 2010 and 2014. The most recent report, while providing continuous improvement recommendations, did not identify any gaps related to radiation source security in the United States.

Recognizing the need to enshrine the Orders in regulations, the NRC commenced rulemaking activities related to source security. The 2013 rule (10 CFR Part 37), which incorporates pragmatic security approaches and interfaces with the NRC's existing safety rules, is an optimized mix of performance-based and prescriptive requirements that allow a licensee to develop a security program for risk-significant material with measures specifically tailored to their facilities. Licensee compliance with the rule was required by March 19, 2014; Agreement State licensee must fulfill compatible requirements by March, 2016.

The NRC radioactive source security program has been the subject of two recent Government Accountability Office (GAO) audits, the first focused on U.S. medical facilities, and the more recent focused on industrial settings. Unfortunately, both audits pre-dated the implementation of the expanded 10 CFR Part 37 regulations, and thus focused only on the NRC security requirements that were issued to licensees by Orders.

The NRC is committed to monitoring and assessing the effectiveness of the Part 37 requirements to determine whether any additional security enhancements are necessary. After the completion of this review, the NRC advocates the conduct of another GAO audit related to the effectiveness of the requirements of 10 CFR Part 37 for NRC and Agreement State licensees.

ENSURING EFFICIENT USE OF RESOURCES

Despite receipt of a late appropriation and future budget uncertainty, the NRC executed $1.1 billion of FY 2014 current and prior year funds, including Nuclear Waste Funds, and it recovered $931 million in license and annual fees of its FY 2014 new budget authority. As of

September 30, 2014, the NRC had $34.2 million in prior year fee-based funds, $4.8 million in Nuclear Waste Funds and approximately $6.3 million in other special use funds available as carryover funding. Under the current FY 2015 Continuing Resolution, the NRC is able to meet all safety and security mission requirements and has sufficient remaining unobligated Nuclear Waste Fund resources for the remaining Commission approved Yucca Mountain license application review activities.

The NRC continues to be prudent in expending agency resources and to carefully scrutinize all budget requests in order to conduct the agency's mission in an efficient and cost-effective manner. The NRC has also taken further steps to address the large fee increases for power reactor licensees in FY 2014. The staff has launched an agency effort to fully understand and maximize staff productive hour rates. Additionally, to further ensure fairness and equity in fee billing, the NRC has engaged an independent firm to conduct a study and provide recommendations on other fee allocation methods, and we plan to conduct a public meeting early in calendar year 2015 to address out-of-scope public comments received on the FY 2014 Fee Rule.

The Commission has directed the NRC staff to take a hard look at how to increase our flexibility and resiliency so that we can adapt more quickly to a changing environment and still ably address tomorrow's unanticipated challenges. The staff is currently working both internally and externally to analyze a range of scenarios that may affect the workload and activities of the agency over the next five years and anticipate commensurate changes to necessary NRC staff skill sets and resources. The objective of this initiative is to develop recommendations corresponding to each scenario to enable the agency to ensure it can effectively, efficiently, and flexibly meet its safety and security mission under any circumstances. The work of our staff's

team and that of the National Academy of Public Administration, whom we have asked for assistance and assessment, is ongoing.

UNDERSTANDING THE CUMULATIVE EFFECTS OF REGULATION

The Atomic Energy Act requires the NRC to provide reasonable assurance of adequate protection of public health and safety and promote the common defense and security in its regulatory activities, and the requirements the NRC imposes are intended to meet this mandate. We recognize that important safety and security enhancements will be most effective if necessary regulatory measures are prioritized appropriately so that licensees can maintain focus on the most safety-significant issues and activities. The NRC has had enhancements to the rulemaking process in place since 2011 to better address the cumulative effects of agency decision-making.

In particular, we are interacting closely with various groups, including industry, government, and members of the public, to ensure that we understand and manage the impacts on licensees of regulatory initiatives and activities that are being implemented concurrently. We are reviewing implementation timelines for new or revised regulations, the priority associated with each action, and the availability of critical skills to complete implementation.

The NRC has also engaged the operating reactor industry to perform “case studies” reviewing regulatory cost and schedule estimates. In addition, we are working with other parts of the regulated community and with our Agreement State regulatory partners to assess and control cumulative effects.

A LOOK AHEAD

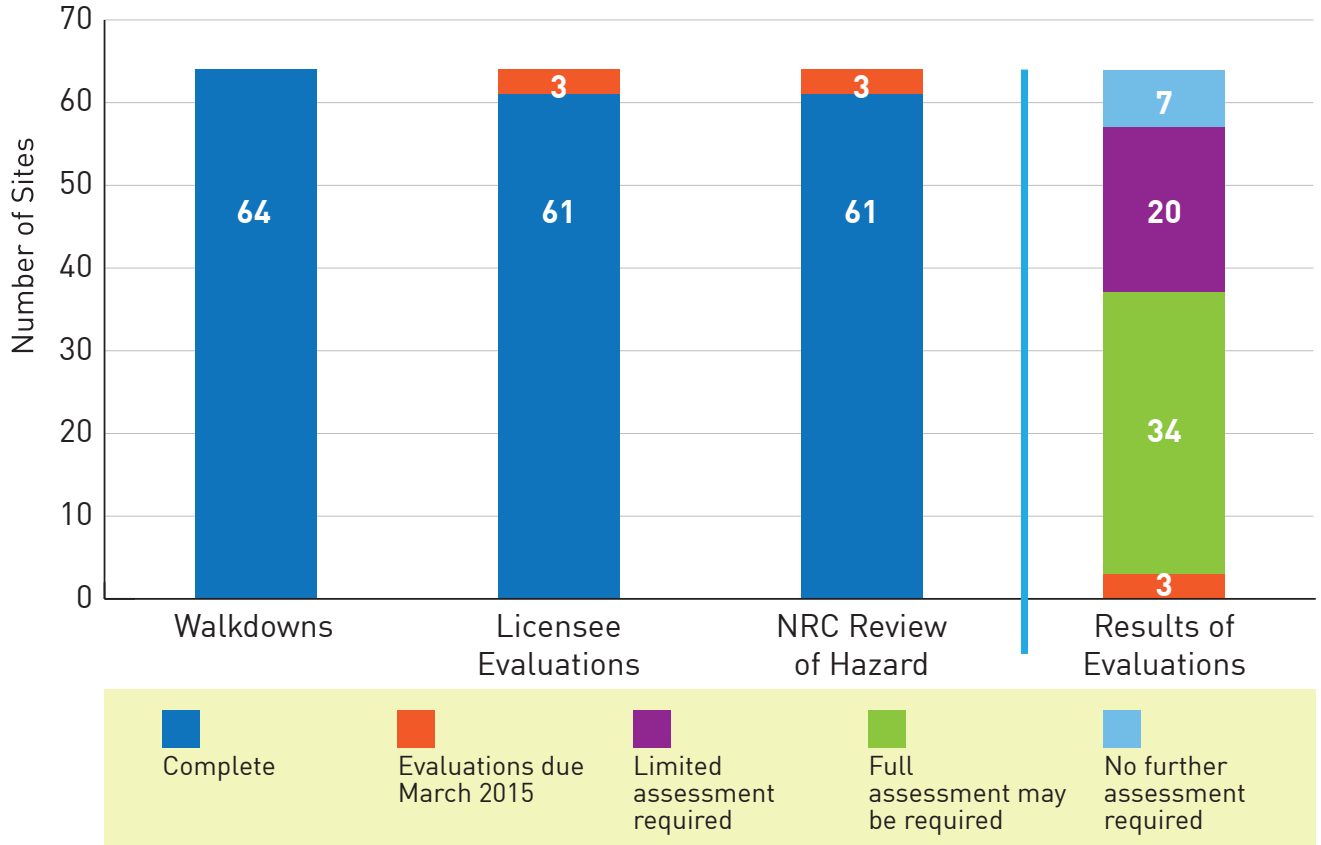
In summary, the NRC is fully engaged in our mission of protecting public health and safety, promoting the common defense and security of our Nation, and protecting the environment. We will continue to focus on:

- Ensuring safe and secure day-to-day operations at all licensed facilities;
- Completing additional safety-significant work on post-Fukushima lessons learned;
- Completing the Safety Evaluation Reports and other activities for the proposed repository at Yucca Mountain using remaining Nuclear Waste Funds;
- Overseeing construction activities at the new Plant Vogtle, V.C. Summer, and Watts Bar 2 reactors;
- Overseeing decommissioning activities at SONGS, Kewaunee, Crystal River-3, Vermont Yankee, and other decommissioning sites;
- Boosting the effectiveness, efficiency, performance, and agility of the agency; and
- Continuing to strengthen our close cooperation with international and interagency partners.

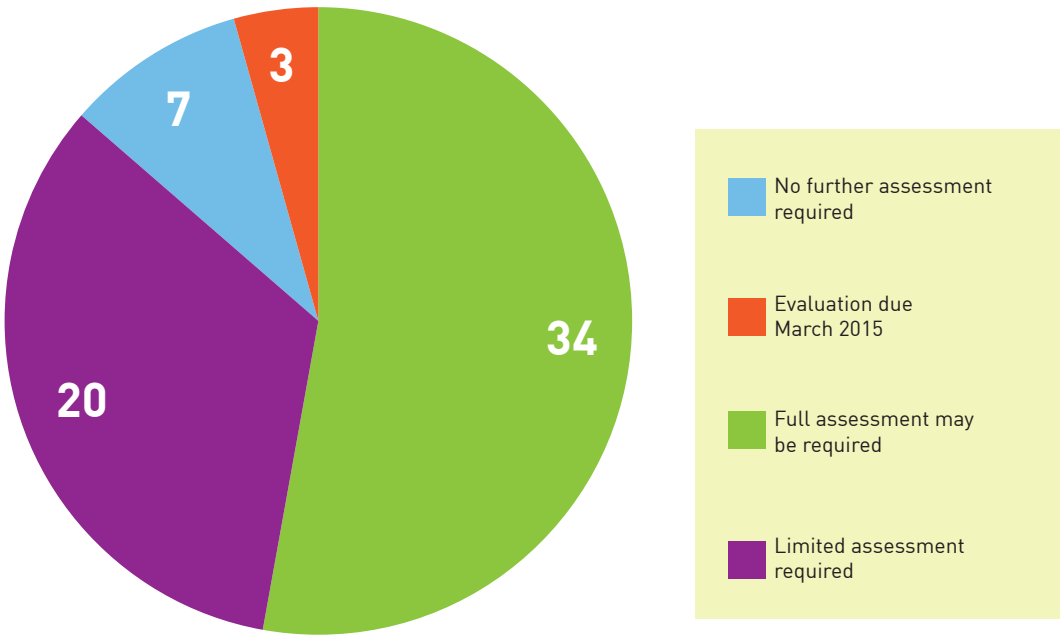
I have been proud to be the Chairman of the NRC over the past two and a half years, and sincerely appreciate the dedication and work of all the men and women at the NRC.

Chairman Boxer, Ranking Member Vitter, Chairman Whitehouse, Ranking Member Sessions, thank you for the opportunity to appear before you today; I would be pleased to answer your questions.

Seismic Hazard Reevaluation Progress
(Total sites: 64)

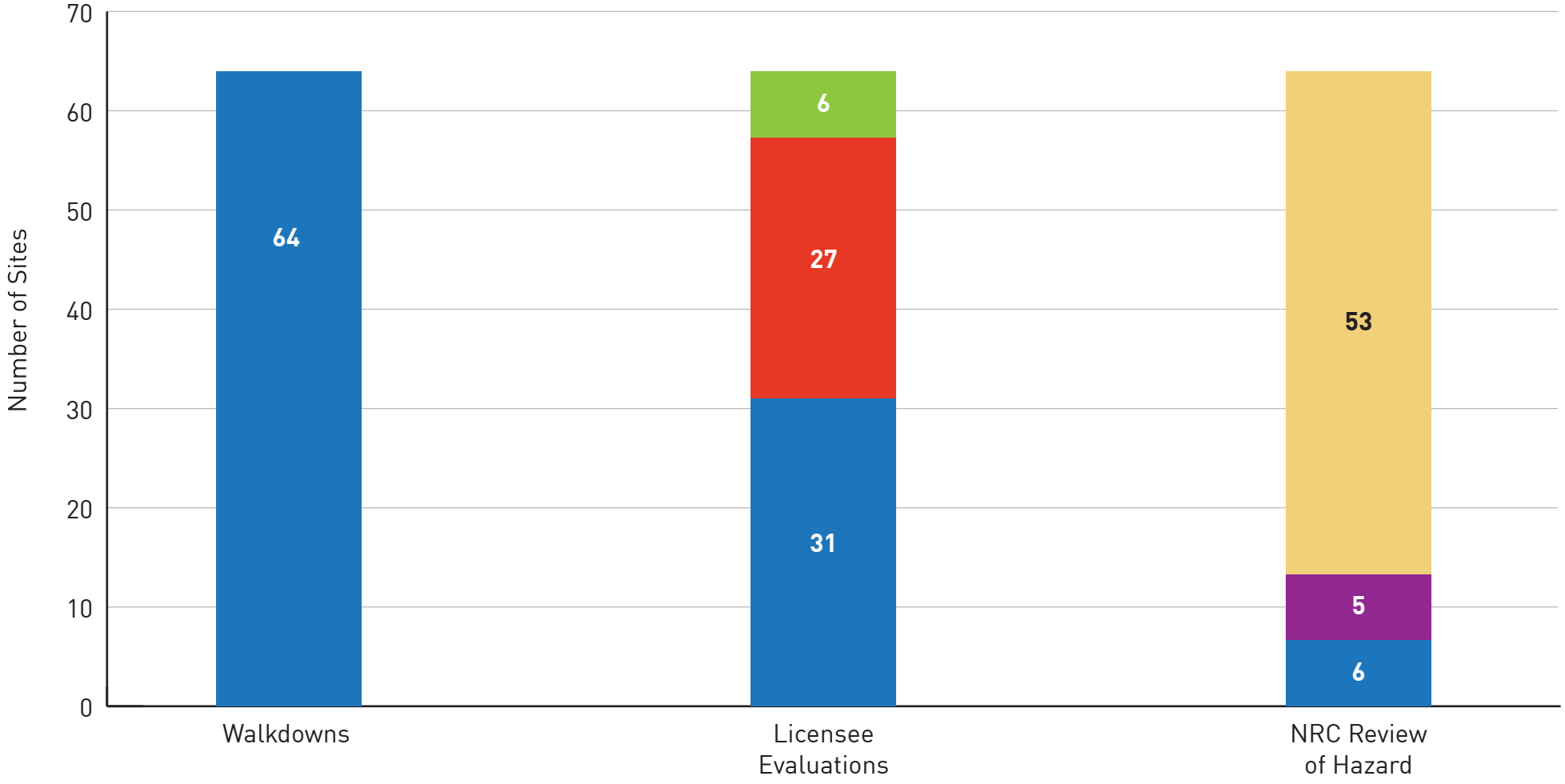


Seismic Hazard Reevaluation Results
(Total sites: 64)



Flooding Hazard Reevaluation Progress

(Total sites: 64)



Complete

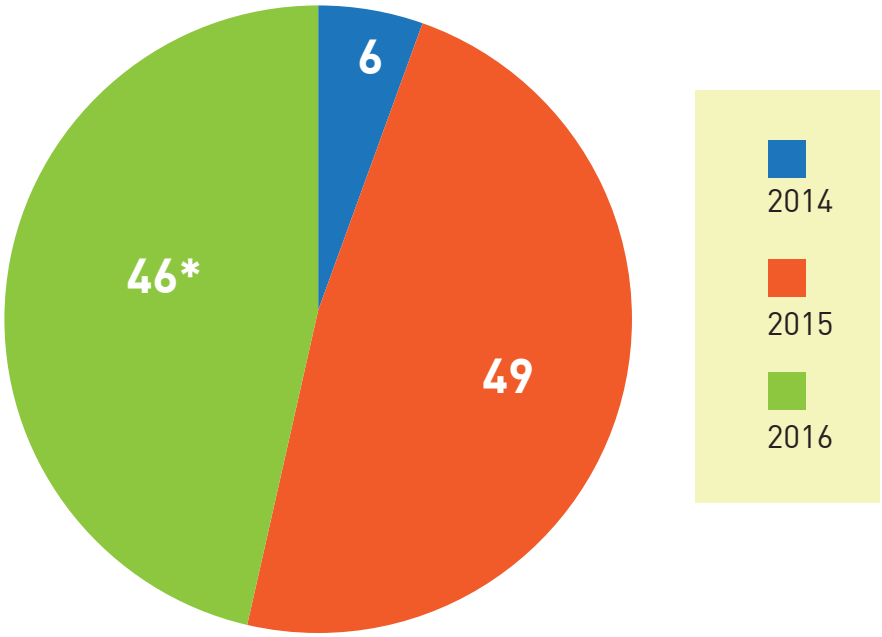
Evaluations due March 2015

NRC review complete January 2015

Evaluation expected March 2016

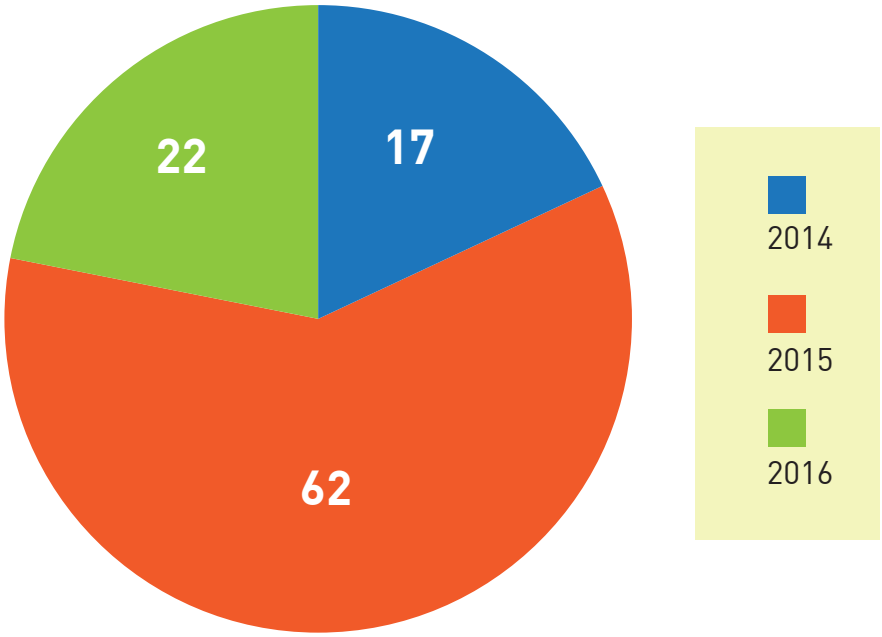
NRC review pending

Mitigating Strategies Equipment: Full Compliance
(Total units: 101)



*Ten units will have all the required equipment and connections in place, but will not be in full legal compliance with the Mitigating Strategies Order until they are in compliance with the Severe Accident Capable Vent Order in 2017-2018.

Spent Fuel Pool Instrumentation: Full Compliance
(Total units: 101)



WRITTEN STATEMENT

BY SAM BLAKESLEE, PH.D.
CALIFORNIA STATE SENATOR, FORMER
CALIFORNIA SEISMIC SAFETY COMMISSIONER, FORMER

TO THE
SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

DECEMBER 3, 2014

Senator Boxer, Ranking Member Vitter, and Members of the Committee,

Thank you for the invitation to testify at today's hearing titled 'NRC's implementation of the Fukushima near-term task force recommendations and other actions to ensure and maintain nuclear safety.' The Fukushima meltdowns raised important concerns about nuclear reactors and one of those concerns relates to seismic safety. As a geophysicist and former California State Senator, I authored AB 1632, a bill that required PG&E to conduct seismic hazard research of the faults near the Diablo Canyon Nuclear Power Plant (Diablo) housed in the community that I reside in and represented for 8 years as a state legislator. Just two months ago, PG&E published the Coastal California Seismic Imaging Project (CCCSIP) Report and the results were astonishing. The Report documents the presence of a number of earthquake faults discovered after the design and construction of the plant that have been found to be larger and more dangerous than previously understood. In a post-Fukushima regulatory environment, it is important that policymakers and regulators understand the ramifications of these findings.

EXECUTIVE SUMMARY

PG&E has a long history of grappling with California's earthquake faults when trying to site its nuclear plants. It had previously proposed a nuclear power plant on the California coast at Bodega Bay but abandoned the plan when it was discovered that the site was to be built overtop the Shaft Fault and within 1000 feet of the San Andreas Fault. Later, PG&E built a small nuclear power plant on the California coast at Humboldt Bay, but the plant was shut down after the discovery of three faults within few thousand meters of the plant. PG&E selected the location for the Diablo plant, representing that the seismic activity in the area was minimal.

In the late 1970s, when Diablo was still under construction, data surfaced on the presence of a large active fault (named the Hosgri) located just three miles offshore from the plant. PG&E first denied its existence. When that assertion was disproved, it argued the fault was likely inactive. When PG&E had to concede it was active, it argued it was not capable of producing particularly large earthquakes. It turned out it that was capable of generating very large earthquakes.

In a recent replay of these events concerning a newly discovered fault system, the Shoreline fault was discovered in 2008 and analyzed with state-of-the-art methods and found to be capable of generating an M7.3 earthquake within a mere 600 meters of the plant.

There is no getting around the fact that PG&E has consistently downplayed seismic hazards on the coast near its nuclear plants. Especially disturbing is that during these past decades the NRC has repeatedly relaxed its seismic standards to accommodate the operation of Diablo Canyon.

Now that the data about the faults near Diablo is indisputable, PG&E has changed tactics and declared the plant safe on the basis of a new set of equations it has developed. PG&E has undertaken major revisions to the complex ground motion equations that have been used to estimate how much shaking can be produced by earthquakes. Unsurprisingly, PG&E's changes to its methodologies have dramatically reduced estimated shaking at the plant from all hypothetical earthquakes. So far, NRC has largely gone along with these changes.

With PG&E's history of playing down seismic concerns these recent developments are cause for deep concern. So is PG&E's documented history of co-opting the very regulatory bodies tasked with overseeing it. Just this year:

- PG&E was found to be inappropriately, and possibly illegally, lobbying California Public Utilities Commissioners and staff to successfully "judge shop" in a case before the CPUC. The revelation resulted in the firings of three senior PG&E executives, the reassignment of the CPUC's chief of staff, and the decision by the President of the CPUC to recuse himself from future PG&E decisions and to not seek re-appointment. The CPUC was just fined a $1.05 million for this back-channel lobbying.

- PG&E was indicted on 12 criminal charges related to safety violations in its gas distribution, including an accusation that PG&E officials obstructed a federal investigation and that the utility "knowingly relied on erroneous and incomplete information" to avoid inspections that would have exposed risks that ultimately killed 8 people in a 2010 gas pipeline explosion

- PG&E was discovered, through email disclosures, to be exploring how and when the Diablo Canyon Independent Peer Review Panel could be disbanded. This is the state-mandated panel tasked with providing third-party quality control of seismic risk analysis at Diablo that is quantified by the Report, which is my subject here.

In 2013, because of steam generator failures, San Onofre, California's only other nuclear power plant was permanently shut down at great cost to ratepayers, shareholders, and grid operations. Last month, the Office of the Inspector General at the NRC issued a report criticizing the NRC's failure to call for a license amendment process, which might have identified the shortcomings of the utility's technical analysis that ultimately led to those leaks. The safety ramifications of steam generator leaks at San Onofre, as serious as they were, are dwarfed by the risks to the public should PG&E's Diablo seismic analysis prove to be incomplete or inaccurate. You would think that after Fukushima the NRC would go beyond a "check the box" review process when confronted, as it is at Diablo, with the

possibility of a 7.3 magnitude earthquake within a half-mile of the plant. So far we have been disappointed.

Remarkably, in all the years of its operation, the facility has never gone through a formal license amendment process to deal with even the Hosgri Fault discovered in the 1970s. Instead, its possible ramifications were more or less explained away in a separate document. More significant faults have been discovered since, which speaks poorly of PG&E's original examination of the area, and of the NRC's supervision of that process. One should not be discovering such faults after building a plant. The potential earthquakes affecting the plant have increased with each major study. But what's equally striking is that the shaking predicted by PG&E for these increasing threats has systematically decreased as PG&E adopted less and less conservative analytical methodologies, and they did so with NRC approval.

It is time to end this hodge-podge of licensing rationalizations. We know a great deal more about seismic issues than we did when Diablo Canyon was licensed. It's time for the NRC to reassess the seismic standards for the plant and submit them to a formal licensing amendment process. The thing that both PG&E and NRC fear most is a public hearing in which they would have to justify what they have done. It is also what we need most to assure seismic safety, and it is what the public deserves.

INTRODUCTION

In 2005, as the elected State Assemblyman representing the Central Coast and as a geophysicist, I became concerned that PG&E's prior seismic hazard analysis in the vicinity of the Diablo Canyon Nuclear Power Plant had failed to utilize modern state-of-the-art geophysical techniques that have proven highly effective at mapping seismic faults. In 2006, I authored, the state legislature passed, and Governor Schwarzenegger signed AB1632, which directed the California Energy Commission to assess existing scientific studies to determine the potential threat of earthquakes to the future reliable operation of Diablo. After extensive review the California Energy Commission concluded that significant seismic uncertainty existed and charged PG&E with the task of acquiring new state-of-the-art geophysical data to reassess the seismic threats to Diablo. In the furtherance of AB1632 the California Public Utilities Commission provided $64M of California ratepayer funds to compensate PG&E for the Coastal California Seismic Imaging Project that resulted in the Report.

At the time of the bill's passage few appreciated the potential threat that large earthquake faults posed to operating nuclear facilities. Since then the public's awareness of the importance of the issue has increased significantly:

- In 2007 the Kashiwazaki-Kariwa Nuclear Power Plant, the largest in the world, was severely damaged and shuttered due to an M6.6 earthquake 19 kilometers offshore from the facility.

- In 2008 the USGS discovered a previously unknown Shoreline Fault only 600 meters from the Diablo Nuclear Power Plant and only 300 meters from the intake.

- In 2011 the Fukushima Daiichi nuclear disaster resulted in the meltdown of three of the plant's six reactors, triggering an emergency review by the NRC of US nuclear reactors and their ability to withstand shaking from earthquakes. This tragedy was caused by an earthquake and Tsunami far larger than the utility believed possible, which produced greater shaking than the plant was designed to withstand.

Two months ago, eight years after the passage of AB1632, PG&E issued its Report, which will likely be relied upon by state and federal regulators in the course of their immediately upcoming deliberations regarding PG&E's request to extend the operating license of the Diablo through 2044-2045. My review of this Report addresses important historic, technical, and regulatory issues that are central to the final conclusion of the Report; specifically, that the facility has been shown to be safe from seismic threats.

PG&E's Report makes a number of key findings regarding earthquake threats. In virtually every instance, the faults surrounding Diablo are now understood to be larger and more connected than previously believed as recently as 2011. Of course the plant was initially licensed assuming these seismic threats were non-existent. Whereas the Hosgri Fault had previously been believed to be the most dangerous fault near Diablo, newly released research shows that the prior Hosgri maximum earthquake assumption is eclipsed by five other fault-rupture threats:

1. <u>SHORELINE FAULT</u>: The newly discovered Shoreline Fault located within 600 meters of the plant, is now twice as long as thought in 2011 and almost three times as long as the lower bound proposed in 2009. With a length now understood to be 45 km long it is capable of generating M6.7 strike-slip earthquake, which is larger than estimated in PG&E's previous 2009 and 2011 reports.

2. <u>SAN LUIS BAY FAULT</u>: The newly reinterpreted 16 km San Luis Bay Fault located within 1,900 meters of the plant, is capable of generating a M6.4 reverse earthquake, which is larger than previous estimated in PG&E's 2011 report.

3. <u>LOS OSOS FAULT</u>: The newly reinterpreted 36 km Los Osos Fault located within 8.1 km of the plant is capable of generating a M6.7 reverse earthquake which is smaller than the M6.8 estimate in PG&E's 2011 report, but still estimated to produce more ground motion than the Double Design Earthquake (DDE), also known as the Safe Shutdown Earthquake in the license.

4. <u>JOINT SHORELINE/HOSGRI FAULT SYSTEM:</u> The newly reinterpreted 145 km joint Shoreline/Hosgri Fault system now assumes that the Hosgri Fault and Shoreline Fault connect, whereas previously the two were considered to be wholly separate and incapable of failing in a larger single rupture. A joint Shoreline/Hosgri strike-slip rupture within 600 meters of the plant could theoretically generate approximately a M7.3 earthquake according to the Report.

5. <u>JOINT HOSGRI/SAN SIMEON FAULT</u>: The newly re-interpreted 171 km joint Hosgri/San Simeon Fault system now assumes that the Hosgri Fault and San Simeon Fault connect, whereas previously the two were considered to be wholly separate

and incapable of failing in a larger single rupture. A joint Hosgri/San Simeon rupture within 4.5 km of the plant is capable of generating a M7.3 strike-slip earthquake, which is larger than the previously estimated M7.1 utilized in numerous prior reports. The newly defined Hosgri Fault is considerably longer than previously presumed by PG&E and NRC.

The predicted ground motion generated by this list of earthquake scenarios are **all greater than the current ground motion estimates for a M7.3 Hosgri Fault earthquake located 4.7 kilometers from the facility**. This result is remarkable as the enormous Hosgri Fault, which can be seen easily on oil company seismic lines and passes the plant at a distance of only three miles, had been argued for many years to be the greatest threat to the facility. (Note: from a regulatory perspective the Hosgri Fault had previously been treated as the "controlling fault", which is to say the fault posing the greatest possible seismic threat to Diablo.)

However, in a seeming contradiction, rather than finding that larger or closer faults produce greater shaking and therefore a greater threat, PG&E argues in the Report that ground motion will be lower than the levels previously estimated. In other words, these newly discovered and re-interpreted faults are capable of producing shaking that exceeds the shaking from the Hosgri, yet that shaking threat would be much reduced from prior estimates.

Though discussed only in passing in the Report, the reason for this seeming contradiction is quite important when assessing whether or not the plant is safe or whether it is operating within its license conditions. The reason the earthquake threat purportedly went down when new faults were discovered is because the utility adopted significant changes to the methodology utilized for converting earthquakes (which occur at the fault) into ground motion (which occurs at the facility). This new methodology, which is less-conservative than the prior methodology, essentially "de-amplifies" the shaking estimated from any given earthquake relative to the prior methodology used during the licensing process.

DIABLO LICENSING BACKGROUND

The Diablo Canyon Nuclear Power Plant was licensed through a strictly adjudicated process that defined the Safe Shutdown Earthquake as the "maximum earthquake potential for which certain structures, systems, and components, important to safety, are designed to sustain and remain functional." In the unique parlance of the Diablo Canyon Nuclear Power Plant this Safe Shutdown Earthquake was defined as the "Double Design Earthquake." The NRC licensing process "ensures that the detailed operability requirements of the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code are met at the higher ground motions."[i] The Design Earthquake (DE) for Diablo was defined during the construction permit process as the largest of four possible earthquake scenarios. The DE was assumed capable of generating a peak ground acceleration of 0.2 g. The Safe Shutdown Earthquake was then defined for Diablo as 0.4g, which is to say the plant must be able to shut down safely if a hypothetical earthquake generates double the 0.2g of shaking that was estimated to be possible from known surrounding threats. This hypothetical Safe Shutdown Earthquake is known as the Double Design Earthquake (DDE) and is a key element in establishing safety standards during the licensing process.

This formal NRC licensing process, which defined the DDE as the Safe Shutdown Earthquake for enforceable regulatory purposes, occurred prior to the discovery of the Hosgri Fault. Upon its discovery the USGS analyzed the Hosgri Fault and determined that it could generate a M7.5 earthquake at a distance of 4.5 km. The NRC negotiated with PG&E to create the 1977 Hosgri Evaluation (HE) exception under the theory that the plant could withstand shaking from this newly discovered fault under a narrow and specific set of assumptions. The HE used considerably less-conservative assumptions than those used for the DDE, which was applied to all other earthquake threats. The reduction of safety margins by the use of these special assumptions for the Hosgri Fault was quite controversial, and was strongly criticized by NRC Commissioners Gilinsky and Bradford in an opinion they issued on the Diablo seismic matters in 1981.[ii] The DDE is the Safe Shutdown Earthquake for Diablo and applies in the Current Licensing Basis to all faults that can affect Diablo, with the exception of the Hosgri Fault, to which the 1977 HE exception and its methodology and assumptions uniquely apply. Because of the differing assumptions the HE exception did not and was never intended at the time to eliminate or supersede the DDE standard.

To operate within its license the utility has been required to show that the plant will not be exposed to shaking beyond either the DDE basis or the less-conservative HE exception for a potential Hosgri earthquake. Later, the 1977 HE exception was modified to assume a slightly smaller M7.2 earthquake but with a slightly more dangerous reverse component of slip. The combination of the two changes produced a modified spectrum that changed only modestly with small enhancement at higher frequencies. That modification became known as the 1991 LTSP spectrum;[iii] however, it never became part of the Current Licensing Basis. (For the rest of this letter the Hosgri shaking estimates will be described as the HE/LTSP spectrum due to the fact that the HE and LTSP are used somewhat interchangeably and differ only slightly, even though the differences are important from a historic and regulatory perspective).

In 2008 history repeated itself and, as in the case of the Hosgri Fault, another offshore fault was discovered, but this time even closer to the plant. USGS found the Shoreline Fault within 600 meters of the reactors and within 300 meters of the intakes. When considering that the fault runs to a depth of 16 km, spatially the nuclear power plant lies virtually overtop the new fault. In the immediate aftermath of the discovery, PG&E's data demonstrates that the nearby faults could produce ground motions significantly higher than the 0.4g peak acceleration permissible under the DDE standard (see table below - note this analysis occurred prior to the seismic studies described in the Report which found that the faults were larger than assumed in table).

Table: Comparison of Reanalysis to Diablo Canyon SSE[iv]

Local Earthquake Fault	Peak Ground Acceleration
DDE	0.40g
Shoreline	0.62g
Los Osos	0.60g
San Luis Bay	0.70g
Hosgri	0.75g

In the face of this conflict with the license, PG&E began to compare the new seismic threats not to the DDE in the license, but rather to the HE/LTSP spectrum. If PG&E could ignore the DDE Safe Shutdown Earthquake standard in the license, PG&E could simply seek to prove that the newly discovered seismic threats were 'bounded' by the HE/LTSP spectrum, with their less conservative assumptions - ergo, notwithstanding the newly discovered and re-interpreted faults, the plant could be said to be operating consistent with its license.

Dr. Michael Peck, the Senior Resident NRC Inspector at the Diablo Canyon Nuclear Power Plant, was concerned that the newly discovered and re-interpreted faults (Los Osos, Shoreline, San Luis Bay) had been shown by PG&E to produce greater shaking than the .04g peak acceleration DDE design basis. He stated that the only approved exception to the DDE was the 1977 HE exception, which applied only to the Hosgri Fault, and that the exception was not transferrable to these other nearby faults - ergo a license amendment was required to correct the inconsistency between the existing license and the new seismic threats.

Buttressing Peck's argument that the less strict spectrum was not to supersede or replace the DDE, on October 12th, 2012 the NRC wrote to PG&E[v]: 'The DCPP Final Safety Analysis Report Update states in Section 2.5,

> "…the LTSP material does not alter the design bases for DCPP." In SSER 34 the NRC states, "The Staff notes that the seismic qualification basis for Diablo Canyon will continue to be the original design basis ***plus*** the Hosgri evaluation basis…" (emphasis added).

Faced with newly estimated ground motions in excess of the DDE Safe Shutdown Earthquake license requirement, PG&E proposed revising its license to eliminate the DDE requirement and have the HE/LTSP spectrum, with its considerably less protective methodological assumptions, apply not just to the Hosgri Fault as an exception to the DDE, but to all faults. The NRC declined to accept the request for review because it failed to meet certain required standards.

CRITICAL ISSUE EXPLORED

I do not seek to engage on Peck's important regulatory issue of whether the utility can now legally disregard the DDE standard and instead meet only the less-conservative HE exception. That is a matter for the NRC to determine based on its safety and regulatory standards and, hopefully, informed by the post-Fukushima understanding of the dangers of lax regulatory oversight. In the aftermath of this disagreement between the Senior Resident NRC Inspector at Diablo Canyon Nuclear Power Plant and NRC staff, deliberation on this regulatory issue is now the subject of a lawsuit filed before the US Court of Appeals for the District of Columbia.

Instead, this analysis seeks to explore a different issue; specifically, is PG&E correct when it asserts that the utility has shown that the new seismic threat is bounded by the 1977 HE exception? (By exploring only this second issue I do not mean to minimize the importance of the first issue, but this second issue is central to the critical conclusion of the Report). In other words, the question is whether or not the new seismic threats have in fact been shown to produce shaking that is smaller than the HE basis exception <u>when the same associated analytical methods used to create the HE basis exception are applied to the new seismic threats</u>.

Why is it important to add this caveat about the same "associated analytical methods?" Because the rest of the NRC statement cited above under SSER 34 goes on to say,

> "The Staff notes that the seismic qualification basis for Diablo continues to be the original design basis plus the Hosgri evaluation basis, ***along with associated analytical methods, initial conditions, etc***."(emphasis added).

If the utility seeks to argue that the 1977 HE exception can be used as an alternative standard to avoid the stricter DDE standard, which is controversial in itself, then the methods which were used to compute the HE exception become of paramount importance. This analysis seeks to document that the "associated analytical methods" used by the utility to analyze the new seismic threats in the Report are markedly less-conservative than those used for the 1977 HE exception.

Why is this change in methodology important, particularly when the methodology is less conservative? Under 10 CFR 50.59, a license amendment is required when the Final Safety Analysis Report (FSAR) is inadequate to describe the circumstances at the plant and there is a

> "departure from a method of evaluation described in the FSAR (as updated) used in establishing the design bases or in the safety analysis." NRC regulations define such a departure as: "(i) **Changing any of the elements of the method described in the FSAR (as updated) unless the results of the analysis are conservative or essentially the same**; or (ii) Changing from a method described in the FSAR to another method unless that method has been approved by NRC for the intended application."

The NRC requires a license amendment when there is a <u>departure</u> from a method of evaluation that established the design basis unless that departure is essentially the same or more conservative. If the utility is allowed to employ less-conservative analytical methods to obtain more optimistic results then prior safety standards could be lowered without the full understanding or regulatory concurrence of the NRC.

It was this very problem that led to the shutdown of the San Onofre SONGS' plant. The failure of the NRC to recognize the need for a license amendment to replace San Onofre's steam generators was identified by the **Office of the Inspector General** at the Nuclear Regulatory Commission as a missed opportunity to identify weakness in Edison's technical analyses[vi]. There is a marked difference between NRC staff review of a utility's change in methodology versus the rigor and process associated with a license amendment.

This analysis contends that because a true apples-to-apples comparison was never made in the Report between the Hosgri and the new seismic threats using analytical methods that are **"conservative or essentially the same"** as those used for the Hosgri evaluation. Therefore, it is inaccurate to assert that the new seismic threats are shown to be "bounded by the Hosgri evaluation basis" – as that phrase has any bearing for regulatory purposes.

This contention is important because - If PG&E is allowed by the NRC to reject both the stricter standard of the DDE and the conservative analytical methods used when the 1977 HE exception was authorized, then the NRC's prior seismic safety licensing standards will have been, for all practical purposes, circumvented.

Making this particularly troubling is that this circumvention will have been achieved without a license amendment process, which would ensure a more robust process for including analysis of differing and minority findings and opinions – findings and opinions which have been proven over time to be right, more often than not.

GROUND MOTION PREDICTION RETROSPECTIVE

Methodologies employed to assess potential shaking at the nuclear power plant can be broken into three broad categories:

1) SOURCE: Estimated energy released by a specific earthquake on a given fault – based on equations that involve factors such fault mechanics, stress drop, radiation pattern, directivity, rupture history, rupture length and width, etc.

2) PROPAGATION: Estimated attenuation and amplification factors that convert the energy released during the fault rupture process to the actual observed free field ground motion at a particular site, based on:

    a. TRANSMISSION EFFECTS: Energy transmission involves absorption and scattering, otherwise known as attenuation, incurred along the propagation path from the earthquake to the vicinity of the particular site, and

    b. SITE EFFECTS: Site amplification and de-amplification effects due to the stiffness of the rocks and soils of the particular site and the impedance contrasts that give rise to a variety of scattering and reverberation effects.

3) TRANSFERENCE: Estimated shaking adjustments from reference free-field station to power-block, turbine-building foundation levels, and then to structures, systems, and components throughout the facility – based on certain projection, coherence, and damping factors.

This analysis seeks to examine #1 and #2a and #2b cited above.

A Ground Motion Prediction Equation (GMPE) is used to predict shaking at a particular distance from an earthquake based on a variety of parameters. A GMPE represents the statistical relationship that best fits the empirical distance-attenuation observations from some database of earthquake recordings. Some of the parameters used to make the estimate include: size of earthquake, fault mechanics, geometry of the fault to the recording station, and the velocity of the rocks immediately below the recording station. GMPEs incorporate a large range of phenomena and effects.

Since discovery of the Shoreline Fault PG&E has significantly changed the GMPE equations used to analyze potential shaking at Diablo. The following summarizes the changes and their net effect on seismic hazard estimates. To help track the evolution of GMPE's they are informally numbered in the following retrospective. (**GMPE-1,** nomenclature for the purposes of this letter would be the methodology used for the DDE and the HE exception from the construction permit).

<u>In 1991,</u> PG&E constructed the LTSP spectrum, which assumed a M7.2 earthquake at a distance of 4.5 km and used a GMPE **(GMPE-2)** derived from their own distance-

attenuation relationship based on a database of strong-motion recordings of earthquakes at a range of distances along with regression analysis

In 2008 the Shoreline Fault was discovered which triggered a requirement that PG&E assess whether or not shaking caused by the newly discovered fault was 'bounded' by the DDE *and* the HE exception, as required by its current operating license. Rather than use the same GMPE to perform that analysis PG&E began introducing new methodologies making it difficult to perform historical comparisons with earlier standards approved through the NRC's regulatory process.

PG&E, in an initial sensitivity report[vii] to the NRC, assumed that the length of the Shoreline Fault was as much as 24 km long with a depth of 12 km and capable of generating a M6.5 earthquake. It then used an assortment of different recently developed GMPEs, known as the Next Generation Attenuation models, to create a new averaged GMPE **(GMPE-3)** to compute shaking estimates at the plant caused by a Shoreline earthquake. GMPE-3 resulted in a de-amplification effect of median estimated shaking, relative to the prior methodology, i.e. a decrease in shaking, relative to GMPE-1 or GMPE-2. This new GMPE was justified based on the use of the Pacific Earthquake Engineering Research Center (PEER) database of some 3,600 earthquake recordings. Using GMPE-3 PG&E reported that the shaking was substantially lower than, or bounded by, the LTSP/HE spectrum[1].

In 2009, NRC staff used PG&E's proposed **GMPE-3** equations but then analyzed the Shoreline Fault assuming it was 24 km long with a depth of 16 km, which was more conservative than PG&E's depth of 12 km. Using these parameters, and including a 1 standard deviation of magnitude estimate, the largest possible earthquake was computed to be M6.85 rather than M6.5. Assuming the somewhat larger earthquake their analysis found,

> "The motions are *very close to* the LTSP/HE in the high-frequency range but fall below the LTSP/HE in the long-period range". and "…seismic loading levels predicted for a maximum magnitude earthquake on the Shoreline Fault are *slightly below* those levels for which the plant was previously analyzed in the Diablo Canyon Long Term Seismic Program" (emphasis added).

Using GMPE-3 shaking from an assumed 24 km Shoreline Fault was found to be "*very close to*" and only "*slightly below*" the LTSP/HE spectrum when using the new GMPE-3 methodology (emphasis added).

The five NGA GMPEs which, when averaged, produce GMPE-3 are each shown in figure 10 from the NRC report. The NRC staff analysis also tested the significance of using the lower-bound estimate of rock velocity rather than the "best estimate" (lower velocity corresponds to higher shaking). Using a rock velocity of 800 m/s instead of 1,100 m/s resulted in a spectrum that, "exceeds the LTSP spectrum by a small amount over some frequencies." In summary, by using reasonable but somewhat more conservative approaches to the three available variables (the NGA model selection, earthquake magnitude estimate, or rock

[1] The LTSP and HE spectra are very similar and are used almost synonymously in some reports cited herein. To avoid confusion caused by switching back and forth, a single term LTSP/HE will be used in some instances even though they differ from a regulatory basis.

velocity) the spectrum was found to be "very close" or "exceeds…by a small amount." This result was quite significant because it showed that, even in the early days when the Shoreline Fault was still believed to be relatively small, shaking could exceed the LTSP Spectrum assuming certain models and certain rock parameters. The Chiou & Youngs (08) GMPE (dotted blue line) exceeds the LTSP Spectrum (solid black line) at about 7 Hz and above, the others are just a little below, hence the characterization that they are *"very close"* (emphasis added).

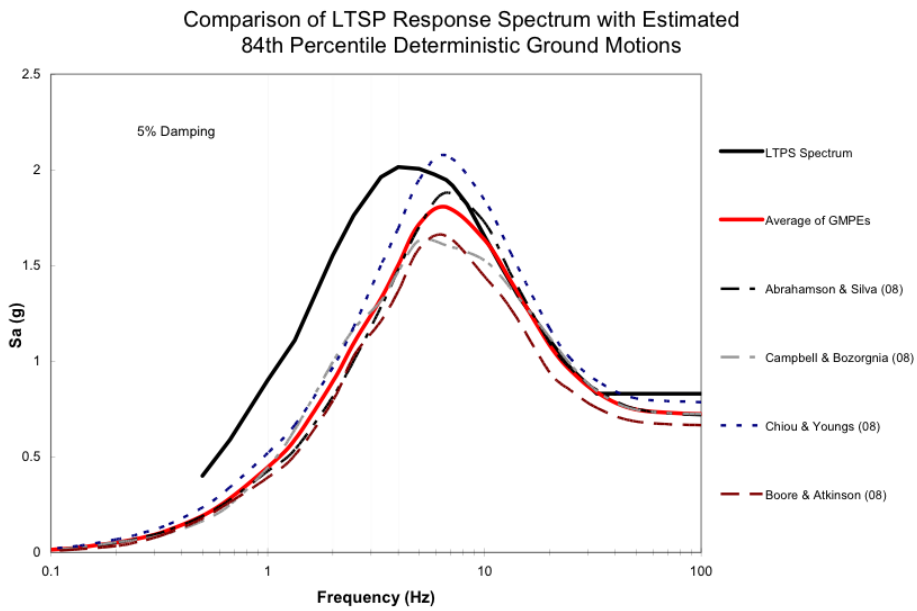


Figure 10. Comparison of Individual 84th Percentile Ground Motion Prediction Equations with Best Estimate Parameters and Diablo Canyon Review Spectrum

This result naturally raises important questions about the effect of the new GMPE applied to the Shoreline. For example: would estimation of shaking on a 24 km rupture of the Shoreline Fault have exceeded the LTSP if GMPE-1 was used rather than GMPE-3? Given what is shown in Figure 10 it appears that the answer would likely be "yes" if the difference between GMPE-3 vs GMPE-1 was anything other than de minimis, but that analysis was not performed in the 2009 Shoreline report.

The effect of which GMPE methodology is employed is highlighted in a NRC staff remark when it wrote, "…epistemic uncertainty in the GMPEs, which tends to be higher in the magnitude-distance ranges with sparse available seismological data (such as large magnitudes at short distances). Generally the GMPEs are the ***largest source of uncertainty*** in the ground motion values produced in seismic hazard analysis" (emphasis added). Here the NRC staff acknowledges that the new GMPEs are the source of the greatest uncertainty, and, that uncertainty is greatest for large earthquakes at short distances, which is exactly the situation for Diablo.

<u>In 2011</u>, PG&E issued its "Report on the Analysis of the Shoreline Fault Zone, Central Coastal California" assuming the same maximum M6.5 earthquake along a 23 km fault, but introducing a number of new factors creating yet another new GMPE, named here as

GMPE-4. The utility started with its 2009 GMPE-3 equation but then added a new hard-rock effect. The rationale for this equation was inferred from work by Silva (2008). The result adjusted estimated shaking downward still further from GMPE-3. Silva's work, which was specific to a particular range of rock hardness along with other factors, did not include the actual rocks at Diablo. Therefore PG&E extrapolated the findings of the published paper so they could be applied to Diablo where a faster rock velocity of 1,200 m/s was assumed (faster rocks equate to lower shaking).

Additionally, PG&E created new equations to reduce the standard deviation of the estimated shaking. Because 84th percentile shaking estimates are the sum of the median shaking plus one standard deviation the total spectrum can be lowered either by reducing the median, reducing the standard deviation, or lowering both.

With the issuance of the 2011 report PG&E reduced both the median and the standard deviation used in the analysis of the seismic threats – the first through yet another new GMPE with hard-rock de-amplification effects; and second, through a statistical approach described as "single-station sigma."

Using this new **GMPE-4** the resulting spectrum that was no longer "*slightly below*" and "*very close*" to the LTSP/HE spectrum, per the prior NRC's findings of 2009 (emphasis added). The new margin was significantly larger thereby allowing PG&E's to again assert that the LTSP/HE spectrum was not at risk of being exceeded by shaking on a M6.5 earthquake on the Shoreline Fault. Note how the PG&E's methodology to compute shaking changed not once but twice in the short period of time since the discovery of the Shoreline Fault in 2008. Both those changes produced reduced estimates of shaking from the newly-discovered Shoreline Fault.

<u>In 2012</u>, NRC staff issued its "Confirmatory Analysis of Seismic Hazard at the Diablo Canyon Power Plant from the Shoreline Fault Zone. The report details staff's review of PG&E's report. NRC staff decided to lower their maximum possible earthquake from M6.85 to M6.7, which was closer to PG&E's figure of M6.5 (smaller earthquakes correspond to lower shaking). Similarly staff decided to revise their estimate of rock velocity upward from 1,100 to 1,200 m/s which was the figure used by PG&E (faster velocities correspond to lower shaking).

They also reviewed PG&E's new hard-rock de-amplification adjustment and pointed out a number of problems with the approach including uncertainty in the estimate of Kappa, a factor that describes damping in basement rock. When NRC staff explored alternative methodologies they found, "the NRC results are conservative relative to the PG&E results at virtually all frequencies."[viii] Nonetheless, NRC staff incorporated a new hard rock effect and added that factor to GMPE-3. Staff elected not to use add "single-station sigma" effect to further lower the 84th percentile of shaking. They did however agree with PG&E's conceptual approach, albeit they noted statistical unreliability of its use at Diablo due to small amounts of available data.

To issue this report, NRC staff acquiesced to PG&E's use of the

1) Use of the new NGA GMPE's,
2) Averaging of NGA GMPE's to eliminate outliers,
3) Smaller earthquake magnitude estimate,

4) New hard-rock rock scaling factor,
5) Increased site rock velocities, and
6) New statistical single-station sigma.

The net effect of adding these factors allowed the NRC to issue a "confirmation" in 2012 of PG&E's assertion that the Shoreline Fault would produce shaking below the LTSP/HE spectrum.

In 2014, after the offshore seismic studies were completed, PG&E issued its Coastal California Seismic Imaging Project (CCCSIP) Report. The Report concluded that the Shoreline Fault is 45 km long (a tripling of the utility's 2009 lower-bound figure) and that a hypothetical joint Hosgri/Shoreline Fault rupture would be 145 km long generating a M7.3 earthquake within 0.6km of the plant (corresponding to a factor of 30 greater released energy relative to the earlier lower-bound estimate). The Report also details the size and location of the Los Osos and San Luis Bay Faults and the potential earthquakes they could generate. Again, all of these threats produce shaking that is greater than their new calculations of shaking from the Hosgri, which had previously been identified as the 'controlling fault"

In Chapters 11 and 13 PG&E analyzes the new seismic threats, which are markedly larger than those analyzed in 2011 using their new GMPE-4 which was used successfully with the Shoreline Report to calculate lower levels of shaking than the earlier methodology. Analyzing the new threats using GMPE-4 the Report finds that even a massive M7.3 earthquake linking the Hosgri and Shoreline Faults, with rupture occurring within 600 meters of the reactors, could not exceed the LTSP/HE spectrum. Demonstrating just how effective these less-conservative methodologies are in lowering estimates of shaking, without a single retrofit, Diablo becomes virtually invulnerable to any imaginable earthquake regardless of size and proximity.

Evidence of the total cumulative effect of these new methodologies can be inferred by looking at the "before" and "after" calculations of shaking of a hypothetical Hosgri Fault earthquake. Such a comparison shows that the peak acceleration is reduced from 0.75g to 0.46g! The de-amplification effect is even larger than suggested by this 38% decrease in estimated shaking because the "before" Hosgri earthquake is smaller than the "after" Hosgri earthquake, which now assumes a joint rupture on the Hosgri/San Simeon Fault System. The importance of using a new methodology that reduces peak accelerations by at least 38% is never singled out for mention in the Report, nor is the prior less-conservative methodology applied to the new seismic threats.

IMPORTANCE OF NEW GMPEs

These changes to GMPEs, documented in the prior section, are crucial to the fate and future of Diablo and give rise to two important questions.

> First, from a technical perspective: Are these rapidly evolving GMPEs appropriate for application to Diablo given the statistics and science embedded in their assumptions?
>
> Second, from a regulatory perspective: Are these rapidly evolving GMPEs appropriate for application to Diablo when dealing with the safety margins and

adjudicated rules that define how nuclear power plant licenses are enforced or amended?

In this retrospective of evolving GMPEs I've made no arguments regarding the technical or scientific merit regarding the half-dozen changes to GMPEs that have occurred. This is a rapidly evolving field of research for which there is insufficient data to provide a simple "yes" or "no" answer. Instead it is more appropriate to identify concerns and to point out alternative interpretations to the existing data. Therefore, I address the first question in an attached appendix, which can be read separately from this letter.

However, as a former policymaker I do believe there is a clear-cut answer to the second question, which I will address here. Making this GMPE chronology troubling from a regulatory and safety perspective is that, as newly discovered or re-interpreted faults are progressively understood to be larger and more dangerous than previously believed the newly derived methodologies adjust shaking downward just sufficiently to accommodate the new threat. In fact, the safety of the facility no longer depends on whether or not dangerous faults actually surround the nuclear power plant and are capable of generating earthquakes that exceed the shaking predicted from the previously defined 'controlling fault.' That question has been answered unequivocally and the PG&E Report acknowledges the presence of such earthquake faults. Instead the safety of the facility depends upon the reliability of new less-conservative equations, which are going through major revisions literally with each newly issued report.[ix]

These facts raise significant regulatory issues that need to be addressed at the highest levels of the NRC. In this instance we see a nuclear power plant that is found to be exposed marked greater seismic threats than ever envisioned during the licensing process. This increase has happened not once, with the discovery of the Hosgri Fault, but twice. With this year's report an entire new class of earthquake threats have been identified that eclipse the prior Hosgri Fault threat. This fact alone should galvanize the NRC to act. But what makes the situation even more dire is that the methodologies used by the utility to analyze the new threats have changed as well. If the utility's associated analytical methods to compute ground motion were the same or more conservative the debate would be solely on the scientific questions surrounding the earthquake potential introduced by the new faults. However, in this case the associated analytical methods to compute ground motion beneath the plant are markedly less-conservative than those ever used before. These methods are less-conservative than when the plant was licensed and less conservative than even six years ago when the Shoreline Fault was first discovered. If the prior methodologies used during licensing were applied to these new faults it is possible, and perhaps likely, that shaking would exceed both the DDE and LTSP/HE spectrum. If true, this means that the plant is currently operating beyond the tolerances established under its license. That is why this is a critical regulatory issue. Threats are going up at the same time the utility's preferred method for analyzing all such threats has become markedly less conservative. From a regulatory perspective, it is this simultaneous convergence of higher threats and less-conservative methodologies that requires the NRC to act immediately.

CONCLUSION

In summary: The geophysical methodologies to locate faults and assess the size of potential earthquakes are well established and have been tested for innumerable instances over many decades. Similarly, the estimation of site effects when dealing with relatively simple geology is well understood. This history has allowed regulators to rely comfortably on the long record of published findings on these important elements of seismic hazards.

However, the geophysical methodologies for determining ground motion in the extreme near-field are in a rudimentary state of development. Similarly, the estimation of broadband site effects when dealing with highly complex and heterogeneous 3D geology is a difficult technical problem and an active area of research (see appendix).

PG&E has progressively used methodologies that produce less-conservative results to analyze the steadily increasing seismic threat. With each successive generation of new information about the threat prior methodologies are modified and more sanguine results are obtained.

Of course, from a research perspective, the fact that a whole series of new methodologies are being explored and new equations are being tested, albeit with limited data (see appendix), is a good thing. However, it is a quite perilous thing from a regulatory perspective, which requires high-levels of scientific and statistical certainty based on large datasets and well-vetted methodologies. The regulatory determination of safety should not hang tenuously upon the results of an ongoing science experiment. When faced with such a situation nuclear regulators must rely upon the existing, more conservative, and historically accepted methodologies to assess risk.

But beyond the imprudence of relying upon rapidly evolving methodologies to obtain lower risk estimates at a nuclear power plant, there is a regulatory reason why such an approach is not allowable. The NRC stated,[x] "The Staff notes that the seismic qualification basis for Diablo Canyon will continue to be the original design basis plus the Hosgri evaluation basis, ***along with associated analytical methods, initial conditions, etc."*** (emphasis added). Clearly the Hosgri evaluation basis, if it is to have any regulatory meaning, can only be applied to a new seismic threat if the same, or more conservative, analytical methods are employed to compare the two. This however is not how the utility is treating the Hosgri evaluation basis. Instead, the utility employs significantly less conservative analytical methods and then states that the lower shaking produced by new seismic threats is 'bounded' by the HE exception.

Finally, if altogether less-conservative methodologies are to be used to analyze altogether new and more dangerous faults it is important that such analysis be performed at arms length through a transparent, rigorous, and strict license amendment process so that the public can have confidence that safety is the foremost consideration of the NRC. This is why such analysis should be performed through the course of a license amendment process.

My overarching concerns with the Report include:

- <u>Disregard of DDE basis</u>: In a post-Fukushima setting the NRC must insist upon the high and robust seismic safety standards at the nation's only nuclear power plant that is

ringed by numerous nearby faults capable of earthquakes, each larger than the earthquakes envisioned from previously assumed "controlling fault." However, to-date the NRC has ignored the cautions of experts and even its own resident inspector who has declared the plant is operating beyond its current operating license based on the DDE.

- Weakening of HE basis: The 1977 HE basis was allowed as an exception that applied only for an earthquake on the Hosgri Fault. However, while the utility is ignoring the DDE standard and is applying the HE exception to all faults, it is also simultaneously seeking to weaken the 1977 HE exception by creating new "associated analytical methods" that are markedly less conservative.

- Lack of Transparency: Notably, the Report never makes an apples-to-apples comparison wherein the same "associated analytical methods" are used to analyze new seismic threats and the HE exception. Nor are lower-velocity parameters input to the new analytical methods to assess their sensitivity to critical real world parameters and uncertainties at the site. The public is never given the opportunity to see the cumulative effect of each generation of new GMPEs or the range of effects due to rock velocity selection. This makes it impossible for PG&E to accurately assert in the Report that, from a regulatory perspective, the new seismic threats are shown to be 'bounded' by the HE basis. From what data are shown by the Independent Peer Review Panel such a transparent and apples-to-apples analysis would likely prove the opposite.

- Rapidly Evolving Analytical Methods: The utility is relying upon less-conservative methodologies that are evolving and changing rapidly, which reduces reliability and confidence from a regulatory perspective. The velocity parameters themselves, upon which some of these new methodologies depend, are in serious dispute. Furthermore, the methodology to compute extreme near-field ground motion in a setting ringed by large strike-slip and reverse faults is nowhere near developed enough to ascribe certainty to median or variance estimates of probable shaking.

- More Seismic Threats to Come?: Two future possible seismic threats remain unknown due to data limitations. It is not clear that the poorly imaged faults under the Irish Hills have been properly identified in the geologic cross-sections which could mean a whole new category of undiscovered threats may exist directly under the plant. The quality of the seismic data obtained onshore just under the Irish Hills is poor and due to the virtual absence of relevant geologic information from deep wells it is difficult to differentiate between active and dormant faults in the seismic data. Whether or not another class of active thrust faults exist under the plant remains an open question. The current data cannot be used to rule out such a possibility and the compressional nature of the topography argues that such faulting could be inferred. Additionally, the study area used by PG&E does not include the area that connects the more northerly San Simeon Fault with the San Gregorio Fault. The Report agrees that the Hosgri Fault is connected with the San Simeon Fault, which has caused the maximum possible earthquake to increase significantly. If the San Gregorio Fault to the north is similarly

connected then the Report has underestimated the maximum earthquake that Diablo might need to survive.

- Troubling History: The utility has a long and remarkable history of producing sanguine technical reports that get the seismic hazard analysis at Diablo exactly wrong. Whenever new data has emerged identifying possible new seismic threats the utility has mobilized its internal and external experts to sequentially argue that nearby faults simply didn't exist, they did exist but were inactive, they were active but not large, and then that they were large but segmented and unconnected. Now that the evidence about the size and location of the faults is indisputable - the argument has suddenly changed again. Now the utility declares that although the faults are quite large, nearby, and interconnected the prior equations used during the licensing process to predict shaking should be abandoned and replaced with less-conservative methodologies which allows the utility to claim that the plant is safe……even from a M7.3 within 600 meters of the facility. One must ask, **"if the utility has been proven to be wrong so many times in the past on so many similar issues and given the high stakes of mishandling this critical issue, should the utility's new-found conclusions be relied upon without the direct regulatory oversight of the NRC's license amendment process?"** As a scientist and a policy maker I believe the responsible answer is "No."

In conclusion, if the NRC were to decide to rely upon the utility's assertion that the facility is operating in conformance with its license based on these new evolving less-conservative equations the NRC would be allowing the HE exception to be markedly weakened by the utility without the third party objectivity, regulatory safeguards, and technical rigor of the license amendment process. Such a decision in the aftermath of the difficult lessons of Fukushima could come back to haunt the NRC, the utility, and more importantly – the public.

APPENDIX

TECHNICAL CONCERNS

The following are some of the reasons I believe that these less-conservative equations and evolving GMPEs are still very much a work in progress, making it premature to apply the methodology to the Diablo Canyon Nuclear Power Plant. If the only possible way to prove that the plant is operating below the LTSP/HE basis is through the use of these new equations then a formal adjudicated license amendment process, especially if the LTSP/HE exception is to be relied upon in lieu of the DDE safety standard.

CONCERN #1 – Methodology limitations in applying PEER derived GMPE's distance-attenuation predications for extreme near-field applications: The Next Generation Attenuation models, which is the basis for GMPE-3 and many of the other subsequent GMPE's, is derived from the PEER database of some 3,600 recordings. The various peer-reviewed and published attenuation-distance equations are based on robust statistical best-fits to the very large PEER dataset. However, the proximity of the plant to the Shoreline and the San Luis Bay Faults are only 0.6 km and 1.9 km. Out of this entire PEER dataset only a couple dozen recordings exist within 2 km of the fault and of those only 8 recordings occur with 0.6 km. This number of recordings is insufficient to create a statistically significant estimate of ground motion in this **extreme near-field setting**. Any statistical estimate of an empirical distance-attenuation relationship in which *over 99% of the data* occur in a range outside of the distance where the relationship will be applied is unreliable for determining a mean or variance of shaking.

The uncertainty in the extreme near-field estimates of ground motion using NGA GMPE's is not reduced through an averaging approach. All of the GMPE's constructed from various subsets of the PEER dataset include the same systematic under sampling of extreme near-field recordings and over sampling of far-field earthquakes. Because this error is systematic rather than random the averaging process cannot be relied upon to improve confidence of extreme near-field shaking estimates.

The new Next Generation Attenuation models used for **GMPE-3** and the even-newer **GMPE-4** both suffer from data limitations that make them problematic for reliable application to Diablo. Simply adding geologic, site effect, and statistical correction factors to the underlying NGA equations does not overcome the statistical problem inherent in applying these equations in the extreme near-field.

CONCERN#2 – Methodology problems in PG&E's site-specific adjustments to shaking estimates at Diablo: As stated above, the Next Generation Attenuation models, which is the basis for GMPE-3 and GMPE-4 is derived from the PEER database of some 3,600 recordings. The vast majority of these recordings occurred in rock types that differed significantly from the rocks types under the Diablo Canyon Nuclear Power Plant.

The NRC pointed out in September 2012 that there are,

> "…only 51 recordings with sites defined with Vs30>=900 m/s. This is less than 1.4% of the database. There are only 15 recordings with Vs30>=1,200 m/s (less than one-half of one-percent)…….Hence, applying a Vs30 of 1,200 m/s directly in the

GMPEs increases uncertainty, as this value is beyond the range well constrained by the observational data.[xi]"

To deal with this deficiency NRC staff and PG&E began constructing a variety of rock type correction factors and single-site correction factors. These new adjustments were derived from the utility's own sparse database.

Such an effort could be justified if the proper dataset were available; however, the Diablo database is inadequate for this purpose. Over the past few years only a handful of strong-motion instruments at Diablo have recorded just two relevant-sized earthquakes (e.g., >=M6.0). These two earthquakes are the M6.0 Parkfield earthquake at a distance of 85 km and the M6.5 San Simeon earthquake at a distance of 35 km. It is simply not possible to perform rigorous statistical analysis on a sample size of two.

What makes the small size of this dataset even more troubling is that neither of these two reference earthquakes occurred to the west or south of the plant, which is where the Hosgri, Shoreline, and San Luis Bay Faults are located. Any site-specific Green's function[2] derived from the small amount of existing strong motion data would not include information about how the site responds to energy from a large earthquake arriving from the west or south.

Wellbore velocity profiles obtained at the site prove that the underlying soft and hard rock environment is neither homogeneous nor layer-cake 1-dimensional. Instead a high degree of 3D complexity with significant impedance heterogeneity is evident in the geology underlying the plant. Therefore a single azimuthally-independent site response will likely fail to incorporate the 3D heterogeneity at the site. Any empirically calculated Green's function based on limited-azimuth data from the north and east will be unreliable in predicting strong ground motion from the Hosgri, Shoreline, and San Luis Bay Faults.

Finally, neither of these two reference earthquakes occurred in the near field. A near-field earthquake cannot be treated as a virtual point source at a fixed azimuth. Instead a near-field earthquake must be treated as a distributed source whose azimuth varies as the rupture propagates up to, along side, and then past the nuclear power plant. This areal source propagates signal to the recording site from a range of azimuths and inclinations, potentially with different Green's functions. Two relatively distant point-source signals, Parkfield and San Simeon earthquakes, from the east and north cannot be used to infer the shaking from a rupture on the Hosgri or Shoreline Faults that actively propagates in the near-field past the plant, and/or stops directly adjacent to the plant to the west.

Given the significant number of large active faults that surround the plant, a dangerous neighborhood to be sure, it is imprudent to base the safety of the plant and the community solely upon reliance on site effects derived from this small dataset.

Future possible research designed to create a numerically simulated 3D site effect (which is reportedly underway and will become **GMPE-5)** to get around the deficiencies of both the

[2] Greens Function: A mathematical term of art defining a system response to an impulse signal which can be used to describe, through convolution and superposition, a system's response to a more complex signal

empirical data sets identified above, would face significant challenges. Accurate numerical elastic wave-equation simulation of a site-specific Green's function would require a 3-D velocity and impedance structure below and around the facility that extends to considerable depth, includes surficial topographic features, and accounts for accurate P-S and S-P and surface-wave conversions calculations, complex ray bending, critical refracting, scattering and focusing effects. To construct such a simulation would require higher-resolution and deeper data than is currently available from the wellbore or near-surface tomographic information.

If somehow such difficulties could be overcome, the numerically simulated site response would still need to be tested to determine how well it predicted the shaking generated by an actual earthquake >=M6.0 impinging on the site from the west and originating in the near-field. A prediction without a test to assess the accuracy of the prediction would be insufficient for regulatory purposes.

CONCERN #3 – Methodology problems in estimating shaking caused by an earthquake located in the extreme near field: This issue is different from the statistical issue regarding the paucity of data available in the near-field recordings or the lack of data for the rock-types in question - which were covered under concerns #1 and #2, respectively. At progressively greater distances from an earthquake the particulars of the dynamic rupture process becomes less important relative to the larger effects of total energy release and energy attenuation during transmission. However, in the extreme near field the location of a recording station relative to an earthquake's rupture history, asperity locations, heterogeneous stress drops, and starting and stopping phases, directivity, and a host of other effects become very important – in some cases the largest effect under consideration. Due to the location of the Shoreline, Los Osos, and San Luis Bay, and Hosgri Faults these effects would likely be significant. As more extreme near-field recordings have been obtained, although still relatively few in number, it has become clear that a simple estimation of an earthquake's magnitude and distance from a site may be insufficient to make precise estimates of shaking.

For example, in 2004, 48 strong-motion recordings within 10 km of the San Andreas Fault were made of the M6.0 Parkfield earthquake[xii]. This dataset was used to test three different attenuation-distance equations. These equations are shown to do a good job of making accurate predictions for distances beyond about 10 km, but the observed shaking becomes highly variable in close proximity to the fault. Rather than finding accurate predictions of mean shaking in the extreme near-field the paper notes,

> "Peak ground acceleration in the near-fault region ranges from 0.13 g at Fault Zone 4, to 1.31 g at Fault Zone 14, ten times larger, to over 2.5 g at Fault Zone 16 (where the motion exceeded the instrument capacity and the actual maximum value is still being estimated)."

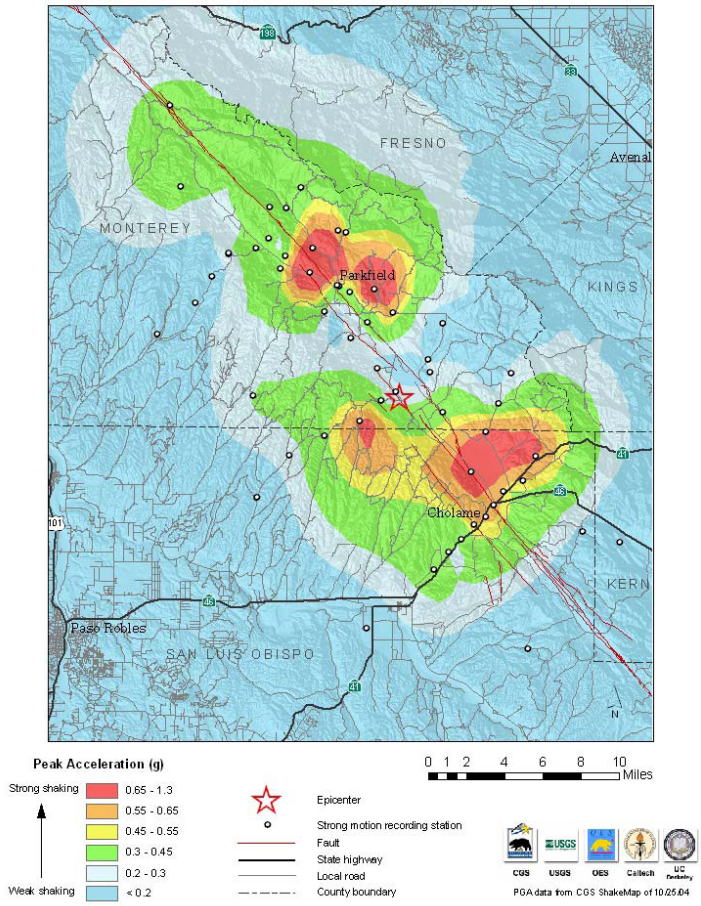


Figure 3: Shakal et. al., 2004 showing remarkably high and low accelerations in the extreme near-field (rupture started where the star is shown and then propagated to the north-east and south-west where they stopped)

The dense strong-motion Parkfield recordings are relevant to the conclusions of the Report for a number of reasons.

- First, these extreme near-field areas of high and low acceleration are not well predicted by a distant-dependent GMPE estimate of shaking. In this extreme near-field setting the particulars of how ruptures start and stop, the direction the rupture propagates, the potential focusing effect of the velocity structure of the fault zone, the locations of specific asperities become major factors that affect ground motion. These factors are not included in the current generation of GMPEs, which were never intended to describe these complex phenomena that are significant effects principally in the extreme near-field.

- Second, the Parkfield data shows that the high degree of variability in the extreme near-field is not a spatially random phenomenon. Instead the highest levels of acceleration are systematically found near the ends of the fault where stopping phases radiated

energy during the rupture process of this specific earthquake. If the nuclear power plant happens to be located in a zone of focused seismic energy the 84th percentile estimate from the GMPE estimate will likely underestimate the observed shaking.

- Third, PG&E has argued in the Report that while an earthquake on 100 km of the Hosgri Fault could jump to the 43 km of the Shoreline Fault creating a 143 km rupture, the likelihood of such an event is purportedly low. They contend that a north-to-south Hosgri rupture that jumped to the Shoreline would terminate due to bending and segmentation before rupturing the full length of the Shoreline Fault. If PG&E is right in this assertion they would be correct to reduce the component of shaking that is derived from the size of the earthquake. But they would then need to account for the markedly higher accelerations produced by stopping phases that would radiate from the segments and asperities associated with terminating the rupture near the facility. Given the high accelerations observed in the Parkfield dataset, an earthquake that propagates the 100 km length of the Hosgri and only 20 km of the Shoreline but violently stops directly adjacent to the nuclear power plant could in fact be more dangerous than a scenario involving the full 145 km of propagation

There are a few ways to demonstrate the significant influence of these new equations. One obvious demonstration is to review the reduction in estimated shaking from an earthquake on the Hosgri Fault relative to PG&E's earlier estimates when creating the HE/LTSP spectrum.

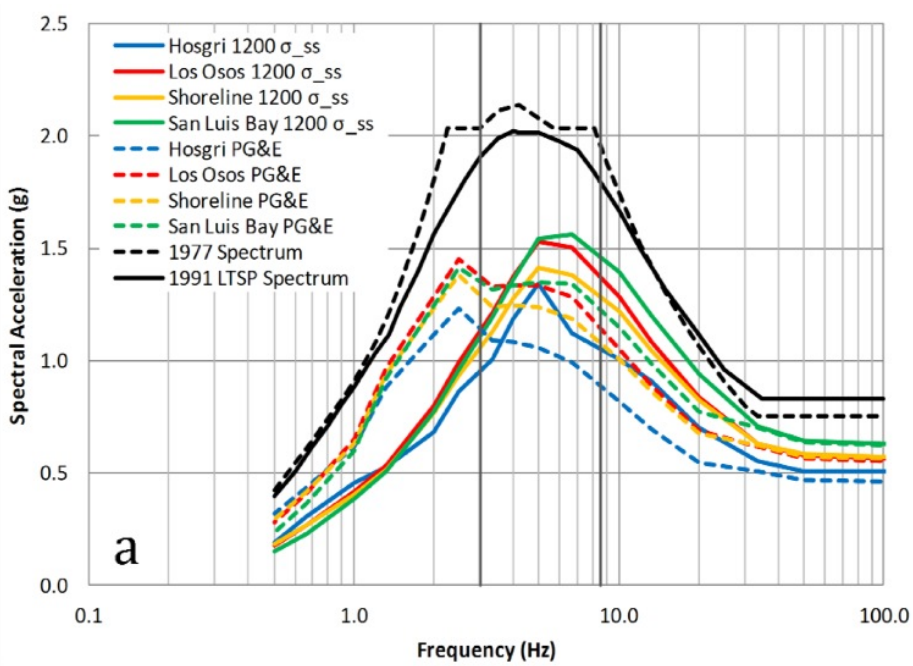


Figure 7. Comparison of deterministic ground motion spectra from PG&E for the DCPP site (dashed color curves; using site amplification term, its uncertainty, and single station sigma) with deterministic spectra of three sensitivity cases (solid curves): (i) a generic site with V_{S30} of 1,200 m/s and single station sigma (Figure 7a); (ii) a generic site with V_{S30} of 760 m/s and single station sigma (Figure 7b); and (iii) a generic site with V_{S30} of 760 m/s and sigma from GMPEs (ergotic sigma, Figure 7c). The PG&E 1991 LTSP/SSER 34, the 1977 HE (Hosgri Earthquake) design spectrum, and the frequency range important to DCPP (marked by vertical dark grey lines) are also plotted for reference.

(Figure 7a from IPRP Report)

As seen in Figure 7a from the Independent Peer Review Panel (IPRP) report and in a number of other related reports, the new less-conservative equations cause a major reduction in shaking across the entirety of the frequency spectrum from a hypothetical earthquake on the Hosgri fault (compare blue lines which use the newly devised methods with black lines which use the prior methods, in figure 7a above). In the frequency range from 2-10 Hz the less-conservative methodologies have cut the maximum estimated acceleration from 2 g down to about 1.3 g. At the peak-frequency range, from 30-100 hz, the maximum estimated acceleration as been reduced by a third from .75 g to under .50 g. In fact the de-amplification effect is even larger than this comparison suggests because the blue lines, which represent the shaking on the re-interpreted Hosgri, assume a larger rupture on the Hosgri Fault than the earthquake that was used to initially create the 1977 HE basis exception.

More importantly, as can be seen in Figure 7a the shaking from the Los Osos, Shoreline, San Luis Bay Faults all exceed the re-interpreted Hosgri (red, yellow, green lines are all above the blue line). **One can reasonably conclude that, if the original analytical methods had been used to estimate ground motion, the new seismic threats would exceed the original HE and LTSP spectra**.

This conclusion is supported by the sensitivity analysis shown in Figures 7b and 7c, which test the importance of various parameters to the new GMPE and site effects. The same IPRP report cited previously states,

> "These two figures also show that if DCPP site had a Vs30 value of 760 m/s rather than 1,200 m/s, and if the site behaves more like an average site in ground motion amplification, **some deterministic spectra would exceed the 1991 LTSP spectrum**[xiii]" (figure 7c below).

In fact, it is more than just "some." Under the scenario shown in Figure 7c the IPRP shows that the LTSP/HE spectrum is exceeded by **all** of the newly discovered and re-interpreted seismic threats, including earthquakes on the Shoreline Fault, the Los Osos Fault, and the San Luis Bay Fault (note that the red, yellow, and green lines are all above the solid black line). The fourth and largest hypothetical earthquake scenario, a M7.3 rupture on a joint Hosgri/Shoreline Fault, is not shown on this figure but could reasonably be assumed to exceed the LTSP/HE as well.

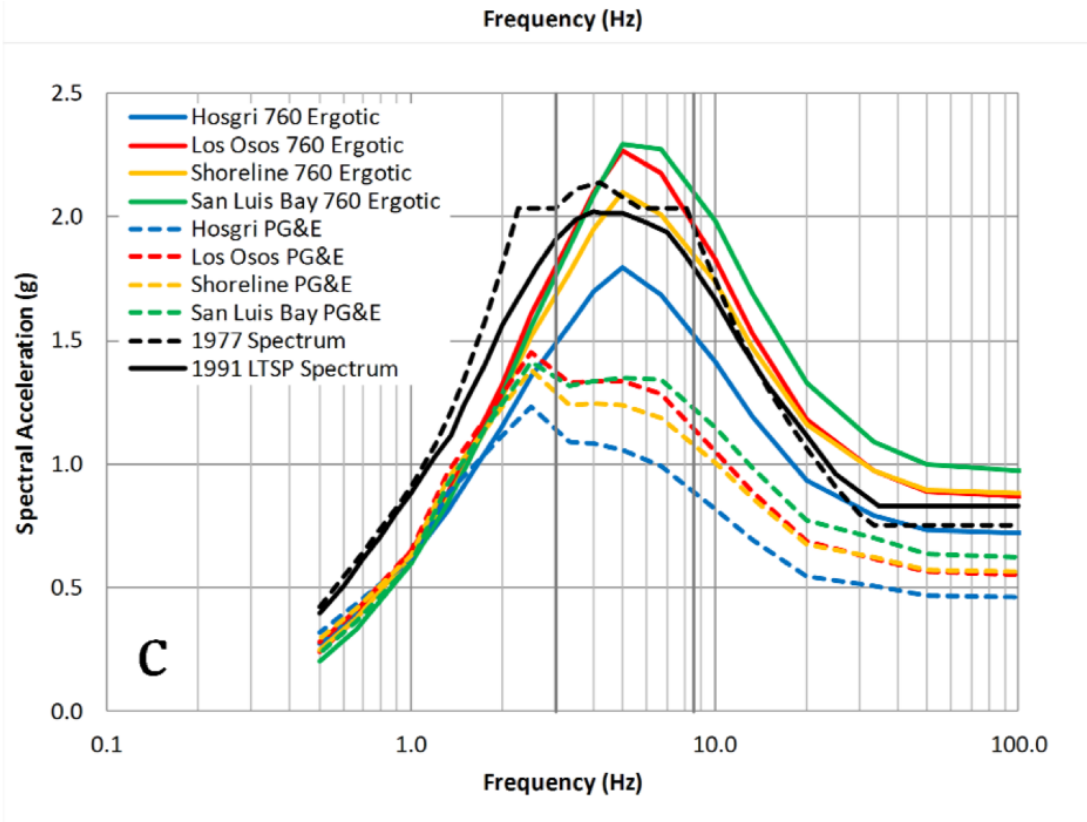


Figure 7. Continued.

(Figure 7c. from IPRP Report)

This sensitivity analysis shows that the cumulative effect of less-conservative fast rock velocities along with less-conservative GMPEs is clearly not a small issue, nor is it a only an academic issue. The IPRP reviewed the limited wellbore data (see IPRP Report 6 Figure 4) and concluded that the wellbore velocities appeared to be lower than those estimated by PG&E, which could result in the conclusion that PG&E has underestimated shaking from new seismic threats even if the new equations are allowed. The IPRP challenged PG&E's use of wellbore data at the ISFSI site to justify the higher 1,200 m/s velocity and instead focused on the velocities measured in the wellbore data closest to the facility.

Specifically, IPRP Report #6 says,

> "Consider the three usable measured profiles, A-2, C, and D, the mean value at 10 m is approximately 800m/s, considerably below PG&E's mean of 1200m/s." and "If A-2 had the same velocity as C at a depth of 5m, consistent with the relative weathering described in the borehole logs, the mean velocity at that depth would be about 650m/s, also below PG&E's mean value of 1000m/s."

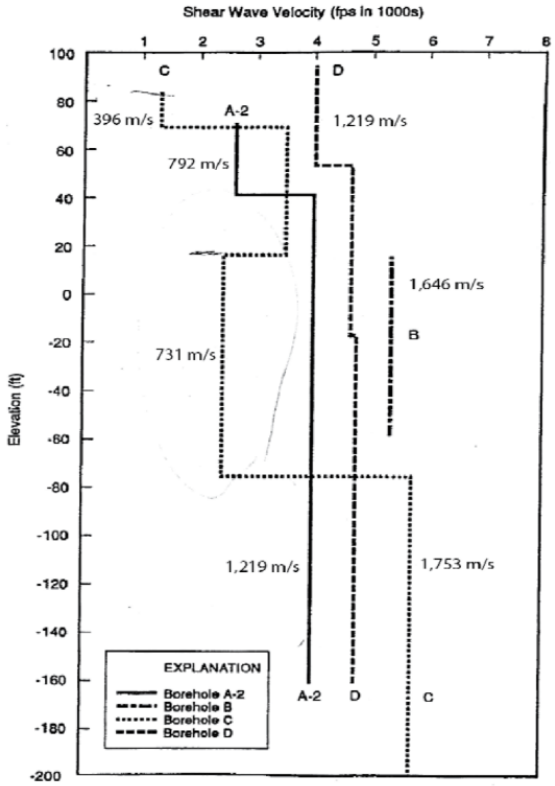


Figure 4. Shear wave velocity profiles from 1978 downhole velocity surveys (provided by PG&E).

IPRP Report 6, Page 5

This appendix does not seek to weigh in on the question of which velocities are appropriate to use when computing site effects at Diablo. Instead, these stated concerns are intended to demonstrate that:

> First, the de-amplification effects of moving from GMPE-1 to GMPE-4 are very large and likely determinative of whether or not the new seismic threats would produce shaking above the HE exception; and
>
> Second, even if one were to accept the use of GMPE-4, which is problematic for the reasons previously stated, the critically important rock velocities upon which the de-amplification factors are based are complex, in dispute, and arguably lower than those used by PG&E, which would mean that shaking would be significantly larger than stated in the Report. Indeed, a conservative approach toward this technical question would have used of the lowest velocities found in the well data rather than the highest.

[i] Peck Differing Professional Opinion – Diablo Canyon Seismic Issues
[ii] Opinion of Commissioners Gilinsky and Bradford on Commission Review of ALAB-644 (Diablo Canyon Proceeding, Dockets 50-275 OL and 50-323 OL)
[iii] Safety Evaluation Report related to the operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2. Docket Nos. 50-275 and 50-323; NUREG-0675, Supplement No. 34
[iv] PG&E submitted to the NRC "Report on the Analysis of the Shoreline Fault, Central Coast California, January, 7, 2011, ML 110140400
[v] Oct 12, 2012 NRC letter from Joseph M. Sebrosky, Senior Project Manager to Mr. Edward D. Halpin, Senior Vice President and Chief Nuclear Officer PG&E; Subject: Diablo Canyon Power Plant, Units Nos. 1 and 2 – NRC Review of Shoreline Fault
[vi] Office of the Inspector General US NRC: NRC Oversight of Licensee's Use of 10 CFR 50.59 Process to Replace SONGS' Steam Generators Case No. 13-006
[vii] Research Information Letter 09-001: Preliminary Deterministic Analysis of Seismic Hazard at Diablo Canyon Nuclear Power Plant from Newly Identified "Shoreline Fault." Pages 8-10.
[viii] U.S. Nuclear Regulatory Commission, 2012. Confirmatory Analysis of Seismic hazard at the Diablo Canyon Power Plant from the Shoreline Fault, Research Information Letter.
[x] Oct 12, 2012 NRC letter from Joseph M. Sebrosky, Senior Project Manager to Mr. Edward D. Halpin, Senior Vice President and Chief Nuclear Officer PG&E; Subject: Diablo Canyon Power Plant, Units Nos. 1 and 2 – NRC Review of Shoreline Fault
[xi] NRC Research Information Letter 12-01, page 56 (September 2012)
[xii] Shakal, A., Grazier, V., Huang, M., Borcherdt, R., Haddadi, H., Lin, K., Stephens, C., and Roffers, P.: Preliminary Analysis of Strong-Motion Recordings from 28 September 2004 Parkfield, California Earthquake. Submitted to SRL November 5, 2004
[xiii] IPRP Report No. 6, August 12, 2013

Statement of
Daniel Hirsch[1]

Before the
Committee on Environment and Public Works

Oversight Hearing
NRC's Implementation of the Fukushima Near-Term Task Force Recommendations and Other Actions to Maintain and Enhance Nuclear Safety

Washington, D.C.
December 3, 2014

Chairman Boxer, Ranking Member Vitter, and Members of the Committee,

Thank you for your invitation to appear before you today to address this critical matter.

The disaster at the Fukushima Daiichi reactors in 2011 had many causes, but at its core were two fundamental and inter-connected problems: a nuclear plant allowed to be designed, licensed, and constructed to only withstand an earthquake and tsunami far smaller than actually occurred; and a too-cozy relationship between the nuclear utility and its regulator that allowed weak safety requirements in the first place.

These problems plague the American nuclear regulatory system as well. My testimony will focus on an examination of one case study – Diablo Canyon – that suggests the Fukushima lessons have not been learned here. This is particularly important in light of the extraordinary and disturbing new seismic discoveries near the site and the inadequate response to them by the Nuclear Regulatory Commission. Unless the underlying dysfunctional nature of nuclear regulation in this country rapidly undergoes sweeping reform, a Fukushima-type disaster, or worse, may occur here, perhaps on the Central California coast.

The late environmentalist David Brower once defined a nuclear reactor as a complex technological device for locating earthquake faults in California. It seems that wherever a reactor was planned or built, earthquake faults were subsequently found, greater than the plant had been designed to withstand.

Arguably, Brower's definition applies nowhere better than Diablo Canyon. When Diablo was designed and granted its Construction Permit, PG&E and the Commission *asserted there were no active faults within thirty kilometers of the plant.* **We now know there are at least four.**

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[1] Lecturer at the University of California, Santa Cruz, teaching nuclear policy, and former Director of the Stevenson Program on Nuclear Policy there. The views presented today are his own and not necessarily those of the University of California. Mr. Hirsch also serves as President of the Committee to Bridge the Gap, a 44-year-old non-governmental organization addressing nuclear policy matters.

Each time there was a new, belated seismic discovery at Diablo, the Commission gave PG&E a pass. Rules were relaxed, safety margins reduced, public hearings denied. The most recent revelations of increased seismic risk have met the same fate to date.

When the Hosgri Fault was revealed shortly after the construction permit had been granted, NRC waived the normal requirements of the license and granted an exception for the Hosgri. It did so assuring the public that the Hosgri was not connected to the nearby San Simeon Fault and that it was essentially impossible that there were any other nearby active faults waiting to be discovered.

A few years later, however, the San Luis Bay and Los Osos faults were found to be active nearby. And in 2008, USGS discovered the Shoreline Fault, coming within 600 meters of the plant. Faced with these embarrassing revelations, NRC and PG&E nonetheless asserted that these new faults were well within the license requirements.

However, the NRC's own senior resident inspector at Diablo, Dr. Michael Peck, soon discovered from PG&E's own estimates that the ground motion from those three new faults would exceed the ground motion permitted under the license. Rather than upgrade the plant, PG&E, at NRC urging, submitted a license amendment request to remove the license conditions they were violating. But the request failed to conform to NRC requirements in scores of instances, and was rejected from consideration. Rather than now require the plant to meet the license, however, NRC allowed it to keep operating in violation of the central seismic requirements.

Dr. Peck took the extraordinary step of submitting a Dissenting Professional Opinion, saying the plant should be shut down until it can demonstrate compliance with the license. After sitting on the DPO for a year, and only after the Associated Press had made its existence public, on September 10 of this year NRC issued its rejection. The DPO denial was neither unexpected nor persuasive.

But here is where the story gets most troubling, with developments essentially not reported to the public until today. On the very same day NRC issued to the news media its DPO denial, PG&E released its long-awaited new seismic study that had been required by the state. To no surprise, it received virtually no coverage, lost in the attention given to the NRC action.

Nonetheless, it is a stunning document. Buried in its more than 1800 pages are the following extraordinary findings:

- Despite longstanding claims that the Hosgri Fault is only 110 kilometers long and not connected to the San Simeon Fault, it is in fact connected, and a joint rupture is therefore possible; and the true length is at least 171 kilometers.
- The Shoreline Fault, which wasn't even known to exist a few years ago, is twice as long as previously thought.
- The Shoreline Fault also connects to the Hosgri, making possible a huge earthquake on both, coming within 600 meters of the plant.

- Despite the repeated claims by PG&E and NRC that the Hosgri Fault is the largest threat to Diablo, the new report estimates ground motions from the Shoreline and San Luis Bay Faults, and the San Simeon-Hosgri and Shoreline-Hosgri connected faults, all in excess of what would now be estimated for the Hosgri Fault alone.
- All of these are estimated to produce ground motion in excess of the Double Design Earthquake requirements in the license that apply to all faults except the Hosgri single fault.

It is *déjà vu* all over again. The PG&E and NRC response has been an almost exact repeat of the pattern evidenced from the beginning of the plant: discoveries of new seismic threats that had been claimed couldn't be possible; responding by sharpening pencils, to try to allow the plant to continue in the face of the new discoveries by removing the last remaining vestiges of conservatism in assumptions and reducing safety margins thereby; and avoiding public hearings where the discoveries and response thereto would be subject to serious scrutiny.

In this case, although the faults are longer, larger, more connected, and closer than previously assumed, PG&E and NRC have remarkably claimed that the seismic challenge to the plant would be lower. They have done so by applying dramatically weakened input assumptions, not allowed under the license and not subject to scrutiny in an evidentiary license hearing.

When the first nearby fault that wasn't supposed to be there was discovered, the Hosgri, the NRC gave PG&E an exception from the seismic conditions of its license that applied to all other faults. When the second, third, and now fourth active faults were discovered, after assurances they couldn't be there, the NRC has again in effect given further exceptions. And it has done so without license amendments and the right to a public hearing that the Atomic Energy Act requires.

As we have seen in the recent San Onofre matter, this pattern is endemic. The resistance to allowing adjudicatory hearings that would permit enhanced independent scrutiny and instead relying on backroom deals between the regulator and the regulated entity result in technically deficient safety decisions. In the Diablo case, the decisions have turned out to be erroneous, over and over again. And yet the pattern is repeated, over and over again. How many times do they get to be wrong before something changes?

If this dysfunctional regulatory system were responsible for relatively minor matters like, say, siting fast-food restaurants, the potential consequences would be marginal. But there are a thousand times the long-lived radioactivity of the Hiroshima bomb in each Diablo reactor, and approximately ten times that in its irradiated fuel pools. An earthquake larger than the plant is capable of withstanding can disrupt the essential cooling, causing massive release of radioactivity.

Unless we fix these problems—of regulated entities pressing for exceptions to and weakening of safety requirements and of regulators viewing themselves more as advocates for and allies of the industry they are to regulate rather than primarily protectors of public safety—we will not have learned the lessons of Fukushima. And a Fukushima-type disaster is just

waiting to occur here. All it takes is an earthquake larger than a plant like Diablo is capable of withstanding. It could happen tomorrow.

I explore these matters in more detail in what follows.

The Fukushima Lessons

The Japanese Diet passed legislation in October 2011 establishing the Fukushima Nuclear Accident Investigation Commission. The Fukushima Commission found:

> The direct causes of the accident were all foreseeable prior to March 11, 2011. But the Fukushima Daiichi Nuclear Power Plant was incapable of withstanding the earthquake and tsunami that hit on that day. The operator (TEPCO), the regulatory bodies (NISA and NSC) and the government body promoting the nuclear power industry (METI), all failed to correctly develop the most basic safety requirements....

The Fukushima Commission found that the accident was clearly "manmade" and preventable:

> The TEPCO Fukushima Nuclear Power Plant accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly "manmade." We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues relating to the competency of any specific individual.

They concluded that "The underlying issue is the social structure that results in 'regulatory capture,'" and that industry had "manipulated the cozy relationship with the regulators to take the teeth out of regulations." The nuclear industry must change, they said, and:

> The Commission has concluded that the safety of nuclear energy in Japan and the public cannot be assured unless the regulators go through an essential transformation process. The entire organization needs to be transformed, not as a formality but in a substantial way.

One could just as correctly make these diagnoses and prescriptions about the troubled U.S. nuclear power enterprise. These Fukushima "lessons learned" apply directly here as well. After all, the Fukushima accident involved American-designed reactors and a regulatory structure markedly similar to ours. The two fundamental problems at the heart of the Fukushima tragedy plague the American system as well: regulatory capture, resulting in weak regulations and enforcement, and the concomitant regulatory fiction of allowing reactors to be designed to only withstand challenges far less severe than they could actually face. We do not appear to have learned those lessons or in any serious way taken steps to repair the broken nuclear regulatory process here so as to avoid a Fukushima or worse occurring in this country.

Diablo Canyon as Case Study: A Potential Fukushima on the California Coast?

In my testimony today I will examine one case study, that of the Diablo Canyon Nuclear Plant in California.[2] The similarity of the Diablo history to the institutional problems that led to Fukushima are striking.

Each of the two Diablo reactors contains, when operating, about fifteen billion curies of radioactivity. To put that in perspective, we generally measure "permissible" concentrations of radioactivity in the environment in pico-curies, millionths of a millionth of a curie.[i] All told, many Chernobyls-worth of long-lived radioactivity reside at Diablo Canyon, in the heart of a seismically active region.

If a significant portion of that radioactivity were to be released to the environment, widespread damage could result--at high doses, close in, prompt death if there hasn't been effective and timely evacuation; at lesser doses, over wide areas, significantly increased rates of cancer and leukemia. Land can be contaminated for long periods of time, forcing relocation of people and cessation of activities such as agriculture. A major release of radioactivity in central California could be devastating.

The radioactivity only stays inside the fuel so long as it is continuously cooled. An atomic reactor is an extraordinary device. It cannot be turned off completely. Even after being "scrammed" (control rods inserted to stop the fissioning), a substantial amount of heat (initially about 7% of the amount when running) is still generated by decay of the fission products. Thus the fuel can, for weeks or months after the reactor is scrammed, melt and release its radioactivity if cooling is lost. An earthquake can trigger such a loss of cooling—e.g., by disrupting offsite power and onsite diesel generators, and/or breaching pipes or damaging pumps needed to circulate the coolant-- as well as the failure of backup systems and mitigation features.

The "Design Basis" Fiction

One would think that reactors would be required to be designed and constructed to safely withstand the greatest challenge (earthquake, terrorism, etc.) they could face. One would be wrong.

From the earliest days of the industry to the present, reactors have only been required to deal with a "design basis" event, which is often far less severe than the maximum challenge they could in fact experience. For example, reactor containments are only required to be designed to withstand the pressure from a break in a main pipe, not the pressures that could be generated from a meltdown. To save money, for instance, Mark I Boiling Water Reactor containments had been allowed to be very small, with backup pressure-reducing systems that could be quickly overwhelmed in a real accident. At Fukushima, the Mark I containments, based on the General Electric design, indeed failed to prevent massive release of radioactivity. U.S. pressurized water reactors (PWRs) likewise are not required to be designed to withstand pressures resulting from events involving major core damage. Recommendations to establish Containment Performance Design Objectives that would improve the situation went nowhere.[ii]

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[2] The research assistance of Cristine Peterson and Dorah Shuey is gratefully acknowledged.

Similarly, the "design basis threat" (DBT) regulations for establishing security provisions at reactors against a terrorist attack long required only protecting against a maximum of three external attackers, on foot, acting as a single team. In the Diablo Canyon operating license proceeding in the 1980s, experts appearing on behalf of Governor Jerry Brown testified that the security plan should be able to protect against a group of at least twelve attackers. PG&E and NRC argued that it wasn't "credible" there would ever be a terrorist attack in this country involving that many people and the design basis threat of three was sufficient.[iii] Of course, on 9/11, there were nineteen attackers, in four separate teams, and they weren't on foot. But the NRC's design basis threat regulations have only been modestly upgraded since, and proposals to increase the DBT to meet a 9/11-level threat have been rejected by NRC.[iv]

For years, evacuation plans were not required for areas surrounding nuclear plants, and environmental reviews did not have to consider accidents involving major releases of radioactivity, because the NRC had declared that Class IX accidents (those involving major core damage) were, in that remarkable phrase used so often, "non-credible." Then major core damage occurred at Three Mile Island, and the Governor of Pennsylvania, on the advice of the NRC, recommended an evacuation of pregnant women and children. The NRC had to admit Class IX accidents could in fact happen and change some of its regulations accordingly, though this was done grudgingly and in a limited fashion.

As seen from the above examples, the nuclear industry and compliant regulators have frequently decided, short-sightedly one must conclude, that it is cheaper to declare by fiat that serious safety or security challenges to nuclear plants are "non-credible" and don't need to be protected against, than to require that the atomic facilities be designed up front to handle the threats that can indeed occur. Over and over again, reality has risen up and bitten industry and regulator on the heels; optimistic assumptions dissolve when the "non-credible" ends up happening.

The Seismic Design Basis Fiction

For earthquakes, the design basis has been two-fold: a "Design Earthquake" or DE (now called the Operating Basis Earthquake, or OBE) and a "Double Design Earthquake" or DDE (now called the Safe Shutdown Earthquake). The first earthquake is the one that the reactor should be designed to be able to ride out without needing to shut down. The second, more serious earthquake is one in the face of which the reactor should be capable of safely shutting down and maintaining cooling and other safety functions thereafter. Despite definitions that indicate the safe shutdown earthquake is the maximum one deemed possible at the site, in practice, industry has pressed for and NRC granted approval for reactors to be designed to only withstand earthquakes and similar natural hazards such as tsunamis and floods far smaller than could indeed occur.

That is what happened at Fukushima. TEPCO and its regulators engaged in a regulatory fiction, establishing the design basis earthquakes (and ensuing tsunami) as considerably less than what turned out to be possible. It is expensive to design against these large challenges. The company instead pressed for, and the regulator acquiesced to, requiring the facility to be designed to a fictional earthquake and tsunami that were far less severe than could actually occur. It was this cutting of corners, in terms of safety, that produced the disaster at Fukushima. Nature

did not go along with the regulatory fiction. It is a similar regulatory pattern that has been evidenced in the long, troubled history of Diablo Canyon and its seismic design.

Nuclear Reactors: Complex Technological Devices for Locating Earthquake Faults in California

As indicated earlier, the late environmentalist David Brower once defined a nuclear reactor as a complex technological device for locating earthquake faults in California. Over and over again, nuclear plants have been planned and/or constructed in the state, only to be followed by the discovery of major faults nearby. These belated seismic discoveries led to the closure of PG&E's Humboldt Bay plant and General Electric's Vallecitos reactor and the abandonment of plans by the LA Department of Water and Power for an atomic power plant at Corral Canyon in Malibu and by PG&E at Bodega Head. Discovery of additional seismic hazard at San Onofre contributed to Unit 1's premature shutdown and cast a cloud over operations of Units 2 and 3, resolved only with their permanent closure last year, albeit for different reasons. For our purposes, however, let us look briefly at the track record of PG&E and the Commission leading up to the Diablo situation.

When PG&E applied in the early 1960s for permission for a nuclear plant at Humboldt Bay, it asserted that the nearby Little Salmon fault was not active and its presence need not be taken into account in designing the plant. In the early 1970s, however, oil company geologists doing studies in the area discovered that the fault was indeed active. (As we shall see, this pattern repeated itself at about the same time with Diablo Canyon.) Rather than upgrade the plant to meet the newly acknowledged seismic threat, it was permanently closed.[v]

In the early 1960s, PG&E applied to construct a nuclear plant at Bodega Head, a bit north of San Francisco. PG&E asserted that there were no serious seismic risks, despite being quite close to the San Andreas Fault, and in particular, that the plant would not be located over an active fault. The firm proceeded to dig a massive hole for the reactor containment foundation, which became known as the "Hole in the Head." Pierre Saint-Armand, a geophysicist at the China Lake naval base volunteered to help the community group concerned about the planned reactor. One weekend, when the excavation was unguarded, he crawled down a ladder into and examined the Hole in the Head and found an earthquake fault exposed therein. In other words, there was a fault directly below where PG&E was planning to construct a nuclear plant.[vi] His revelation led to the abandonment of the plant, and, ironically, PG&E turning its attention southward to Diablo Canyon as a prospective site.

Thus, PG&E and the Nuclear Regulatory Commission had two strikes against them already leading into the Diablo Canyon matter: Humboldt Bay and Bodega Head. In both cases, PG&E had claimed to have done thorough seismic evaluations beforehand; in both cases, someone other than PG&E or the regulator had subsequently revealed active faults nearby or indeed, at Bodega, directly beneath where the plant was to go. Both had to be abandoned.

Diablo Canyon: Hearing Denied on Possible Nearby Faults

Arguably, Brower's definition applies nowhere better than Diablo Canyon. When Diablo was designed and it obtained its Construction Permit, PG&E and the Atomic Energy

Commission asserted there were *no* active faults within thirty kilometers of the plant.[vii] We now know there are at least four major active faults nearby.

During the proceeding over PG&E's construction permit application for Diablo Canyon Unit 2 in 1970, the local intervenor in the hearing, the Scenic Shoreline Preservation Conference, requested a half day to present evidence of potential previously unidentified faults. PG&E and the Atomic Energy Commission staff opposed allowing any such evidence to be heard. By a two to one vote, the Atomic Safety and Licensing Board (ASLB) ruled with PG&E and the AEC staff and refused the request. The third ASLB member, Dr. Tom Pigford, who was for many years Chair of Nuclear Engineering at the University of California, Berkeley, vigorously dissented, saying in essence, shouldn't we find out before we pour concrete whether there are nearby earthquake faults? His concerns were overridden, the evidence of additional faults was not considered, and the construction permit was granted.[viii]

The plant was thus permitted and designed based on the premise put forward by PG&E and the AEC staff that there were no active faults within thirty kilometers.[ix] The Design Earthquake/Operating Basis Earthquake was set at 0.2 g peak ground acceleration. The Double Design Earthquake/Safe Shutdown Earthquake was set at double the DE/OBE, or 0.4 g.

Hosgri Fault Belatedly Discovered

The Construction Permit for Diablo Unit 2 was issued in December 1970, predicated on no active faults anywhere in the vicinity. Shortly thereafter, in 1971, the discovery of a massive offshore fault, the Hosgri, by two Shell Oil geologists, Hoskins and Griffiths, was published. By the time PG&E acknowledged the existence of the fault and NRC began to consider the ramifications, several years passed and the plant was already 80% constructed. The Construction Permit proceedings were not reopened to address the new discovery, something NRC Commissioners Victor Gilinsky and Peter Bradford more than a decade later stated was a mistake:[x]

> No hearings were held when the Hosgri fault was discovered. The persistence of litigation over these issues to this day suggests that it would have been wise policy, as well as good law, to reopen the construction permit at that time.

The U.S. Geological Survey estimated the Hosgri was capable of a 7.5 magnitude earthquake. It was clear that such an earthquake could produce ground motion considerably in excess of that for which the plant was designed. The staff of the Nuclear Regulatory Commission (which had, by this time, been formed after Congress broke up the AEC due to concerns about the conflict of interest in both being a regulator and advocate of nuclear power) urged that senior management attempt to pressure USGS to back off its estimate.[xi] USGS remained adamant.

Rather than abandon the plant because of the failure to characterize adequately the nearby seismic situation prior to construction, or undertake subsequent very expensive upgrades, PG&E reanalyzed the design using far less conservative (i.e., less protective) assumptions and argued that the plant could go forward without significant upgrades. PG&E did this by carving out

significant conservatisms from the seismic analysis that had been performed when the plant was designed, markedly reducing safety margins.

Pencil Sharpening Rather Than Significant Plant Upgrade

The central issue is translating earthquake magnitude and distance into acceleration (essentially the severity of shaking) at the plant. USGS recommended relying on its Circular 672, which estimated 1.15g peak acceleration for a M7.5 earthquake.[xii] If Diablo had to be retrofitted to withstand 1.15g peak acceleration, it is unclear that the facility could be upgraded to meet that requirement; in any case, the cost would be very high. Instead, PG&E, with NRC support, sharpened pencils and, by use of at least four modifications to normal practice at the time, dramatically reduced—alas, only on paper—the presumed ground motion that the plant should have to be retrofitted to withstand.

First, the NRC staff and PG&E argued that rather than use actual peak acceleration, they should use "effective" acceleration, i.e., employ a far lower value. They proposed 0.75 g, instead of 1.15 g, a large reduction. The "effective" acceleration figure of 0.75 g appeared arbitrary even to the Atomic Safety and Licensing Appeal Board which stated, "It is not entirely clear how the anchor point acceleration of 0.75g ultimately settled upon for the basic response spectrum was actually obtained."[xiii] Nonetheless, the Appeal Board upheld this and all the other reductions.

So, the first step taken by NRC staff and PG&E was to reduce the peak acceleration dramatically by putting forward a far smaller "effective" acceleration. They then reduced it even further by assuming a less conservative damping factor than had been used in the seismic design basis for the plant during construction (i.e., the methodology used for the DE and DDE). This second modification further reduced estimated acceleration and safety margins.

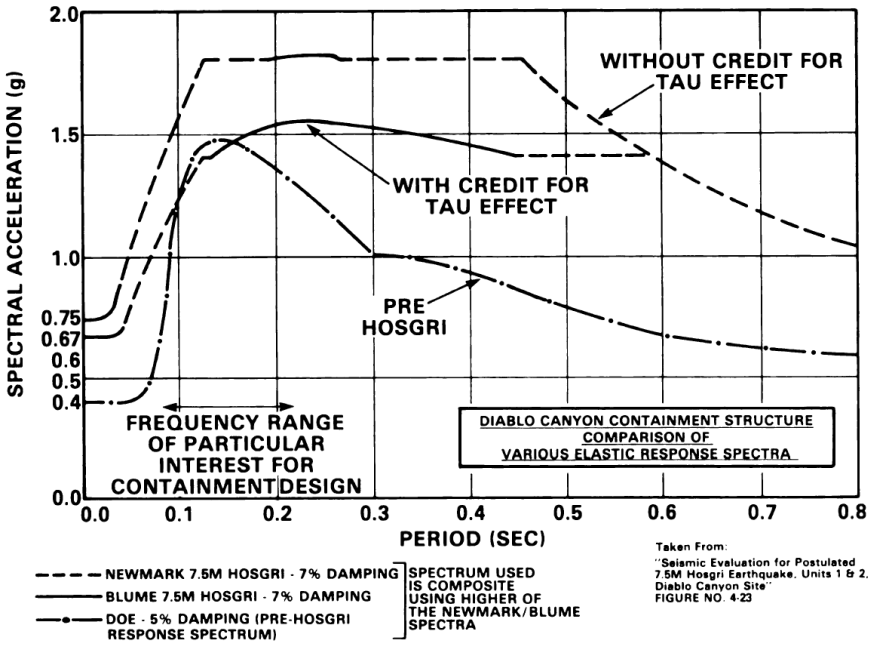
Third, PG&E proposed, and NRC allowed, the use of average estimates of as-built strength for components instead of code-allowable strengths, as normally required. This further reduced safety margins.

And finally, and most controversially, PG&E and NRC proposed a new reduction factor, never used before in nuclear licensing, which they called the "tau effect." They argued that peak acceleration should be reduced not just by their far smaller estimate of "effective" acceleration, weakened further by a less conservative damping factor, and relaxed further by use of average as-built strengths rather than code-allowable, but on top of all those reductions, one should further reduce significantly the acceleration by what was widely viewed as an arbitrary never-before-used fudge factor they called "tau." Their analogy was that a large ship is tossed about in the sea less than a small one, and therefore the reactor structures should be assumed to react less to an earthquake than normal structures. The "tau" factor thus resulted in about a 20% further reduction in presumed acceleration, on top of all of the other reductions.[xiv]

When added together, these cumulative relaxations of normal procedures for estimating ground motion from a large earthquake resulted in the new, far larger challenge to Diablo from the Hosgri Fault being estimated to produce little more acceleration than the far smaller quakes for which the plant was originally designed. For some frequencies of interest, indeed, the

estimated acceleration from the lesser quakes was in fact greater than that now estimated for the far more dangerous Hosgri event, because of the use of so many new non-conservative assumptions for the Hosgri analysis. As NRC Commissioners Victor Gilinksy and Peter Bradford noted in their opinion on the matter:[xv]

> With the changes and adjustments permitted by the [Atomic Safety and Licensing Appeal] Board it turns out that the post-Hosgri seismic response spectrum does not in all respects represent a more severe seismic standard than the one used before the discovery of the Hosgri fault. As the accompanying diagram illustrates, in the frequency range between 5 and 10 hertz (cycles per second), a range of particular interest in the analysis of the containment building surrounding the reactor, the two response spectra are quite close. [footnote omitted] For part of this range, in fact, the old spectrum shows a <u>higher</u> response. In other words, for that part of the range the original design conditions were <u>more</u> demanding than the new ones imposed after the discovery of the Hosgri fault. This new spectrum is the basis of the engineering reanalysis and ultimately determined the extent to which the containment was to be modified. Not surprisingly, in view of the above, only minor changes were required in this area.
>
> (emphasis in original)



As the above graph taken from the Opinion of Commissioners Gilinsky and Bradford shows, the use of the "tau factor" permitted PG&E to presume far less acceleration from a Hosgri earthquake than would normally be presumed, and thus avoid having to do much upgrade at all of Diablo to deal with the far greater threat to the plant posed by the Hosgri compared to

the earthquake threat for which the plant was originally designed. The reduction resulting from the use of the tau factor, less conservative damping factors, etc. is so large that, in the frequency of concern for key structures, there is little difference between the assumed threat by the larger, closer Hosgri and the earlier lesser seismic challenge on which design was predicated. Indeed, at some frequencies, the old design requirements for the lesser earthquakes are greater than those for the far larger, new Hosgri.

Note that the graph only shows the large difference created by the use of the tau effect and the less conservative damping factors. Compare the dashed lines, which are presumed ground motion after having been reduced by the tau effect and the new protective damping assumptions, with the DDE line based on the pre-Hosgri input assumptions required by the existing permit. When the other factors are taken into account – the huge reduction of actual peak acceleration by instead assuming a far smaller "effective acceleration" and the use of average presumed as-built strengths instead of the normal requirement to assume code-tolerance strengths – the actual challenges to the structure could literally be off the chart, i.e., the challenge to the plant could be higher than the graph goes.[3]

In any case, these modifications, or fudge factors, depending on one's perspective, resulted in the extraordinary result that little upgrade to the plant ended up being required by NRC despite a vastly larger earthquake challenge quite close to the facility now being known to be possible. Indeed, because of the less conservative input assumptions, in some circumstances, the reductions were so large that the Hosgri was claimed to produce less risk than the far smaller quakes upon which the plant design had been originally based.

The Commission Refuses to Review; Commissioners Gilinsky and Bradford Dissent

The local community group that was the intervenor in the operating license proceeding, Mothers for Peace, and subsequently Governor Jerry Brown when he entered the case on behalf of the state, challenged these reductions in ground acceleration estimates. The Atomic Safety and Licensing Board ruled down the line for PG&E and the NRC Staff, as did the Atomic Safety and Licensing Appeal Board. The majority on the Commission itself did not agree to even undertake review of the rulings. Commissioners Gilinsky and Bradford issued a stinging opinion, faulting the Commission for not undertaking review and criticizing the Appeal Board's decision.

As they put it in their opinion, the central issue was what to do regarding the "discovery of the nearby Hosgri fault, which had not been taken into account in the original design of the plant." They said:

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[3] Peak acceleration is "anchored" at 100Hz (essentially the vertical axis on the left in the Bradford-Gilinsky graph above), and then a response spectrum in constructed from that axis for other frequencies that are of interest for the seismic response of various kinds and elevations of structures. In the graph, the frequencies of special interest for containment design are marked, and for those, the Hosgri acceleration, modified by tau and other reductions, is not much different and in some cases lower than that presumed under the pre-Hosgri DDE for a smaller/further away earthquake.

> Since the plant was in large part already constructed at this point, the reanalysis and redesign understandably did not proceed as they would have in a plant yet to be built. Every advantage was taken of slack in safety margins left in the pre-Hosgri analysis, both in developing the response spectrum and in its application. To cite a couple of examples: a larger damping value was used in analyzing structures (7 percent instead of the earlier 5 percent), which reduced the effect of ground vibrations on the structures. At the same time, credit was taken for the actual – "as-built" -- strengths of materials (rather than the minimum required strengths, as is the usual practice) so that larger vibrations became tolerable....The point is that these further relaxations come on top of a redesign that has already shaved safety margins...."

They continued, "on top of all this trimming, the Board permitted a further substantial reduction, more-or-less across the board, in the response spectrum," by allowing the use of the so-called "tau effect," which they say reduced the acceleration response spectrum "by about 20 percent over the frequencies of interest." In accepting with virtually no basis the value proposed for the "tau effect," they say, the "Licensing Board's justification sounds almost mystical." They similarly criticize the Appeal Board's acceptance of the proposed tau factor, saying what isn't clear "is whether either Board had any idea what it was talking about." The tau value that was put forward, the Commissioners wrote, "is merely conjecture." They said, "The fact is that the tau effect has not been used in any other nuclear plant analysis. To our knowledge, it has not been used in the design of any other large building."

Commissioners Gilinsky and Bradford concluded, "Altogether, we cannot escape the impression that the Commission is declining review not because the opinion is essentially sound, but because it is unsound and the prospect of reviewing it is so unsettling."

Had there been one more vote on the Commission to review the Diablo matter, the present situation might not face us. But in the absence of Commission review, the approval of the operating licensing by the licensing board and the appeal board stood, and Diablo was allowed to commence operations without the significant upgrades that would have been required had the NRC not allowed the safety margins to be so dramatically eroded by use of these various reductions factors.

Upgrades Done Backwards, Erroneously Using Mirror-Image Blueprints

But the problems did not end at that point. Although PG&E was not required to do the full range of upgrades that would have been required without the use of the relaxed assumptions allowed, it still had to do some. And those it got astonishingly wrong.

The two Diablo units were built to mirror image blueprints of each other. When it came to making the modifications required, however, PG&E used the wrong set of blueprints for one of the units, i.e., the mirror-image blueprints for the other unit. It thus put the pipe supports and whip restraints and other upgrades in the wrong places. The error was revealed only a few days (!) after NRC had issued PG&E an operating license for low power testing, in part based on findings of adequate quality assurance controls. When the error was discovered, NRC had to

temporarily suspend the license, and PG&E had to go back and do the seismic retrofits all over again.

These errors—failing to do sufficient seismic characterization to identify the Hosgri before construction, and failing to have adequate quality assurance controls, resulting in putting the upgrades in the wrong locations due to use of the wrong blueprints—contributed to a plant that was supposed to cost $320 million ending up with more than a $5 billion cost overrun, much of which was passed on to the ratepayers.[xvi]

Errors Continue; New Seismic Discoveries Continue to Erupt, Disproving Past Claims

1. Los Osos and San Luis Bay Faults Found to Be Active Nearby Faults

Despite the embarrassment of not identifying or disclosing the Hosgri Fault before construction and the use of the wrong blueprints for the upgrades, PG&E and NRC assured the public that there were no other likely seismic problems yet to be addressed. PG&E and NRC staff all asserted, and the licensing board expressly ruled in the operating license proceeding, for example, that the Hosgri Fault was not connected to the San Simeon fault. If there were such a connection, there could be a larger quake, but they were sure there was no such link. PG&E and NRC staff also claimed, and the board so ruled, that there was essentially no chance that there were other active faults not yet discovered.[xvii]

A few years later, however, in its Long Term Seismic Program (LTSP), PG&E admitted there were at least two other active faults near the plant not previously identified in their original site characterization, the San Luis Bay and Los Osos Faults. These would turn out worrisome, as we shall see, because the subsequent estimates of ground motions possible from those new faults exceeded the limits in the license

2. Shoreline Fault Discovered

More than a decade after the LTSP, in 2008, USGS identified another new large active fault, this one the Shoreline Fault, coming within 300 meters of the plant intake and 600 meters from the reactor itself. This was deeply troubling, because its proximity to Diablo could result in an earthquake quite challenging for the plant to withstand. We were now up to four nearby active faults, whereas PG&E and the AEC had asserted at the time of the Construction Permit that there were none.

3. PG&E Analyses of Ground Motion from Shoreline, San Luis Bay, and Los Osos Faults Exceed the Double Design Earthquake/Safe Shutdown Earthquake in the Licensing Basis

In its subsequent Shoreline analyses, PG&E estimated ground motions for the Shoreline, San Luis Bay, and Los Osos Faults. PG&E asserted that these ground motions were below those spelled out as part of the license. However, Dr. Michael Peck, the NRC's Senior Resident Inspect at Diablo, noticed that in fact PG&E's ground motion estimates for these three faults all exceeded the DDE/SSE in the license. One will recall that the DDE/SSE is set at 0.4 g. To the extent that the Hosgri Exception was part of the licensing basis – and there appears question

whether it made its way into the license at all—it was an exception to the DDE/SSE and only applied to the Hosgri Fault. (PG&E took the position that the DDE of 0.4 g was the SSE and the Hosgri was not part of the SSE.[xviii])

PG&E estimated in its Shoreline analysis that the Shoreline Fault was capable of producing 0.62 g of ground motion, compared to the 0.4 g limit for the DDE/SSE. The Los Osos Fault was estimated as producing 0.60, also in excess of the 0.4 g limit. And the San Luis Bay Fault was estimated as producing 0.70 g, far above the 0.4 g level.

Dr. Peck pointed out that by PG&E's own estimates, these three new faults exceeded the DDE/SSE in the license. PG&E had two choices, he told them: come into compliance with the license by evaluating the capability of all the plant's safety components to withstand the higher levels of shaking and upgrading those that can't, or amend the license to remove the requirement they were violating.

License Amendment Sought, Then Withdrawn

PG&E chose the latter course. Rather than bring the plant into compliance with its license, it proposed amending the license so as to eliminate the provisions they weren't meeting.[xix] In particular, it proposed changing the Safe Shutdown Earthquake to be the Hosgri, with its far weaker assumptions and methodologies. The Hosgri exception would become the rule. The Shoreline, rather than have to meet the DDE/SSE, would be considered an "included case" of the far more lax Hosgri exception.

NRC staff requested PG&E provide a comparison table showing any deviations between the methodologies and acceptance criteria proposed in the license amendment request and NRC's Standard Review Plan. The subsequently provided comparison tables went on for hundreds of pages, identifying a vast number of deviations from NRC current requirements.[xx]

NRC concluded it could not accept the license amendment request for review (in part, apparently, because PG&E hadn't met the standards for a showing of "no significant hazards considerations" necessary for avoiding the opportunity for a prior public hearing if one was requested.) PG&E withdrew the application.

That should have been the end of the matter. Diablo should then have been shut down until it could be upgraded as necessary to meet the requirements of the license and the newly discovered and analyzed seismic threats. This was not to be.

Instead, NRC remarkably suggested to PG&E that it merely amend its Final Safety Analysis Report Update (FSARU) to include the Shoreline as an included case in the Hosgri evaluation. In essence, amend the license without amending the license; all to avoid the detailed scrutiny that would occur by NRC if there were a license amendment request and the transparency of a public license amendment hearing in which experts from parties other than NRC and PG&E could participate and testify. Without any public notice, PG&E quietly did so late last year.

Unfortunately, NRC regulations do not permit this. If the FSARU is to be amended to allow the use of methodologies and assumptions less conservative, i.e., with smaller safety margins, than those currently in the FSARU, a license amendment—and opportunity for public hearing—is required anyway. See 10 CFR §50.59.

Dr. Peck objected. He first filed a non-concurrence, and then a Dissenting Professional Opinion (DPO), a gutsy and rare move.[xxi] Peck asserted that under NRC's regulations, the plant needed to be shut down until it could be shown to be able to withstand the ground motions from the new faults, using the assumptions and methodologies in the license for the DDE/SSE.

Despite Dr. Peck's formal request that his DPO be made public, it remained hidden from public view for a year, until the Associated Press obtained a copy and published a major article about it. Shortly thereafter, the DPO denial was issued.

The Latest Embarrassment: the AB 1632 Seismic Study Findings

On the same day as the DPO denial was released, PG&E issued 1800+ pages of its AB1632 seismic study.[xxii] Required by California agencies in response to legislation authored by then-Assemblymember Sam Blakeslee in 2006, the study was to examine the earthquake faults that could potentially affect Diablo. Buried in it are following remarkable findings:

- PG&E now concedes that the Hosgri Fault is connected to the San Simeon Fault, making a joint rupture possible, and is thus much longer than previously assumed (61 kilometers longer).[4]
- They further admit that the Shoreline Fault is twice the length and capable of a larger earthquake than previously assumed.
- On top of that, the Shoreline appears to be connected to the Hosgri, thus allowing rupture on one to trigger rupture on the other, coming within a few hundred meters of the plant.
- Estimated ground motions for the Shoreline, San Luis Bay, and Los Osos Faults all continue to exceed the 0.4 g DDE/SSE of the license.
- Estimated ground motions for the Shoreline and the San Luis Bay Faults exceed those from the Hosgri (even when connected to the San Simeon). The Shoreline-Hosgri joint rupture produces ground motions greater than all of these.

When the plant was designed and got its construction permit, it was assumed, as indicated earlier, that there were no active faults within 30 kilometers and the plant was thus constructed to safely shutdown at ground motions up to 0.4 g. Now it is known there are at least four large, active faults close to the site, one coming to within a few hundred meters, and that all of them produce ground motions far in excess of 0.4 g.

After the Hosgri was discovered, PG&E and NRC argued it was not connected to any other major fault. After the San Luis Bay, Los Osos, and Shoreline Faults were discovered to be active near the plant, PG&E and NRC asserted that none could produce ground motion greater

[4] The Hosgri-San Simeon Fault could be considerably longer, but PG&E chose not to examine its potential connections with the San Gregorio Fault.

than the Hosgri. Now it is admitted that the Hosgri *is* connected to the San Simeon Fault Fault, making the Hosgri effectively much longer than previously presumed. It is also connected to the Shoreline, making possible a large joint rupture that occurs with the nearest approach a few hundred meters from the plant.

Most intriguingly the new report estimates ground motions for an earthquake on the San Luis Bay fault to be greater than the ground motion from an earthquake on the Hosgri-San Simeon. It similarly estimates that the Shoreline Fault can produce more ground motion than the Hosgri-San Simeon Fault. It estimates that a joint rupture on the Shoreline and Hosgri Faults would cause more ground motion than on the Hosgri-San Simeon. And presumably a joint Hosgri-San Simeon rupture would cause more ground motion than on the Hosgri alone.

In other words, the Hosgri Fault, long claimed to be unconnected to other major faults like the San Simeon, is now not necessarily the primary threat to Diablo. The new findings indicate these other, more recently identified faults, and recently admitted connected faults, can cause more damage to Diablo than the Hosgri.

The defense by NRC and PG&E for not taking action to deal with these increased potential challenges to Diablo is that the newly estimated ground motions, while larger than those now estimated for the Hosgri and the DDE/SSE, are smaller than they presumed long ago for the Hosgri. But that is dependent upon using the non-conservative, non-standard assumptions allowed only for the Hosgri exception, and then apparently using new, even less conservative assumptions on top of them. These new methodological presumptions are not allowed under the license. And there has been no license amendment, nor any vetting of these assumptions and their associated reduced safety margins in any adjudicatory hearing, where they may not withstand detailed scrutiny.

Once again, PG&E has commenced a process of sharpening its pencils, using new, even less conservative input assumptions to drive down estimated ground motions even as its studies identify longer, more connected faults capable of larger threats to the plant than the Hosgri. And PG&E and NRC have resisted licensing hearings to address these critical issues. The historical pattern seems to be repeating itself.

<u>The Historical Pattern Continues</u>

This has been the pattern throughout Diablo's troubled history. NRC and PG&E attempt to avoid public licensing hearings on the critical seismic issues. Overly optimistic assumptions are thus chosen, only to be, time and time again, disproven by newly discovered scientific facts. Rather than shut the plant down or require sufficient upgrades to address the newly revealed seismic challenges, NRC and PG&E carve more and more safety margins out of the design, using ever less conservative (i.e., less protective) assumptions and methodologies. And they try to do this behind closed doors, with the public locked out of their right to evidentiary hearings.

Right now there is an Atomic Safety and Licensing Board that is supposed to consider PG&E's application for extending the life of Diablo at least two decades beyond its original design life and license. The position of both the NRC staff and PG&E is that the new seismic

discoveries are forbidden to be considered in those hearings on the Atomic Energy Act license renewal matters.

Right now, NRC has allowed PG&E to eliminate the DDE/SSE requirements and methodologies in its license that it cannot meet, and to do so via amending its Final Safety Analysis Report but without a license amendment request that would trigger a public right to hearing. NRC and PG&E have taken the position that the public has no right to a hearing on those seismic issues either. Essentially, on the critical seismic new discoveries, NRC and PG&E want to be allowed to just work it out between themselves, behind closed doors, with the public and independent experts frozen out.

This has not worked very well in the past. The public has generally been right, and NRC and PG&E wrong, over all these years. In 1970, for example, the intervenor group alleged evidence of undiscovered faults; they were denied the right to present the evidence in the hearing. Then the Hosgri Fault was revealed. The construction permit proceeding wasn't reopened.

The intervenor group in the operating license proceeding, Mothers for Peace, alleged that the Hosgri Fault was connected to the San Simeon Fault, that PG&E hadn't done an adequate job studying the seismic situation in the area, that there could be more undiscovered faults, and that there were inadequate quality assurance controls. PG&E and NRC Staff argued to the contrary, and the licensing board and appeal board ruled with them. The group of mothers turned out to be right on each count, and PG&E and NRC wrong on each.

Now we face one more repetition of history. Newly released findings show longer, more connected faults, capable of more ground motion than the Hosgri. But once again the pencil sharpeners are out, trying to make the findings go away by using ever less conservative and protective assumptions, carving out more and more safety margin, and doing so without the scrutiny of public licensing hearings.

The problem is that nature may not go along with the regulatory fictions. As at Fukushima, an earthquake larger than the plant can withstand could occur at any moment. And as at Fukushima, it will not be an act of nature, but a manmade disaster, caused by the failure of our institutions.

Conclusion

When the application for the Diablo Canyon construction permit was being heard in 1970, PG&E and the Commission blocked a hearing on the prospect of additional, previously unidentified faults. They asserted that there were NO active faults within 30 kilometers.

A few years later, when the plant was almost complete, the first such active nearby fault was discovered, the Hosgri. Rather than upgrade to the full risk from the fault, they created an exception for the Hosgri from the normal requirements of the license, and modified the inputs in the calculation of ground motion to reduce the estimates and allow operation with minimal

upgrades. But they asserted there were no other significant undiscovered faults in the area, and that the Hosgri wasn't connected to the San Simeon Fault (or further, to the San Gregorio).

A few years later, however, the San Luis Bay and Los Osos Faults were identified as active and nearby. Again there confidence was expressed there were no other additional undiscovered faults.

Then the Shoreline Fault was discovered. At least four active faults have thus been found near the plant, after PG&E and the Commission had asserted that were none.

Now it is conceded that the Hosgri Fault is much longer than previously assumed and is connected to at least the San Simeon Fault. (PG&E did not look to see if it is also connected to the San Gregorio Fault, as many geologists believe, claiming that was "outside the study area." Not looking, of course, doesn't make a potential fault connection disappear.)

Now it is admitted that the Hosgri Fault is also connected to the Shoreline Fault, making possible a joint rupture coming within a few hundred meters of the plant.

Repeating past practice, in the face of all these troubling discoveries, PG&E has tried to downplay the challenge to the plant by use of new input assumptions that reduce, on paper, the ground motions expected from these larger seismic challenges. Even so, their own ground motion estimates show the Shoreline and San Luis Bay Faults individually produce more ground motion than the Hosgri, with the same situation for the Shoreline-Hosgri and San Simeon-Hosgri joint ruptures. The new information about the seismic threat shows these individual faults and connected faults to be more of a risk than the Hosgri alone.

In short, virtually every seismic claim about Diablo made by PG&E and the NRC over the years has proven erroneous and overly optimistic. The failure to allow these issues to be aired fully in public adjudicatory hearings has contributed to these problems, and is being repeated again. The barring of public hearings suggests a fear of not being able to withstand strict scrutiny.

Fukushima occurred because the reactor was designed for a smaller earthquake and tsunami than turned out to be possible. Reviews of the accident have suggested that a too-cozy relationship between regulator and industry contributed to allowing the selection of a fictional, small earthquake and tsunami as the design basis. Nature did not go along with the regulatory fiction. One can only hope that history does not repeat itself on the Central California Coast.

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[i] See NRC radiation protection regulations in 10 CFR 20 Appendix B; and EPA's Superfund cleanup preliminary remediation goals (PRGs) [http://epa-prgs.ornl.gov/radionuclides/]

[ii] See, e.g., NRC Commissioner James Asselstine to Victor Stello, Jr. NRC Executive Director for Operations, Subject: *NUREG/CO-0084, Proceedings of the Workshop on Containment Performance Design Objective,* April 13, 1987, transmitting attached paper by Daniel Hirsch,

Director, Stevenson Program on Nuclear Policy, University of California, Santa Cruz, *Minority Report: Assessing the Need for Containment Performance Design Objectives,* July 20, 1986.

[iii] Daniel Hirsch *et al.,* "Protecting Reactors from Terrorists," *The Bulletin of the Atomic Scientists*, Vol. 42, No. 3, March 1986; Daniel Hirsch, ""The Truck Bomb and Insider Threats to Nuclear Facilities," in Paul Leventhal (Ed.), *Preventing Nuclear Terrorism*, Lexington Books, Lexington, MA: 1987; Daniel Hirsch *et al., Nuclear Terrorism: A Growing Threat*, A Report to the Safeguards and Security Subcommittee, Advisory Committee on Reactor Safeguards, U.S. Nuclear Regulatory Commission; May 7, 1985. Reprinted in monograph series, Stevenson Program on Nuclear Policy, UC Santa Cruz, SPNP-85-F-1

[iv] Daniel Hirsch, "The NRC: What Me Worry?", *Bulletin of the Atomic Scientists,* January/February 2002; Daniel Hirsch, Edwin Lyman, and Dave Lochbaum, "The NRC's Dirty Little Secret: The Nuclear Regulatory Commission is Still Unwilling to Respond to Serious Security Problems," *Bulletin of the Atomic Scientists,* May/June 2003; Committee to Bridge the Gap, Petition to the Nuclear Regulatory Commission for Rulemaking**,** *PROPOSED AMENDMENTS TO 10 C.F.R. PART 73 (Upgrading the Design Basis Threat, Regulations for Protection Against Terrorist Attacks on Nuclear Reactors)*, July 23, 2004; NRC, SECY-05-0106, *Proposed Rulemaking to Revise 10 CFR 73.1, Design Basis Threat (DBT) Requirements.*

[v] David Lochbaum, *Seismic Shift: Diablo Canyon Literally and Figuratively on Shaking Ground,* Union of Concerned Scientists: November 2013

[vi] Gayle LeBaron, "Battle Over Bodega Head Nuclear Plant Set the Stage," April 15, 2011, *Press Democrat;* David Okrent, *Nuclear Reactor Safety: On the History of the Regulatory Process,* University of Wisconsin Press, 1981; Thomas Reymond Wellock, *Critical Masses: Opposition to Nuclear Power in California, 1958-1978,* University of Wisconsin Press, 1998.

[vii] U.S. Nuclear Regulatory Commission, *Safety Evaluation Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2, Docket Nos. 50-275 and 50-323*, NUREG-0675, Supplement No. 34 (hereafter SSER 34), p. 2-39

[viii] Thomas H. Pigford, *Building the Fields of Nuclear Energy and Nuclear Waste Management, 1950-99,* University of California, Berkeley, University History Series, Regional Oral History Office, The Bancroft Library, 2001, pp. 144-150. Pigford reports that one of the factors involved in the ASLB refusing the request for a few hours to present evidence of nearby faults was that the ASLB chairman was running for election as County Manager of Montgomery County in Maryland and was in a hurry to return to the campaign.

[ix] The design was based on an earthquake more than 20 miles away on the Naciemento Fault, or a much smaller aftershock, not on an existing fault, arising from an earthquake on the San Andreas Fault, which is located 48 miles away. FSARU §2.5.2.9

[x] *Opinion of Commissioners Gilinsky and Bradford on Commission Review of ALAB-644 (Diablo Canyon Seismic Proceeding),* CLI-82-12A, 16NRC8,10

[xi] R.C. DeYoung, Assistant Director for Light Water Reactors Group 1, Division of Reactor Licensing, to Roger Boyd, Acting Director, Division of Reactor Licensing, USNRC, *Diablo Canyon Geology-Seismology,* January 5, 1976.

[xii] In these proceedings, peak acceleration is benchmarked at 100 Hz for comparison purposes. USGS did indicate one could modify the values from Circular 672, but did not recommend how or any other value.

[xiii] Atomic Safety and Licensing Appeal Board, *In the Matter of Pacific Gas and Electric Company, Diablo Canyon Nuclear Power Plant Units 1 and 2, Dockets No. 50-275 (OL) and 50-323 OL (Seismic Proceeding*), ALAB-644, 15 NRC 903, June 16, 1981
[xiv] Gilinsky-Bradford opinion at 12.
[xv] Gilinsky-Bradford Opinion at 13-14
[xvi] Barbara Byron, California Energy Commission, *California's Policies and Recommendations for Advanced Seismic Research at Diablo Canyon,* September 9, 2010.
[xvii] Atomic Safety and Licensing Board, *Partial Decision*, Diablo Canyon Units 1 and 2, September 27, 1979.
[xviii] PG&E took the position that the Hosgri analysis was not part of the Safe Shutdown Earthquake, that the SSE was the DDE at 0.4 g. See NRC SSER7, p. 2-3, citing a PG&E letter to NRC of April 11, 1978.
[xix] Pacific Gas & Electric, License Amendment Request 11-05, "Evaluation Process for New Seismic Information and Clarifying the Diablo Canyon Power Plant Safe Shutdown Earthquake," October 20, 2011.
[xx] Pacific Gas & Electric, Standard Review Plan Comparison Tables for License Amendment Request 11-05, "Evaluation Process for New Seismic Information and Clarifyinq the Diablo Canyon Power Plant Safe Shutdown Earthquake," December 6, 2011
[xxi] The Peck DPO, its Denial, the Appeal DPO Denial, and the Denial of the Appeal were released by NRC on September 10, 2014, available on the NRC ADAMS database at ML12452A743.
[xxii] available at http://www.pge.com/en/safety/systemworks/dcpp/seismicsafety/report.page

Tony Pietrangelo
Senior Vice President and Chief Nuclear Officer
Nuclear Energy Institute

Committee on Environment and Public Works
United State Senate

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Chairman Boxer, Ranking Member Vitter, and members of the committee, thank you for the opportunity to appear before you today.

I am Tony Pietrangelo, the Senior Vice President and Chief Nuclear Officer at the Nuclear Energy Institute.

My testimony today will cover four issues:

1. Some of the challenges we see in the nation's electricity system;
2. A view from the industry on the NRC's regulatory process;
3. An update on the industry's post-Fukushima safety enhancements; and
4. Some perspective on NRC's seismic regulations, particularly with regard to the Diablo Canyon Nuclear Power Plant.

America's 100 nuclear power plants provide approximately 20 percent of our electricity and nearly two-thirds of our carbon-free electricity.

They produce that electricity 24 hours/day and are not dependent upon wind or sun, or fuel delivered by trucks, barges, rail lines or pipelines to do so.

They produce electricity at low, stable prices and are base-load facilities that are essential to controlling voltage and frequency for the entire electric grid.

The nuclear energy industry employs over 100,000 workers, provides a significant fraction of the tax base at the state and local level, and represents hundreds of millions of dollars in both direct and indirect economic benefits to each state in which the plant operates.

Finally, nuclear power plants provide vital clean air compliance value. In any system that limits emissions – of the so-called "criteria" pollutants or carbon dioxide – the emissions prevented by nuclear energy reduce the compliance burden that would otherwise fall on emitting generating capacity.

Other sources of electricity have some of these attributes, but nuclear energy is unique in this value proposition.

With that said, some electricity markets in portions of the country are creating serious challenges for base-load generation including nuclear energy.

Since a number of states restructured their electricity markets in the late 1990s, the business of producing and transmitting electricity has evolved into two distinctly different enterprises.

In those states still using traditional cost-of-service regulation, companies and regulatory commissions use the process of integrated resource planning to evaluate resource options on a long-term basis, analyze project economics over a 40-year or 60-year time horizon, and assign value to "public goods," such as fuel and technology diversity and forward price stability in the electric sector.

States with competitive electricity markets have not yet developed mechanisms to value these "public goods" and internalize them in their decision-making.

As a result, regulated states have been able to create the conditions under which companies can undertake long-term, capital-intensive projects and preserve fuel and technology diversity. In the South and Southeast, state legislatures and regulatory commissions provide the assurance of prudent cost recovery necessary for capital-intensive projects. This is why the Vogtle and Summer nuclear energy projects are under construction in Georgia and South Carolina.

One of the key questions first raised in the late 1990s – can restructured markets develop mechanisms to preserve fuel and technology diversity and support investment in a diverse portfolio of generating assets? – remains unanswered. Absent significant market redesign or creation of new market mechanisms, it is not clear how merchant markets will ever stimulate investment in anything but the lowest-cost, short-term option. Given today's conditions, this will be natural gas-fired generation, thanks to the relatively low initial capital outlay for a gas-fired combined cycle plant.

This and other factors have led to sustained economic stress on some existing generating capacity, particularly base-load capacity. At a time when the surplus of generating capacity in the eastern United States is decreasing, as existing generating capacity retires, effective and efficient market design and operating practices in the capacity and energy markets are more critical than ever.

At the same time the electric industry is dealing with challenging market conditions, it is also dealing with the cumulative impact of regulations produced by the NRC.

The NRC currently has more than 50 rulemakings underway in various stages. Almost all of them, if implemented, would require modifications to plant systems and operations, yet the NRC does not appear to be prioritizing or even coordinating many of its rulemakings.

Last year, Senator Vitter and House Energy and Commerce Chairman Upton requested that the Government Accountability Office review the NRC's use of cost-benefit analysis, and we look forward to the results of that analysis. For our part, we have numerous examples in which the actual cost of meeting new NRC requirements was 5 to 20 times the NRC's estimated cost. We believe that if the NRC more accurately estimated the costs of its regulatory requirements, it would find that many of its requirements do not pass a simple cost-benefit test. As a result, resources are being spent complying with requirements that have little or no safety benefit. Let me be clear: The industry will implement requirements that have a direct safety benefit. However, regulatory requirements with little or no nexus to safety result in a diversion of resources from both the industry and the NRC to higher safety-significant requirements and operational priorities – the sorts of things that keep our plants reliably producing the electricity for which they are intended.

I want to take a moment to quickly summarize the state of post-Fukushima preparedness.

After Fukushima, the industry took immediate steps to strengthen our strategies to protect our nuclear energy facilities from severe natural events like earthquakes and floods. We didn't wait for NRC requirements. Each company that operates nuclear power plants has added yet another layer of backup safety equipment to ensure that the facilities will have access to power and water that are necessary to keep reactors safe in the rare event of a severe natural event. Moreover, we developed national response centers in Memphis and Phoenix. Each of those centers is stocked with five sets of emergency equipment – backup generators, pumps, standardized couplings and connectors for hoses and cables – that are ready for delivery to any U.S. reactor in 24 hours.

The companies, using some of the nation's best experts, also are reevaluating natural hazards – like earthquakes and floods – for their sites using the latest methods and data. The next step is to review the protective and mitigating measures put in place against the latest site-specific hazard information to determine if any refinements are necessary. We are in the process of conducting those evaluations and expect to have largely completed implementation by the end of 2016.

Finally, I would like to offer a perspective on seismic regulations, particularly at the Diablo Canyon Nuclear Power Plant.

Nuclear plants have several aspects of seismic protection, including safety factors applied to the reactor designs, conservative requirements in engineering codes and standards, and specific requirements for the strength of steel and concrete used to build the plants. These design and

construction practices are above and beyond the protection needed to safely withstand significant ground motion. In addition, engineering and materials design, seismic study technologies and methodologies have evolved significantly over time, which allows for more certainty as to how a nuclear power plant's structures, systems and components will react to a seismic event, and diminishes the reliance on overly conservative techniques and assumptions. When Diablo Canyon was under construction, the nearby Hosgri fault was discovered. Because the ground motions from the Hosgri fault could exceed the double design earthquake postulated in the plant's operating license, prior to commencing operations, the plant was retrofitted to withstand the ground motions from the Hosgri fault. In addition to these retrofits, a commitment also was made to constantly study the local geologic features and global seismic events to ensure seismic safety at Diablo Canyon, referred to as the Long Term Seismic Program (LTSP) through an open-ended licensing agreement. Diablo Canyon is, therefore, a unique facility in the industry, in that it is licensed for three earthquake designs: the Design Earthquake, Double Design Earthquake (equivalent to the Safe Shutdown Earthquake), and the Hosgri Earthquake, and has continually studied the geologic features surrounding the plant through the LTSP

It is through the Long Term Seismic Program that the Shoreline fault was discovered, in cooperation with the U.S. Geological Service, in 2008. The Shoreline fault, like the San Luis Bay and Los Osos faults, are below the Hosgri ground motion levels for which the plant was retrofitted in the 1970s, prior to commencing operation. As a result, the plant is able to withstand the largest ground motions that could be expected to be generated from any of the nearby faults, because none exceed the plant's robust Hosgri Earthquake design, which was also confirmed again as a result of recently completed advanced seismic studies using state of the art two and three dimensional imaging.

I realize this issue is even more complex because some staff at the NRC filed a differing professional opinion on issues related to Diablo Canyon and the Shoreline fault. Differing professional opinions do occur among the 4,000 staff at the NRC, and the NRC has a process for addressing them. In this case, the conclusion was that, "there is not now nor has there ever been an immediate safety concern" with this issue at Diablo Canyon. In addition, the panel concluded that older analytical techniques were overly conservative and no longer technically justified since the license at Diablo Canyon allows for newer technologies to be used.

Chairman Boxer, that concludes my prepared remarks, and I look forward to answering any of your questions.