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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION

Michael X. Franovich, Deputy Director

In the Matter of	)	Docket Nos. 50-275 and 50-323
	)	
	)	
	)	
Pacific Gas and Electric Co.	)	License Nos. DPR-80 and DPR-82
	)	
	)	
Diablo Canyon, Nuclear Power Plant,	)	
Units 1 and 2	)	

PROPOSED DIRECTOR'S DECISION UNDER 10 CFR 2.206

I. Introduction

On March 4, 2024, the San Luis Obispo Mothers for Peace, Friends of the Earth, and Environmental Working Group petitioned the U.S. Nuclear Regulatory Commission (NRC) requesting that the NRC exercise its supervisory authority to order the immediate closure of Diablo Canyon Nuclear Power Plant, Units 1 and 2 (Diablo Canyon), due to "the unacceptable risk of a seismically induced severe accident" (Agencywide Documents Access and Management System Accession No. ML24067A066). On March 12, 2024 (ML24072A529), the Office of the Secretary of the Commission referred the petitioners' request to the enforcement petition process under Title 10 of the *Code of Federal Regulations* (10 CFR) Section 2.206, "Requests for action under this subpart."

The basis for the petitioners' request, as included in the original petition and in the petitioners' supplements, is summarized below:

Concern 1: Thrust faulting is neglected by Pacific Gas & Electric Company's (PG&E) 2015 Seismic Source Characterization (SSC) model because the model assumes that a majority of large earthquakes affecting Diablo Canyon are strike-slip and disregards the significant contribution of thrust faulting earthquake sources under the Diablo Canyon site and the adjacent Irish Hills. In addition, the hazard characterization performed by PG&E did not use a hanging-wall term for the modeling of potential ground motions from the Los Osos and San Luis Bay thrust faults.

Concern 2: The January 2024 magnitude 7.5 earthquake centered in the Noto Peninsula (Japan), with an average slip of 2 meters on the fault, is analogous to future potential thrust mechanism earthquakes beneath Diablo Canyon. Based on the slip rate of an "inferred" offshore thrust fault proposed by the petitioners, which is located beneath the Irish Hills adjacent to Diablo Canyon and the slip of the Noto earthquake, large ground motions from thrust fault earthquakes will occur, on average, every 715 years near the Diablo Canyon site.

Concern 3: PG&E's SSC model does not account for an "inferred" offshore thrust fault that has the potential for producing a magnitude 7.5 earthquake. Based on regional stratigraphy, gravity modeling and global positioning system (GPS) modeling, the total thrust faulting slip rate beneath the Irish Hills is between 2.0 to 2.8 mm/yr, which is not accounted for in PG&E's SSC model.

Concern 4: Seismic core damage frequency, estimated by PG&E in 2018 to be 3×10^{-5}, should be 1.4×10^{-3} per year (about once every 715 years) based on this higher recurrence rate for thrust earthquakes.

In accordance with the handbook for NRC Management Directive (MD) 8.11, "Review Process for 10 CFR 2.206 Petitions," dated March 1, 2019 (ML18296A043), Section III "Petition Review Board (PRB)," NRC staff promptly deliberated on the request for immediate action and began the screening process. On March 28, 2024 (ML24088A238), the petitioners were informed that the NRC staff concluded that no immediate action is necessary, that the concerns expressed in the petition screened into the 2.206 process, and that a PRB would be assembled to evaluate the concerns.

In an email dated May 15, 2024 (ML24136A162), the petition manager informed the petitioners that the PRB's initial assessment was that the petition did not meet the criteria in MD 8.11 for accepting petitions under 10 CFR 2.206 because "the issues raised have previously been the subject of a facility-specific or generic NRC staff review" and the petition does not provide significant new information that the staff did not consider in a prior review.

On June 7, 2024, the petitioners submitted a supplement to the petition (ML24162A079).

The NRC held a public meeting with the petitioners on July 17, 2024. The petitioners' presentation (ML24198A105) and the meeting transcript (ML24218A164) are considered supplements to the petition. This supplemental information provided by the petitioners is addressed below as part of the NRC staff's response to Concern 3.

On August 27, 2024 (ML24205A066), the NRC issued an acknowledgement letter informing the petitioners that the concerns raised in the petition, as supplemented, now meet the criteria in MD 8.11 for accepting petitions under 10 CFR 2.206 and that the concerns would undergo further review by the PRB. The letter also informed petitioners that the PRB determined that there is no imminent safety concern that warrants immediate shutdown of Diablo Canyon.

On October 24, 2024, PG&E provided a voluntary submittal (ML24298A234) to the NRC related to the PRB review of the petition. On October 31, 2024, the petitioners submitted a supplement to the petition (ML24305A187) in response, in part, to the October 24, 2024, PG&E voluntary submittal.

On December 5, 2024 (ML24317A038), the NRC issued a supplemental acknowledgement letter informing the petitioners that two concerns from the October 31, 2024, supplement would be included in the ongoing PRB review. These supplemental concerns provided by the petitioners are addressed below as part of the NRC staff's response to Concern 3. The letter also informed petitioners that the PRB determined that there is no imminent safety concern that warrants immediate shutdown of Diablo Canyon.

Publicly available documents created or received at the NRC are accessible electronically through ADAMS in the NRC's Library at http://www.nrc.gov/reading-rm/adams.html. Persons who do not have access to ADAMS, who encounter problems in accessing the documents located in ADAMS, or who want to inspect publicly available documents at the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD 20852 should contact the NRC's PDR reference staff by telephone at 1-800-397-4209 or 301-415-4737, or by email to pdr.resource@nrc.gov.

II. Discussion

Concern 1: Thrust faulting is neglected by PG&E 2015 SSC model because the model assumes that a majority of large earthquakes affecting Diablo Canyon are strike-slip and disregards the significant contribution of thrust faulting earthquake sources under the Diablo Canyon site and the adjacent Irish Hills. In addition, the hazard characterization performed by PG&E did not use a hanging-wall term for the modeling of potential ground motions from the Los Osos and San Luis Bay thrust faults.

Based on its previous review in 2016 of the seismic models developed by PG&E (ML15071A046) in response to the NRC's 50.54(f) request (ML12056A046), the PRB disagrees with the petitioner's claims that thrust faulting was not adequately accounted for by PG&E in its seismic source model and that a hanging-wall term was not implemented in the seismic ground motion model. The PRB supports the NRC's conclusion in 2016 (ML16341C057) that PG&E adequately accounted for reverse or thrust faulting in the alternative fault geometry models developed for the SSC model and that a hanging-wall term was implemented for the Ground Motion Characterization (GMC) model, which increased the ground motion as expected. The bases for the PRB conclusions are provided below.

Diablo Canyon is located on the southwest slope of the Irish Hills in the northern part of the San Luis Range in central coastal California. The current tectonic setting for the region around Diablo Canyon is a transform plate boundary that accommodates horizontal relative motions consisting of strike-slip faults with transpressional deformation, resulting in localized areas of uplift and folding alongside the major fault zone. Strike-slip faults display predominantly horizontal movement, usually along a nearly vertical fault surface, and transpression refers to a type of strike-slip deformation where shortening (compression) occurs perpendicular to the fault plane because of the presence of bends along the fault line. The San Luis Range in central coastal California is a topographic and structural elevation high (maximum elevation of 1,784 meters) that formed within this region of reverse and oblique slip faults due to this transpressional deformation. A reverse fault is a fault where the upper side of the fault, called the hanging wall, moves up and over the lower or foot wall side of the fault, and an oblique slip fault is a fault in which the two sides of the fault simultaneously move both vertically and horizontally. For its SSC model, developed in response to the NRC's 50.54(f) request, PG&E modeled the uplift of the Irish Hills, located in the San Luis Range adjacent to Diablo Canyon, assuming rigid block uplift resulting from reverse faulting on the moderate to steeply dipping (45 to 80 degrees) Los Osos and San Luis Bay faults rather than from folding deformation on a low-dip angle (25 degrees) "inferred" offshore thrust fault, as postulated by the petitioners. Thrust faulting is a type of reverse faulting with a dip angle of 45 degrees or less. To develop the SSC model, PG&E used recently acquired offshore and onshore two- and three-dimensional seismic reflection data, multibeam bathymetric data, geodetic data, and an updated seismicity catalog to better define the location, geometry, and slip rate of the faults in the area around Diablo Canyon. Modeling the uplift of the Irish Hills as a rigid block is based on this extensive geologic field work and geophysical surveys, which PG&E has been supporting for many years going back to the 1980s.

PG&E's reevaluation of the seismic hazard in response to the NRC's 50.54(f) request determined that four faults contribute to the majority of the seismic hazard at Diablo Canyon. These four faults are the Hosgri, Los Osos, San Luis Bay, and Shoreline faults. The Hosgri and Shoreline faults are near-vertical strike-slip faults, and the Los Osos and San Luis Bay faults are reverse faults that border the northeastern and southern margins of the Irish Hills, respectively. Figure 1,[1] from PG&E's SSC Senior Seismic Hazard Analysis Committee (SSHAC) report and incorporated into NUREG/KM-017, "Seismic Hazard Evaluations for U.S. Nuclear Power Plants: Near-Term Task Force Recommendation 2.1 Results (ML21344A126), shows the location of Diablo Canyon relative to the Irish Hills and the four faults that contribute the most to the hazard.

As specified in the 50.54(f) request, PG&E implemented the SSHAC approach in NUREG-2213, "Updated Implementation Guidelines for SSHAC Hazard Studies" (ML18282A082), to develop the SSC and GMC models used to determine the seismic hazard for the Diablo Canyon site. The SSHAC approach is focused on two critical activities: evaluation and integration. The evaluation activity is defined as an assessment of the complete set of data, models, and methods that are relevant to the hazard analysis as proposed by the larger technical community, consisting of geologists and seismologists with expertise in coastal California tectonics. The SSHAC guidelines provide a method for facilitating interactions with the SSHAC team and members of the larger technical community to exchange viewpoints and to challenge proponents of differing hypotheses. The integration activity is the development of SSC and GMC models that capture all technically defensible interpretations, as informed by the evaluation activity. There are four SSHAC study levels, with the higher levels involving a greater number of participants and a longer duration to more fully assess available data, models, and methods. A key element of the SSHAC approach is participatory peer review from an outside

[1]See the "Attachment to the Proposed Director's Decision: Figures 1 through 9" in ML25093A060 for Figures 1 through 9.

panel (Participatory Peer Review Panel or PPRP) to ensure that the full range of data, models, and methods are considered in the evaluation phase and that the center (median), body (16th to 84th percentile), and range (5th to 95th percentile) of technically defensible interpretations are integrated into the seismic source and ground motion models to capture the uncertainty in seismic hazard as required by 10 CFR 100.23, "Geologic and seismic siting criteria."

In response to the 50.54(f) request, PG&E performed a Level 3 SSHAC study for its reevaluation of the seismic hazard for the Diablo Canyon site. Development and documentation of the source and ground motion models were performed from June 2011 to March 2015 and included three formal workshops conducted in San Luis Obispo, California, which were open to the public. Dr. Bird, expert witness for the petitioners, participated in the second public workshop in 2012 and presented his views "on both strike-slip and compressional deformation rates affecting the region" (ML15071A046). Elements of Dr. Bird's views (uplift of Irish Hills due to slip on low-angle reverse or thrust faults) were incorporated into the SSC model developed by the SSHAC team; however, other alternative models were also developed by the SSHAC team in order to capture the uncertainty in the local faulting mechanisms and underlying tectonics. As observers of the three formal public workshops in 2012, the NRC staff viewed the wide range of hypotheses proposed by the experts for the current regional transpressional tectonic setting around Diablo Canyon.

To accommodate the multiple hypotheses proposed by the experts, PG&E developed three alternative fault geometry models to capture the range of potential mechanisms driving uplift of the Irish Hills. These models include the Outward-Vergent, Southwest-Vergent, and Northeast-Vergent models. The Southwest-Vergent model considers the San Luis Bay fault as a reverse or thrust fault with a dip angle of 45 degrees and incorporates aspects of theories proposed by the petitioners. In addition to the three fault geometry models, the SSC model also accounts for earthquakes potentially occurring on previously unidentified faults by developing a "background" seismic source zone surrounding Diablo Canyon. This background zone considers the possibility of low-angle (35 degrees) thrust or reverse faults with fault lengths of 50 kilometers (km) and magnitudes as high as moment-magnitude (Mw) 7.1. In its review of the SSC model, the NRC staff concluded that PG&E adequately implemented the SSHAC process and developed multiple alternative models for the uplift of the California Coast Ranges that are based on the modeling of geological and geophysical field data (ML16341C057). This conclusion was also supported by the SSHAC PPRP in its project closure letter, which states that "the data, models, and methods within the larger technical community have been properly evaluated, and the center, body, and range of the technically defensible interpretations have been appropriately represented in the SSC model" (appendix B of the PG&E SSC Model (ML15071A046)).

In addition to stating that PG&E neglected the potential for thrust faulting, the petition claims that PG&E did not use a hanging-wall term for the modeling of potential ground motions from the Los Osos and San Luis Bay reverse faults. The "hanging-wall" effect is the increase in ground motion at a site located on top of the hanging wall side of the fault due to the site being located directly above the fault and closer to the rupture area. Based on its review of the SSHAC Level 3 GMC model (appendix C of the PG&E SSC Model (ML15071A046)), the NRC staff determined that a hanging-wall term was implemented and that this term increased the ground motion as expected (ML16341C057).

In summary, based on its previous review in 2016 of the seismic models developed by PG&E in response to the NRC's 50.54(f) request, the PRB disagrees with the petitioners' claims that thrust faulting was neglected by PG&E in its seismic source model and that a hanging-wall term was not implemented in the seismic ground motion model.

Concern 2: The January 2024 magnitude 7.5 earthquake centered in the Noto Peninsula (Japan), with an average slip of 2 meters on the fault, is analogous to future potential thrust mechanism earthquakes beneath Diablo Canyon. Based on the slip rate of the "inferred" offshore thrust fault proposed by the petitioners, which is located

beneath the Irish Hills adjacent to Diablo Canyon, and the slip of the Noto earthquake, large ground motions from thrust fault earthquakes will occur, on average, every 715 years near the Diablo Canyon site.

Due to differences in the primary tectonic driving forces, the types of earthquake focal mechanisms, rate of seismic activity, and the lack of direct observations from geophysical surveys of a major "inferred" thrust fault off the coast of central California in the vicinity of Diablo Canyon, the PRB concludes that the January 2024 magnitude 7.5 Noto Peninsula earthquake is highly unlikely to be analogous to a future potential thrust mechanism earthquake beneath Diablo Canyon. The bases for the PRB conclusion are provided below.

The Noto Peninsula in Japan is located on the eastern margin of the Sea of Japan on the west coast of Honshu (largest island of Japan) and was formed as a result of back-arc rifting arising from subduction of the Pacific Plate beneath the Eurasian plate along the Japan Trench. Back-arc rifting is a process that occurs when one tectonic plate subducts beneath another, causing the overlying plate to stretch and thin, forming a back-arc basin. Subsequent to back-arc rifting during the Pliocene Epoch (3 million years ago), the tectonic regime along the west coast of Honshu shifted to compression, which reactivated older rift faults as reverse or thrust faults, causing uplift of former basins on the peninsula. The west coast of Honshu is now a convergent boundary between the Amurian (eastern edge of the Eurasian plate) and Okhotsk microplates, with convergence rates ranging from 14 to 16.5 mm/yr.[2] Figure 2 shows the location of the Noto Peninsula relative to the boundary between the two converging microplates. Several large earthquakes and tsunamis have occurred along this convergent boundary between the two microplates including the most recent Mw 7.5 earthquake on January 1, 2024. The 2024 Noto earthquake occurred on a shallow reverse or thrust fault with the rupture

[2] Ito, C., T. Hiroaki, and O. Mako, "Estimation of convergence boundary location and velocity between tectonic plates in northern Hokkaido inferred by GNSS velocity data," Earth, Planets and Space, 71.1: 1-8, 2019.

extending over 100 km in length from the southwestern portion of the Noto Peninsula to Sado Island along a southeast-dipping fault.[3] Figure 3, from the U.S. Geological Survey's (USGS) website for the 2024 Noto earthquake, shows the distribution of slip based on the finite fault model developed by USGS for the 2024 Noto earthquake. According to the USGS model, slip occurred mostly beneath the peninsula with the zones of largest slip occurring to the southwest of the earthquake hypocenter and with earthquake rupture propagating from the peninsula to the seafloor[4].

In contrast to the Noto Peninsula tectonic regime of compression, the tectonic setting for the region surrounding Diablo Canyon is a transform plate boundary that produces horizontal relative motions along strike slip faults with transpressional deformation. The tectonic setting for the central coastal California region is roughly triangular with the San Andreas fault on the east, the San Gregorio-San Simeon-Hosgri fault on the west, and the Western Transverse Ranges on the south.[5] Figure 4, from Langenheim,[6] shows this triangular region that bounds the California Coast Range with the numerous north-northwest striking faults that cut through Cenozoic Era (approximately 66 million years ago until today) sedimentary rocks that overlie older Mesozoic Era (approximately 252 to 66 million years ago) basement rocks such as the Franciscan Complex metamorphosed rock.

Although faulting is primarily strike-slip, steady uplift over at least the past 125,000 years has occurred along a 400-km long portion of the central California coast. Along the San Gregorio-Hosgri fault system, late Quaternary age (2.6 million years ago) to modern reverse fault slip rates are on the order of 10 to 30 percent of the strike-slip fault slip rates (O'Connell and Turner, 2023). Near Diablo Canyon, the San Luis Range forms the core of the San

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[3] U.S. Geological Survey, "M 6.5 - 10 km NE of San Simeon, California." Accessed December 1, 2024. https://earthquake.usgs.gov/earthquakes/eventpage/us6000m0xl/executive.
[4] Id.
[5]. Langenheim, V. E., R. C. Jachens, R. W. Graymer, J. P. Colgan, C. M. Wentworth, and R. G. Stanley, "Fault geometry and cumulative offsets in the central Coast Ranges, California: Evidence for northward increasing slip along the San Gregorio–San Simeon–Hosgri fault," Lithosphere, 5(1), 29-48, 2013.
[6] Id.

Luis-Pismo Block, a structural block that trends northwest to southeast. It is bounded by strike slip fault zones on the west (Hosgri fault) and east (Oceanic-West Husana fault), and by a series of reverse faults to the northeast (Los Osos fault) and southwest (Southwestern Boundary Zone including the San Luis Bay fault).

Geologic field studies[7] show that the San Luis Range is uplifting at rates between 0.1 mm/yr to 0.2 mm/yr. According to PG&E's SSC model, slip rates near Diablo Canyon are estimated to be:

- Hosgri strike-slip fault: 1 to 2 mm/yr
- Los Osos reverse fault: 0.2 to 0.4 mm /yr
- San Luis Bay reverse fault: 0.1 to 0.3 mm/yr

For comparison, horizontal slip rates on the San Andreas fault in central California, located approximately 85 km northeast of Diablo Canyon, are estimated to be 25 to 36 mm/yr.

The tectonic differences between the Noto Peninsula and central coastal California are further demonstrated by the types of earthquakes in the two regions as evidenced by the focal mechanisms of the earthquakes. In the Noto Peninsula, the earthquake focal mechanisms are predominantly reverse, whereas in the vicinity of Diablo Canyon, the focal mechanisms are a mixture of strike-slip, reverse and oblique mechanisms. Figure 5 shows that the focal mechanisms for earthquakes near Diablo Canyon exhibit this mixture of different types of fault slip and orientations (ML15071A046).

The other major difference between the Noto Peninsula in Japan and the Irish Hills in the western part of the San Luis Range in central coastal California are the historical earthquake recurrence rates. In addition to the 2024 Mw 7.5 Noto earthquake, several other large earthquakes have recently occurred beneath the Noto Peninsula, including an earthquake

[7] Hanson, K.L., J.R. Wesling, W.R. Lettis, K.I. Kelson, and L. Mezger, "Correlation, Ages, and Uplift Rates of Quaternary Marine Terraces, South-Central California," I.I. Alterman, R.B. McMullen, L.S. Cluff, and D.B. Slemmons, eds., Seismotectonics of the Central California Coast Range, Geological Society of America Special Paper 292. Pp. 45-72, 1994.

swarm for the last 3 years with the largest earthquake being a Mw 6.3 earthquake occurring on May 5, 2023. This earthquake swarm was preceded by the Mw 6.9 2007 Noto Hanto earthquake, which occurred at a depth of 10 km near the west coast of the Noto Peninsula. Similar to the Noto Peninsula, along central coastal California and in the Transverse Ranges there have been numerous earthquakes in the Mw 5 to Mw 7 range, including the 2003 Mw 6.5 San Simeon earthquake and the 1927 Mw 7.0 Lompoc earthquake. However, near Diablo Canyon, in the vicinity of San Luis Bay and the Irish Hills, McLaren and Savage[8] document only two magnitude five events in 1913 and 1916. Figure 6, from PG&E's SSC SSHAC report, shows the locations of historical earthquakes in central coastal California. In summary, the historical rate for large earthquakes in the vicinity of Diablo Canyon is much smaller than the rate for the Noto Peninsula.

An additional issue with the existence of the petitioners' "inferred" offshore thrust fault capable of producing an Mw 7.5 earthquake similar to the 2024 Mw 7.5 Noto Peninsula earthquake is the lack of evidence from the recently acquired offshore and onshore two- and three-dimensional seismic reflection data and multibeam bathymetric data. Based on recent fault length versus magnitude relationships for reverse or thrust faults, such as Thingbaijam et al.,[9] the length of the "inferred" offshore thrust fault would need to be on the order of 70 to 100 km. In addition, the petitioners assert, as described below in Concern 3, that the slip rate of this "inferred" offshore thrust fault is between 2.0 to 2.8 mm/yr. That a thrust fault of this length and this relatively high activity rate would go undetected considering the numerous geophysical surveys and detailed studies of the regional seismicity (e.g., Hardebeck[10]) is highly unlikely. However, to account for the possibility of earthquakes occurring on previously unidentified

[8] McLaren, M.K. and W.U. Savage. "Seismicity of South-central Coastal California: October 1987 through January 1997," Bulletin of the Seismological Society of America, Vol. 91, Issue 6., pp. 1,629-1,658, 2001.
[9] Thingbaijam, K. K. S., P. M. Mai, and K. Goda, "New empirical earthquake source-scaling laws," Bulletin of the Seismological Society of America, 107(5), 2225-2246, 2017.
[10] Hardebeck, Jeanne L., "Seismotectonics and fault structure of the California Central Coast,"" Bulletin of the Seismological Society of America, 100.3: 1031-1050, 2010.

faults, PG&E developed a background seismic source zone for its SSC model that includes 18 virtual offshore and onshore faults with lengths of 50 km, magnitudes as high as Mw 7.1, and activity rates based on the regional seismicity catalog. The style of faulting for these virtual faults includes the possibility for both strike-slip and reverse or thrust faulting on low-angle (35 degrees) dipping faults. Figure 7, from the NRC staff's confirmatory analysis of PG&E's hazard models, shows the Hosgri, Shoreline, Los Osos, San Luis Bay, and the 18 virtual faults used to systematically account for the possibility of earthquakes on previously unidentified faults near Diablo Canyon (ML16341C057).

In summary, due to differences in the primary tectonic driving forces, the types of earthquake focal mechanisms, rate of seismic activity, and the lack of direct observations from geophysical surveys of a major thrust fault off the coast of central California in the vicinity of Diablo Canyon, the PRB concludes that the January 2024 magnitude 7.5 Noto Peninsula earthquake is highly unlikely to be analogous to a future potential thrust mechanism earthquake beneath Diablo Canyon.

Concern 3: PG&E's SSC model does not account for an "inferred" offshore thrust fault that has the potential for producing a magnitude 7.5 earthquake. Based on regional stratigraphy, gravity modeling and global positioning system (GPS) modeling, the total thrust faulting slip rate beneath the Irish Hills is between 2.0 to 2.8 mm/yr, which is not accounted for in PG&E's SSC model.

The PRB concludes that the stratigraphic profile, gravity anomalies, and GPS modeling used by the petitioners do not provide adequate evidence to support the existence of a major "inferred" offshore thrust fault that extends beneath the Irish Hills with a fault length of 70 to 100 km and a slip rate between 2.0 to 2.8 mm/yr. The bases for the PRB conclusion are provided below.

The petitioners assert that folding beneath the Irish Hills within the San Luis-Pismo block has been ongoing for the past 5 to 6 million years due to low-angle thrust faulting and that this has resulted in the uplift of the Irish Hills. Based on this hypothesis, the petitioners estimate that there has been 1.6 to 2.2 km of vertical throw of the Obispo Formation over the past 5 million years and that this vertical offset can be used to arrive at a “minimum total thrust” fault slip rate of 1.5 to 2.1 mm/yr beneath the Irish Hills. Figure 8, from the petitioners’ July 17, 2024, presentation, shows the petitioners’ interpretation of the location and geometry of the faults beneath the Irish Hills in red overlain on Figure 13-17 from PG&E’s SSHAC report. On Figure 13-17 from the SSHAC report, the petitioners have redrawn each of the more steeply dipping faults to be at 25 degrees and added the “inferred” offshore thrust fault, which extends from just offshore towards the eastern edge of the San Luis-Pismo block. The petitioners also added a vertical line in the upper left to show throw of the Obispo Formation (designated Tmo), which is depicted as the light blue layer.

The Obispo Formation is a marine deposit made up of lavas and tuffs that is about 20 million years old. The Obispo Formation is present beneath several younger rock formations in the offshore and onshore Santa Maria Basins and the onshore Pismo Basin. From the Miocene to the early Pliocene (20 to 5 million years ago), normal faulting on the margins of these basins resulted in subsidence of the basins. The location, thickness, and offset of rock formations across these basins is highly uncertain, especially for the older formations such as the Obispo Formation. Therefore, the use of the vertical offset of the Obispo Formation across multiple basins to determine the slip rate on a previously unidentified “inferred” thrust fault beneath the Irish Hills is questionable. The petitioners relied on the use of vertical offset of a single rock layer (Obispo Formation) to support the hypothesis for low-angle thrust faulting beneath the Irish Hills at a slip rate nearly twice that of the strike-slip Hosgri fault, which is the most active fault near Diablo Canyon. In contrast, PG&E relied on several geologic studies performed in the region that use geomorphic evidence (i.e., study of landforms and landform evolution) to demonstrate that folding within the San Luis-Pismo block has ceased or continued at a very slow rate during the past half million years and that the current vertical deformation of the Irish Hills is associated with brittle failure and block uplift (Killeen,[11] and Lettis et al.[12]). Killeen states that, “marine terraces, and stream profiles show low, zero, to almost zero rates of Quaternary activity around the Pismo syncline,” and “Data from paleo stream terrace gradients suggest that synclinal folding of the Pismo syncline has ceased, and that block uplift is the dominant style of deformation.” The Pismo syncline forms the core of the San Luis-Pismo block. Lettis et al., state that elevations of dated marine terraces show rigid uplift at a near constant rate of 0.1 to 0.2 mm/yr during the late Quaternary in the northwestern part of the block. This geologic evidence of block uplift of the Irish Hills is not consistent with the petitioners’ hypothesis of ongoing low-angle faulting over the past 5 to 6 million years on an “inferred” offshore thrust fault. However, as stated previously, the SSC model developed by the SSHAC team includes multiple alternative fault geometries to capture the range of potential mechanisms driving uplift of the Irish Hills. One of these alternative fault geometry models (Southwest-Vergent) considers the possibility of thrust faulting as the primary driving force for the uplift of the Irish Hills.

To further support the slip rate estimate for the “inferred” offshore thrust faulting beneath Diablo Canyon, the petitioners propose the use of the Airy isostatic gravity model in which the Earth’s crust floats on the denser mantle with variations in crustal thickness compensating for surface topography. Under this model, mountains have thicker crustal roots extending deeper into the mantle to balance the mass of the elevated terrain. This balancing mechanism is called isostasy, with a buoyant iceberg floating in water used as an analogy for the Earth’s crust floating on the denser mantle below. Based on a negative isostatic gravity anomaly across the Irish Hills, the petitioners assert that “the topography of the Irish Hills is not just isostatically compensated, it is over-compensated by crustal thickening.” The petitioners then use an “Airy ratio of 6:1” to calculate a slip rate of 2.8 mm/yr for the “inferred” thrust fault under the Irish Hills.

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[11] Killeen, K. M., “Timing of folding and uplift of the Pismo syncline, San Luis Obispo County, California,” University of Nevada, Reno, 1989

[12] Lettis, W. R., K. L. Hanson, J. R. Unruh, M. McLaren, W. U. Savage, and M. A. Keller, “Quaternary tectonic setting of south-central coastal California,” US Geological Survey, 2004.

An Airy ratio of 6:1 implies that for every 1 meter of vertical uplift of the Irish Hills, the crustal root beneath grows downward by 6 meters. The gravity profile that the petitioners use to support their claim of an extensive crustal root beneath the Irish Hills is from an American Geophysical Union meeting abstract[13] that shows a gravity low over the Irish Hills along coastal California near Diablo Canyon. In a peer-reviewed paper published in the journal *Lithosphere*, Langenheim et al.[14] provides their interpretation for the gravity low previously shown in the gravity map at the American Geophysical Union (AGU) meeting. Langenheim et al. combines gravity data together with aeromagnetic data to conclude that the gravity low across the Irish Hills originates from rock density contrasts within the upper 10 to 15 km of the crust rather than a deep extensive crustal root extending into the mantle. Specifically, the authors conclude that the gravity low across the Irish Hills is due to the density contrast between the low density (D=2270 kilograms per cubic meter (kg/m^3)) younger sedimentary rock that overlies the higher density (D=2710 kg/m^3) older basement rock. This conclusion is also supported by the aeromagnetic data gathered over the Irish Hills that shows “fairly” magnetic rocks underlie the upper younger sedimentary rocks.[15] Figure 9, from Langenheim et al.,[16] shows the gravity and magnetic models across the Irish Hills along with a geologic cross-section that provides the density and magnetic susceptibility values for each of the rock units. The low likelihood of a massive crustal root beneath the Irish Hills is further supported by the conclusions of Lowry and Pérez-Gussinyé,[17] which use a coherence analysis of gravity and topography to estimate an effective elastic thickness of 10 to 15 km along central coastal California. Under the simple Airy

[13] Langenheim, V. E., R. C. Jachens, R. W. Graymer, and C. M Wentworth, “Implications for Fault and Basin Geometry in the Central California Coast Ranges from Preliminary Gravity and Magnetic Data,” In AGU Fall Meeting Abstracts (Vol. 2008, pp. GP43B-0811), 2008.

[14] Langenheim, V. E., R. C. Jachens, R. W. Graymer, J. P. Colgan, C. M. Wentworth, and R. G. Stanley, “Fault geometry and cumulative offsets in the central Coast Ranges, California: Evidence for northward increasing slip along the San Gregorio–San Simeon–Hosgri fault,” Lithosphere, 5(1), 29-48, 2013.

[15] Id.

[16] Id.

[17] Lowry, A. R., and M. Pérez-Gussinyé, “The role of crustal quartz in controlling Cordilleran deformation,” Nature, 471(7338), 353-357, 2011.

isostatic model, the crust has no flexural rigidity, and its effective elastic thickness is assumed to be zero.

Finally, the petitioners use modeling of GPS data in the region to develop a third independent estimate for the total thrust fault slip rate beneath the Irish Hills. This estimate is not based on actual GPS measurements near Diablo Canyon as only the direction of shortening or compression (N15°E) is known in the region near the site. Despite this limitation, the petitioners used deformation modeling to determine a shortening rate of 2.0 mm/yr across the Irish Hills. In their presentation to the NRC staff, the petitioners acknowledged that the deformation models rely on “low resolution” finite element grids in the Irish Hills region (ML24198A105). Despite the low resolution of the model grid, the petitioners allocate all the 2.0 mm/yr of shortening across the Irish Hills to the “inferred” offshore thrust fault to determine a total thrust fault slip rate of 2.2 mm/yr beneath the Irish Hills. The amount of shortening (2.0 mm/yr) as well as the allocation of all the shortening across the Irish Hills to a single “inferred” thrust fault is questionable as there are other known active faults in the region that could accommodate the shortening.

The NRC staff’s review of PG&E’s SSHAC report documented PG&E’s consideration of GPS geodetic velocities useful for site-specific hazard estimation (ML16341C057). PG&E considered geodetic data and associated analyses to inform patterns and rates of deformation. Geodetic data and models were presented in 2012 at SSHAC Workshop 2 and in 2014 at SSHAC Workshop 3. The NRC staff’s review concluded that the SSHAC team used available geodetic data to provide regional constraints on the slip budget available for the study region (ML16341C057). However, the SSHAC team did not use geodetic data and numerical deformation models to directly assign slip rates to specific faults or rupture sources. Instead, the SSHAC team used the numerous geologic field studies and data gathered from geophysical surveys to estimate fault slip rates. The decision to rely primarily on geologic and geophysical data for seismic source characterization and to use GPS data as a secondary source of information to constrain the slip budget in the study region is justified because of the limited number of onshore GPS stations and the lack of offshore GPS stations in the region surrounding Diablo Canyon. Johnson et al.,[18] provides an overview of the deformation modeling approaches and concludes that deformation models have not reached sufficient maturity and require further research to identify uncertainties associated with these models.

In summary, the PRB concludes that the stratigraphic profile, gravity anomalies, and GPS modeling used by the petitioners do not provide adequate evidence to support the existence of a major “inferred” offshore thrust fault that extends beneath the Irish Hills with a fault length of 70 to 100 km and a slip rate between 2.0 to 2.8 mm/yr.

Concern 4: Seismic core damage frequency, estimated by PG&E in 2018 to be 3×10^{-5}, should be 1.4×10^{-3} per year (about once every 715 years) based on this higher recurrence rate for thrust earthquakes.

Based on its assessment of the petitioners’ concerns, described above in Concerns 1 to 3, the PRB concludes (1) that the seismic models developed by PG&E do not neglect the potential for thrust or reverse faulting beneath Diablo Canyon, (2) the tectonic setting along central coastal California differs substantially from that for the Noto Peninsula, and (3) the existence of a 70- to 100-km long “inferred” offshore thrust fault adjacent to Diablo Canyon with a slip rate between 2.0 to 2.8 mm/yr is highly unlikely. Therefore, the PRB concludes that a recurrence interval of 715 years for large ground motions from a Noto Peninsula type earthquake beneath Diablo Canyon and subsequent seismic core damage frequency (SCDF) of 1.4×10^{-3} per year are not credible values. The bases for the PRB conclusion are provided below.

[18] Johnson, K. M., W. C. Hammond, and R. J. Weldon, “Review of geodetic and geologic deformation models for 2023 US National Seismic Hazard Model,” Bulletin of the Seismological Society of America, 114(3), pp.1407-1436, 2024.

Using an average slip of 2 m from the 2024 Mw 7.5 Noto Peninsula earthquake and slip rates ranging from 2.0 to 2.8 mm/yr for the “inferred” offshore thrust fault, the petitioners estimate a recurrence interval of between 715 to 1000 years for an analogous event beneath Diablo Canyon. Based on the assumption that peak ground accelerations would be extremely large from this earthquake at Diablo Canyon, the petitioners assume that seismic core damage would occur and, therefore, the SCDF should be 1.4×10^{-3} per year (1/715 year). This SCDF value is about 47 times higher than the SCDF value (3×10^{-5} per year) determined by PG&E (ML18120A201) from its seismic probabilistic risk assessment (SPRA), performed in response to the NRC’s 50.54(f) request. The SPRA performed by PG&E used the hazard curves from its implementation of the SSHAC Level 3 SSC and GMC models in a probabilistic seismic hazard analysis (PSHA) to assess the frequency of seismic core damage at Diablo Canyon. The NRC staff reviewed the SPRA performed by PG&E and concluded that it adequately characterized the risk of seismic damage for Diablo Canyon (ML18254A040). As previously stated in the NRC staff’s response to Concern 1, based on its review of the SSC and GMC models, the NRC staff concluded that PG&E adequately captured the uncertainty in the data, models, and methods through use of the structured SSHAC approach (ML16341C057). Based on its assessment of the petitioners’ concerns, described above in Concerns 1 to 3, the NRC staff concludes that (1) the seismic models developed by PG&E do not neglect the potential for thrust or reverse faulting beneath Diablo Canyon, (2) the tectonic setting along central coastal California differs substantially from that for the Noto Peninsula, and (3) the existence of a 70- to 100-km long “inferred” offshore thrust fault with a slip rate greater than 2 mm/yr is highly unlikely.

In summary, the PRB concludes that a recurrence interval of 715 years for a Noto Peninsula type earthquake beneath Diablo Canyon and subsequent SCDF of 1.4×10^{-3} per year are not credible values.

III. Conclusion

As a result of the PRB review of the petitioners' concerns, the NRC has denied the petitioners' request. The request to shutdown Diablo Canyon is denied because the PRB concludes that (1) the seismic models developed by PG&E do not neglect the potential for thrust or reverse faulting beneath Diablo Canyon, (2) the tectonic setting along central coastal California differs substantially from that for the Noto Peninsula, (3) the existence of a 70- to 100 km long "inferred" offshore thrust fault adjacent to Diablo Canyon with a slip rate greater than 2 mm/yr is highly unlikely and, (4) the return period of 715 years for seismic core damage is not justified. Therefore, there is an insufficient basis on which to take enforcement action against PG&E and the petitioners' request is denied.

In accordance with 10 CFR 2.206(c), a copy of this director's decision will be filed with the Secretary of the Commission for Commission review. As provided for by this regulation, the decision will constitute the final action of the Commission 25 days after the date of the decision unless the Commission, on its own motion, institutes a review of the decision within that time.

Dated at Rockville, Maryland, this day of <Month Year>.

For the Nuclear Regulatory Commission.

Michael X. Franovich, Deputy Director,
Office of Nuclear Reactor Regulation.