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PG&E Letter DCL-25-003

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Independent Peer Review Panel
California Public Utilities Commission – Energy Division
505 Van Ness Avenue
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Re: Pacific Gas and Electric Company's Response to California Public Utility Commission Independent Peer Review Panel Report No. 16

In accordance with your request, attached is a formal response to the comments provided by the California Public Utility Commission Independent Peer Review Panel (IPRP) Report 16 on PG&E's 2024 seismic assessment report. The seismic update was performed in response to Senate Bill 846 (SB-846), which was passed in September 2022 to extend operation of the Diablo Canyon Power Plant (DCPP) and included a covenant to perform an updated seismic assessment. PG&E completed the seismic assessment update report in February 2024 -- hereafter referred to as the 2024 seismic assessment. The 2024 seismic assessment is a stand-alone report that fully addresses the requirements of SB-846. Any additional studies or assessments will be performed under the existing Long Term Seismic Program (LTSP).

The IPRP provided a technical peer review of selected elements of the seismic source characterization and ground motion characterization in the PG&E report. This letter addresses IPRP comments and questions on the seismic source characterization used in the 2024 model, including their proponent views on the modeled slip rate and weighting of four evaluation sites on the Hosgri fault. This letter also provides information requested by the IPRP on consideration of seismic studies that were not used directly in the seismic assessment and responds to questions and comments on the use of new ground motion models, site characterization inputs and adjustments, and the hazard methodology used in the 2024 model. PG&E will consider IPRP recommendations for additional seismic research under the LTSP, including an assessment whether faults (e.g. Casmalia fault) and fault parameters in the Santa Maria Basin are relevant to the hazard at DCPP and the potential for additional seismic studies to further reduce uncertainty in fault geometry models used in the 2024 assessment.

If you have any questions or require additional information, please contact Mr. Thomas Jones at (805) 459-4530.

Maureen R. Zawalick

January 14, 2025
Date

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Pacific Gas and Electric Company's Response to CPUC Independent Peer Review Panel Report No. 16

1 Introduction

This letter responds to the California Public Utility Commission (CPUC) Independent Peer Review Panel (IPRP) Report 16 on PG&E's 2024 seismic assessment report. The seismic update was performed in response to Senate Bill 846 (SB-846), which was passed in September 2022 to extend operation of the Diablo Canyon Nuclear Power Plant (DCPP) and included a covenant to perform an updated seismic assessment. PG&E completed the seismic assessment update report in February 2024 -- hereafter referred to as the 2024 seismic assessment. The 2024 seismic assessment is a stand-alone report that fully addresses the requirements of SB-846. Any additional studies or assessments will be performed under the existing Long Term Seismic Program (LTSP).

2 Background

2.1 Senate Bill 846

SB-846 states that the loan agreement with the California Department of Water Resources (DWR) must include:

> *A covenant that the operator shall conduct an updated seismic assessment.*

2.2 Seismic Assessment Process

The 2024 seismic assessment was conducted from June 2023 to January 2024. The scope and schedule of the project were developed given the overall goal and schedule of SB-846 to evaluate the impact of updates in seismic hazard to determine if plant modifications or retrofits may be required during the period of extended operations. The project plan was reviewed by the Diablo Canyon Independent Safety Committee (DCISC), and DWR that serves as the lead agency. The update was organized following best practices of a Senior Seismic Hazard Analysis Committee (SSHAC) Level 1 study, which includes defining Technical Integration (TI) teams of subject matter experts to conduct the work and a Participatory Peer Review Panel (PPRP) to review the process of data and model evaluation, development, and documentation by the TI Teams. A SSHAC Level 1 study is specified to be an appropriate level for performing review of existing SSHAC Level 3 studies such as previously performed for the DCPP and accepted by the U.S. Nuclear Regulatory Commission (NRC) in 2015.

The participants in the seismic update assessment are topical experts in the areas of seismic geology, seismology, earthquake engineering and seismic risk, have considerable experience performing nuclear seismic SSHAC studies, and were involved with the 2015 SSHAC studies for DCPP. In accordance with the SSHAC process, the TI Teams were responsible for evaluating the data, models, and methods, integrating the data into updates to the hazard models, and developing documentation. Participatory review occurred at two levels. The first level was the PPRP, a standard element for a SSHAC study. Additionally, a team of external reviewers from the University of California (UC) Los Angeles B. John Garrick Institute for the Risk Sciences and UC Santa Barbara provided a second level of external review that focused on the evaluation process. The project was executed with oversight from the DCISC and DWR including observation of technical workshops addressing review of previous studies, new information and models, impact evaluation and analyses results.

In accordance with the SSHAC process, the 2024 assessment reviewed the center, body, and range of the technically defensible interpretations of both new and previously available data, models, and methods. The TI Teams began with a documentation review of what methods and models were used in the previous comprehensive 2015 SSHAC seismic study and what new information has become available since that time. New information was reviewed with respect to relevance for the seismic hazard input and ground motion evaluation, data quality, and documentation. Each TI Team, with oversight from the PPRP, evaluated new data and applied appropriate criteria for inclusion. This step of determination of inclusion is supported in NUREG 2213 (NRC, 2018):

> *The imperative to capture the full range of the integrated distribution should not lead the experts doing the model-building to include alternatives in their models only as a means to convey the impression of broad capture of epistemic uncertainty. The integration process need not be inclusive of all available interpretations and those interpretations deemed not credible by the TI Team must be culled from analysis.*

While the TI Team members assessed a broad range of data, models and methods in their review of published and unpublished literature, including from public testimony, they included only models and parameter values defensible for site-specific hazard and risk analysis in their final analyses. These decisions were reviewed by the PPRP team and documentation of these decisions is included in the report.

2.3 Model Development

The starting seismic hazard model for the update was developed in 2015 and was based on information from two programs. The first program involved extensive new seismological, geophysical, and geological data collection at and near the DCPP site under the LTSP and California Assembly Bill 1632. The second program involved developing new models for probabilistic seismic hazard analysis (PSHA) under the SSHAC Level 3 process in response to a request from the NRC following the

Fukushima Dai-Ichi accident in Japan. The SSHAC Level 3 studies examined new information and technically defensible data, models, and methods that could impact seismic hazard or represent a significant change in seismic risk. Even though the 2015 SSHAC Level 3 PSHA model was used as a starting basis for the seismic update, considerable effort was spent to critically review the existing model and integrate any new significant information or updates to approaches.

In PSHA, the seismic source characterization (SSC) defines the sources of earthquakes that can produce ground motions of engineering significance and the magnitudes and rates of those earthquakes. In site-specific PSHA, the SSC modelling approach includes a screening process to evaluate the most significant sources and focuses effort on those seismic sources that contribute most to the annual hazard at the site at the hazard levels and spectral frequencies that are the most important to seismic safety. The sources and source parameters from the 2015 SSC model that contribute most to this hazard are related to the Hosgri, Los Osos, Shoreline, and San Luis fault sources and the local background seismic source zone (Figure 1). The 2024 assessment focused on these sources.

The ground-motion characterization (GMC) in PSHA quantifies the ground shaking associated with seismic sources. The GMC model defines the median, aleatory variability, and epistemic uncertainty of ground motion. The ground-motion characterization for the 2015 study for DCPP followed a partially non-ergodic approach as part of the 2015 Southwest United States (SWUS) model. In the 2024 assessment, the median ground-motion model was evaluated in terms of (1) approach; (2) treatment of features such as location relative to the hanging wall, directivity, splay ruptures, and complex ruptures; and (3) performance compared to recent preliminary empirical ground-motion data.

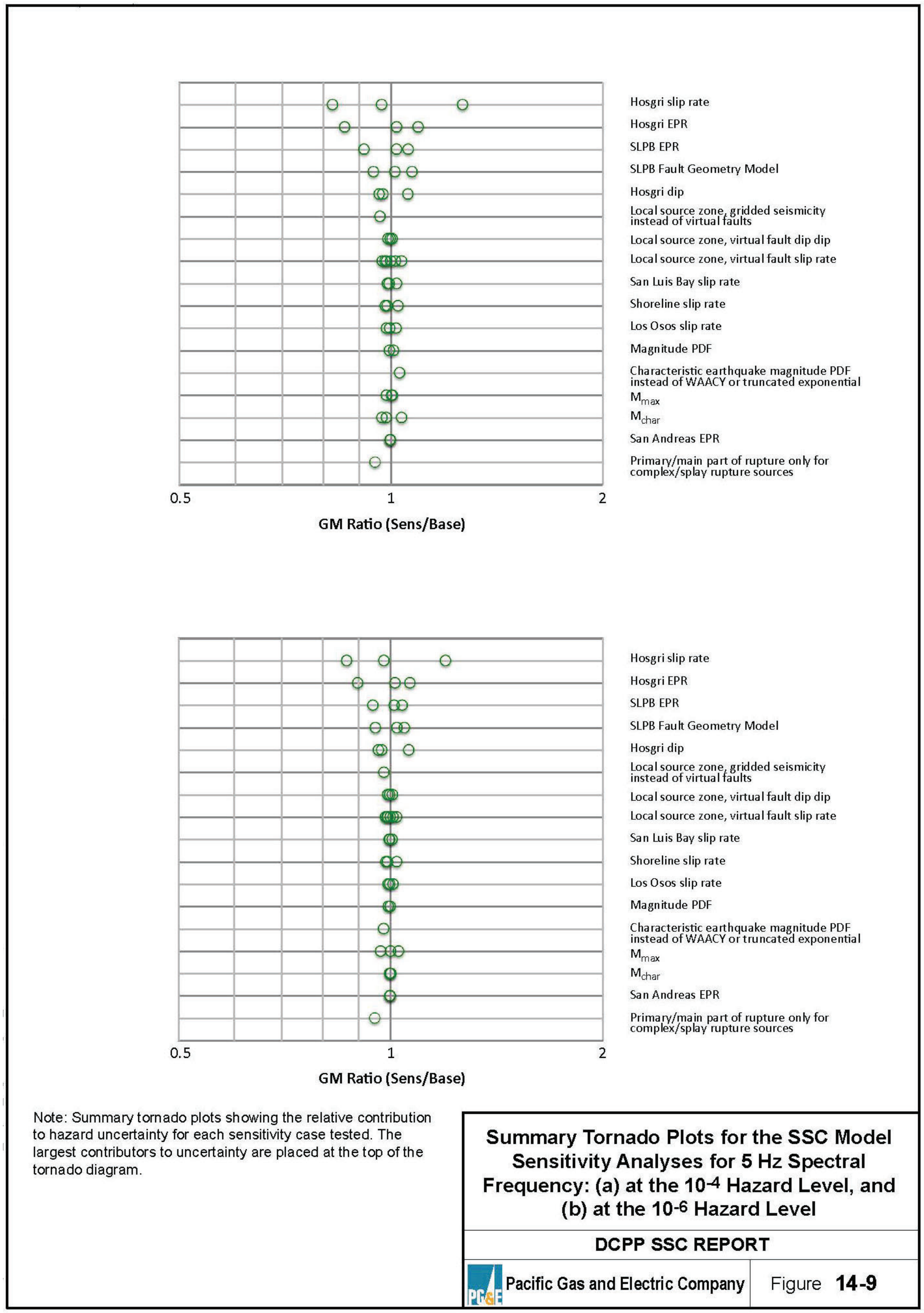

Figure 1. Tornado Plots Highlighting Hazard Significant Seismic Source Parameters for DCPP for 5 Hz. (from PG&E, 2015, Figure 14-9).

2.4 Seismic Assessment Results

For the SSC model component of the 2024 seismic update, the review of recently published data, models, and methods found that most new information is consistent with information available to the 2015 SSC SSHAC TI Team, and no new information, including proponent models offered through public testimony, warrant changes to the model. The exception to this general finding is new information from several publications concerning the Hosgri and Los Osos fault slip rates. Based on new research on the origin, stratigraphic development, and age of a sea-floor feature called the Cross-Hosgri Slope (CHS) that is located north of DCPP (offshore Point Estero), the estimated geologic slip rate at this site is interpreted to be more reliable and given a higher logic tree weight (0.5) than it was during the 2015 SSC studies (0.2). As a consequence of this new information, slip rates at three other sites were assigned lower weights to account for the increased weight of the CHS rate. Based on these modifications, the geologic slip rate of the Hosgri fault near DCPP has been recalculated, and the weighted-mean slip rate of the Hosgri fault source is 26 percent higher than in the 2015 SSC model (2.14 millimeter/year [mm/yr] weighted-mean slip rate compared to 1.70 mm/yr in the 2015 SSC model).

In addition to the revision to the Hosgri fault source slip rate, the slip rate of the Los Osos fault source has been revised in this seismic update. The change in Los Osos fault slip rate is based on a new model of tectonic uplift rates along the central California coast as recorded by marine terraces. This new model provides more refined estimates of paleosea levels at the time of marine terrace formation based on the incorporation of local glacio-isostatic adjustment effects. Including the new uplift rate model in the Los Osos fault source slip rate calculations results in a decrease in mean slip rate compared to the 2015 SSC model of about 9 percent to 15 percent. The magnitudes of the changes in mean slip rate for the Los Osos fault source range between 0.02 and 0.04 mm/yr, which are an order of magnitude less than the 0.44 mm/yr change in mean slip rate for the Hosgri fault source.

This increase in mean Hosgri slip rate has resulted in a change in another SSC model element called the equivalent Poisson hazard ratio (EPHR) that captures uncertainty related to time-dependent earthquake recurrence behavior. The change in mean EPHR for the Hosgri fault source due to the increase in mean slip rate is an increase of approximately 3 percent, from an EPHR of 1.20 in the 2015 SSC model to 1.24. No changes to the mean EPHR for the Los Osos fault source were warranted.

Because the recommended changes to the models were limited to SSC parameters that affect the rate of earthquakes from specific seismic sources, the updated hazard was captured through scaling the 2015 PSHA hazard results. The same scaling approach was used to adjust the EPHR for the Hosgri fault. This scaling process was performed for 17 spectral frequencies from 100 hertz (Hz) to 0.333 Hz. Scaled updated mean hazard curves for each spectral frequency for the reference rock horizon were computed, and the resulting uniform hazard spectra and ground-motion response spectrum were estimated. A comparison of these results with the previous 2015 Uniform Hazard Spectrum results shows an increase in ground motions of about 5–7 percent in the lowest frequencies range and about 3–4 percent in the intermediate to high-frequency ranges that the plant systems, structures, and components are sensitive to. Even with these minor increases in hazard, seismic risk for the plant remains well below NRC thresholds, as discussed further below.

In the 2024 assessment, the median ground-motion model was evaluated in terms of (1) approach; (2) treatment of features such as location relative to the hanging wall, directivity, splay ruptures, and complex ruptures; and (3) performance compared to recent preliminary empirical ground-motion data. Based on this evaluation, the median ground-motion predictions from the SWUS ground-motion model were found to be generally consistent with new empirical data, and comparisons of the median predictions from the DCPP model to available non-ergodic ground-motion models also indicated consistent results. The aleatory variability model developed as part of the SWUS study was also evaluated. It was determined that the newly developed preliminary datasets are not sufficiently complete in terms of the metadata to be used to calculate updated components of aleatory variability for the large-magnitude and short-distance ranges of interest for DCPP (e.g., M > 5 and R_{RUP} < 50 km). Furthermore, components of the DCPP aleatory variability model were compared to more recent studies. The model was found to be consistent in the approach, elements of the logic tree, and results in the magnitude and distance ranges of interest. Based on these conclusions, no changes are warranted for the median and aleatory variability models of GMC.

In 2015, site-specific adjustment factors were developed to adjust the SWUS GMC model to site-specific conditions at DCPP. These site-specific adjustments were developed using analytical site-response analysis, as well as an empirical approach based on recordings at the plant. No new ground-motion data were recorded at the plant since the conclusion of the 2015 study. The site-adjustment approaches were reviewed, and no changes are warranted. A preliminary non-ergodic ground-motion modeling approach was applied to estimate the empirical site term at DCPP and its regional and uncorrelated components. Results from the non-ergodic analysis indicate that the regional site term in the vicinity of DCPP shows a below-average trend in ground motion consistent with that observed in the 2015 empirical site term at frequencies greater than 1 Hz. This consistency in the trends between the regional and the site-specific empirical terms supports and explains the 2015 site terms. The site term from the non-ergodic analysis was not adopted due to the preliminary nature of the dataset used and the preliminary nature of the analysis performed.

Impacts of the changes in scaled hazard for plant risk were evaluated utilizing the current Diablo Canyon Probabilistic Risk Assessment (PRA) model of record, a full-scope model including internal events, internal flooding, internal fire, and seismic hazards. This model was recently updated in August of 2023 and includes updates to equipment reliability data and resolutions to industry peer-review comments. The results of this assessment indicate that the total core damage frequency and large early release frequency (LERF) for DCPP remain below region II risk criteria from Regulatory Guide 1.174 Revision 3 (total core damage frequency and LERF are less than 10^{-4} yr^{-1} and 10^{-5} yr^{-1}, respectively) for all the hazard scaling factors used in this assessment.

2.5 Independent Peer Review Panel and Review of 2024 Seismic Assessment

Background

In 2006, the California Legislature enacted Assembly Bill 1632 (AB 1632), which was codified as Public Resources Code Section 25303. AB 1632 directed the California Energy Commission (CEC) to assess the potential vulnerability of California's largest baseload power plants, which includes DCPP, to a major disruption due to a major seismic event and other issues. CPUC decision D. 10-08-003 approved funding for the proposed seismic hazard studies and established the IPRP.

The IPRP members represent the California Geological Survey, California Coastal Commission, California Seismic Safety Commission, County of San Luis Obispo, as well as the CEC and the CPUC. Since 2011, the IPRP has held public meetings, participated by PG&E, and issued reports to comment on seismic hazard studies proposed by PG&E.

Studies conducted in response to AB 1632 are described in a series of reports collectively known as the Central Coastal California Seismic Imaging Project (CCCSIP). Reviews and comments on these studies are contained in IPRP reports.

Following the completion of studies authorized by AB 1632 and submission of the CCCSIP report to the NRC, the California Legislature passed and the Governor signed AB 361, which authorized continuation of the IPRP to review seismic studies of the DCPP area through the term of the plant's operating license. Although the studies authorized by AB 1632 and IPRP review of those studies have been completed, the IPRP continues to monitor PG&E-sponsored research conducted under the LTSP for DCPP, especially for research opportunities identified by the CCCSIP studies as part of discussion and recommendations for studies conducted under the LTSP.

Review of 2024 Seismic Assessment

The IPRP released IPRP Report Number 16, titled Initial Review of the PG&E "Updated Seismic Assessment, February 2024," by the Independent Peer Review Panel for Seismic Hazard Studies of the Diablo Canyon Nuclear Power Plant on August 26, 2024.

The scope of the review is described as follows in the report introduction:

> *This technical review will focus on issues that the IPRP has been actively engaged with since the inception of the IPRP, namely the seismic source characterization and ground motion characterization of the earthquake hazard at DCPP. We will discuss PG&E's revisions to the seismic source model. We will also comment on additional data and studies that may influence the SSC model that were not considered in the Update. We follow this with a summary of the ground motion data and analyses presented in the Update. Our conclusions will follow each of the three issues reviewed: Hosgri fault slip rate, Los Osos fault/Irish Hills Tectonic Model, and Ground Motions. Since the ground motions are based on SSC documented in the Update (PG&E, 2024) and the IPRP has open questions about the SCC, our ground motion review is limited to the methods and not on the final hazard results.*

The IPRP review does not consider changes to the EPHR or contentions by Dr. Peter Bird which it expects to address in the future.

The intent of the IPRP's report is to share the findings of its technical review with the public, PG&E, and the DCISC. The IPRP expects a written response to its findings. This letter constitutes PG&E's response to the IPRP report.

IPRP Review Comments and PG&E Responses

The following sections summarize IPRP review comments on seismic source characterization and ground motion models used in the 2024 seismic assessment and the PG&E response. Each section is divided into subject areas where the IPRP provided comments. In this response, each subject area includes subsections that include relevant background information (as needed), comments extracted from the IPRP report (italicized) and the PG&E response. Comments that address similar topics are bundled and addressed together.

The responses are based on input from the 2024 seismic assessment report authors, including the TI Team, PPRP and PG&E sponsors. PG&E met remotely with a subset of IPRP members, including Dr. Gordon Seitz, Timothy Dawson, Dr. Rue Chen and Dr. Judy Zachariason of the California Geologic Survey and Philip Johnson of the California Coastal Commission to ask clarifying questions about selected comments in the IPRP report.

3 SEISMIC SOURCE CHARACTERIZATION

IPRP review comments on the SSC focused on the Hosgri fault slip rate characterization in the 2024 seismic assessment and focused on three topics:

modelled offset and age uncertainties for the CHS site offshore of Pointe Estero, weights assigned to slip rate cumulative density functions for the four Hosgri slip rate sites considered in the model and consideration of an independent NRC-sponsored study (Center for Nuclear Waste Regulatory Analyses [CNWRA], 2016) on the Hosgri fault slip rate.

3.1 Hosgri Slip Rate: Cross-Hosgri Slope, Point Estero

Context

In the Point Estero study area, Johnson et al. (2014) documented a submerged linear slope (the CHS) and interpreted the feature to have formed slightly below sea level during the Younger Dryas stadial (~12.8–11.5 ka). They interpreted that the CHS was abandoned during meltwater pulse 1B, directly after the Younger Dryas stadial, when sea level rose rapidly. Johnson et al. (2014) used slope-normal profiles from slope maps derived from a high-resolution multibeam echosounder (MBES) survey to interpret a lateral offset of the lower slope break. Assuming an age of the submersion and preservation of the lower slope break from global sea-level curves, they interpreted a lateral slip rate for the primary strand of the Hosgri fault.

Since completion of the 2015 SSC SSHAC study, as part of LTSP-supported research, new data has been collected that improves our understanding of the genesis and evolution of the CHS. New data includes high-resolution seismic reflection data, vibracores, radiocarbon analyses, and optically stimulated luminescence (OSL) analyses of sediments collected from the vibracores. Interpretations of these data, together with the data themselves, are presented in recent publications by Kluesner et al. (2023) and Medri et al. (2023). The new data demonstrate that the CHS has a complex depositional history and consists of two primary stratigraphic units.

This improved understanding of the complexity of the CHS demonstrates that the offset measurements used by Johnson et al. (2014) to calculate slip rate were from a different surface than the shoreface that was abandoned at the end of the Younger Dryas stadial. Kleusner et al. (2023) conclude that the seismic reflection and core data indicate that the lower slope break reasonably represents the base of the original shoreface (unit 1). They note that the overlying deposit that post-dates the shoreface (unit 2) thins downslope, becoming only about 50-60 cm thick at the lower slope break near the Hosgri fault trace, and suggest that the presence of unit 2 does not compromise this distinct geomorphic feature as an offset marker across the fault (a piercing point). They also note that even if they ignore or remove the thin unit 2 cover, it would not change the locations of the lower slope break relative to one another on bathymetric slope profiles. As a result, Kleusner et al. (2023) use the same offset amounts and uncertainties characterized by Johnson et al. (2014), together with a refined age model, to recalculate the Hosgri fault slip rate.

The new information on the stratigraphy and age dating of the CHS resulted in changes to PG&E’s SSC model of uncertainties representing the lateral offset amount of the CHS and age of the offset feature. Instead of adopting the published uncertainty estimates for the lateral offset amount and age model, PG&E’s SSC model approach is to define uncertainty probability density functions (PDFs) based on the information in the published report and independent analysis that is documented in PG&E’s reporting and was reviewed and discussed with the PPRP. For the lateral offset amount, the PG&E seismic update adopts the same preferred range of lateral offset of 26–35 m that was used in the 2015 model. The TI Team concurs with Kluesner et al. (2023) that the approach adopted by Johnson et al. (2014) remains the best available means to measure the lateral offset of the feature. This range of lateral offset, which is used to define the top of a trapezoidal uncertainty distribution, represents the ± 1 standard deviation values estimated by Johnson et al. (2014) using the lower slope break of the CHS and the United States Geological Survey (USGS) MBES dataset.

The minimum and maximum offset values in the trapezoidal PDF are expanded in the updated assessment to account for additional sources of uncertainty in the offset of the relict shoreface feature. The updated limits are set to 10 m beyond the ± 2 standard deviation values from the Johnson et al. (2014) analysis.

IPRP Comments and PG&E Responses

Several IPRP comments focus on how uncertainty in displacement measurements for the offset CHS was considered by Johnson et al., 2014/Kluesner et al., 2023 and the 2024 PG&E seismic assessment.

> *Johnson et al. (2014) included an estimate of uncertainty in the CHS offset measurement, and Kluesner et al. (2023) report that the previously unrecognized blanketing layer does not appear to impact the offset measurement significantly: " ... we do not think it compromises this distinct geomorphic feature as a piercing point". Their measurements have defined uncertainties, based on documented best matching of piercing lines, they published their method, and have gone through two peer reviews (2014, 2023).*
>
> *As all (Johnson et al., 2014, Kluesner et al., 2023, PG&E, 2024) assessments of the CHS agree that the lower slope break is the most reliable offset feature to measure, the modification of values to account for less reliable features does not appear well supported. From the data presented in Johnson et al. (2014) and Kluesner et al. (2023), their estimates with uncertainties appear justified as-is with no additional modifications.*
>
> *PG&E (2024) used this near-surface layer and speculative interpretations of the slope morphology to modify the offset measurement probability density function (PDF) from that presented by*

> *Kluesner et al. (2023) (Fig.3 a). PG&E stated: " ... there is no good basis for a preferred offset within this range ... " in support of their decisions to apply a trapezoidal PDF to the reported offset data," ... as there are several remaining uncertainties related to the approach used to define the lower slope break".*

As noted in the 2015 PG&E report, the slope includes erosional hollows near the top and depositional lobes near the bottom, suggesting that the CHS has been modified by slumping and, perhaps, incision by submarine currents. Slope break measurements from the top and the bottom of the CHS include steps and bulges that appear to be associated with these slumps, suggesting that the top and bottom of the slope have been modified since it was formed. Given the likelihood that the feature is composed of saturated sand and has undergone multiple earthquake ruptures and associated strong ground motion, some slope failures or lateral spreading can be expected.

Only a subset of slope break measurements was used by Johnson et al. (2014) to characterize offset of the CHS feature, therefore it is not clear that the subset used to measure offset best represents the original geometry of the feature. The part of the slope directly east of the fault appears to have degraded, and the slope may have widened, moving the lower slope break farther south from its original position. The slope break points that are east of the fault and are used to measure offset are significantly farther from the top of the slope than the slope break points from the steeper, and possibly more intact, part of the slope farther to the east. Regressing different subsets or the entire collection of measurements yields markedly different estimates of offset.

Kluesner et al. (2023) use the same offset amounts and uncertainties characterized by Johnson et al. (2014) to recalculate the Hosgri fault slip rate. They note, however, that “it seems possible that undetected variations in unit 2 thickness could lead to greater uncertainty in locating the minimally buried base of the latest Pleistocene shoreface, but that increase cannot be quantified with current data.”

The TI Team agrees with Kluesner et al. (2023) that the presence of unit 2 burying the relict shoreface, and the potential variability in the thickness of unit 2, leads to greater uncertainty in locating the base of the shoreface, and consequently, greater uncertainty in estimates of the amount this feature is offset by the fault. Kluesner et al. (2023) provides four new chirp profiles, with one of the four profiles having information from sediment cores. It is difficult, therefore, to accept with high confidence the assumption made by Kluesner et al. (2023) that the variability in thickness of unit 2 at the lower slope break is negligible and can be ignored. As noted above, fault offset of the shoreface was interpreted by Johnson et al. (2014) from measurements of the break-in-slope between the face of the CHS and the gently sloping seafloor below. The position of the slope break was selected from each bathymetric profile as the intersection of straight lines fitted to both slopes (Johnson et al., 2014). This method of selecting slope break locations is highly sensitive to the slope of the feature itself, which is defined by the deposition of unit 2 sediments, and not by the top of the shoreface deposits (top of unit 1).

As in the 2015 SSC study, the TI Team for the 2024 study continues to believe that there is no good basis for a preferred offset amount within this range that should be used as a mean value in a normal distribution, given the several remaining uncertainties related to the approach used to define the lower slope break, the number of bathymetric profiles used to define an original shape of the lower slope break away from the fault, and the multibeam data and data processing itself.

The expansion of the minimum and maximum offset values in the trapezoidal PDF justifiably account for additional sources of uncertainty in the offset of the relict shoreface feature given the new information about the erosional history and stratigraphic complexity of the CHS feature (Kluesner et al., 2023) and the unknown variability or systematic differences in the modification of the feature due to erosion and deposition since its formation during the Younger Dryas stadial and subsequent abandonment.

> *PG&E made changes to the [CHS] chronology, although these revisions are not documented sufficiently for a full evaluation. PG&E should explain their decisions to broaden the uncertainties and by how much.*

Radiocarbon and OSL dates from the CHS shoreface unit are consistent with deposition during the Younger Dryas stadial. For the age of the offset feature, the uncertainty PDF in the 2015 model used a triangular distribution with a preferred value of 12 kiloannum (ka) and a minimum and maximum ages of 11.5 and 12.5 ka, respectively, after Johnson et al. (2014). For the 2023 update, the TI Team interprets an age uncertainty distribution that has a similar maximum age limit, but has a preferred age range and a minimum limiting age that are younger than the values considered in 2015 (Table 5-14 in the 2024 assessment). This adjustment to the age uncertainty PDF is based on radiocarbon ages of reworked shell hash dated by Kluesner et al. (2023) and the additional age dating and stratigraphic information that suggests the slope was likely active at the end of the Younger Dryas. Specifically, it reflects possible smoothing/renewing of the slope break after the shoreface was formed and while an offset feature was still subject to strong wave energy. This age uncertainty PDF encompasses, but is broader than, the 11.7 ± 0.1 ka age of the CHS lower slope break adopted by Kluesner et al. (2023) in their slip-rate calculations. This narrower age range is based on a preferred age model from Bayesian modeling. The main basis for expanding the age uncertainty range for the SSC model update is because the age of interest for the slip rate calculation is when the offset feature was no longer modified by wave energy and started recording measurable lateral offsets, rather than the interpreted age of the shoreface itself.

> *The Kluesner et al. (2023) results are peer-reviewed and well documented. If PG&E chooses to reinterpret the data and develop an*

> *independent slip rate estimate, rather than simply integrate what has been published into the SSC, this should be carefully documented, published formally, and peer-reviewed independently as a new stand-alone model. In particular, the choice of Offset PDF in the 2023 SSC Update for the CHS is a significant departure from the published Kluesner et al. (2023) model and should be further vetted and if pursued should be documented at a peer-review level.*

As part of the SSHAC process, published data are evaluated by the TI Team and any modifications or decisions are carefully documented and reviewed. The idea that adjustments to published data need to be published before inclusion in seismic hazard assessments is not consistent with SSHAC process or engineering state of practice. The basis for decisions made to expand uncertainties in displacement estimates and the abandonment age of the CHS were carefully considered and documented in the 2024 seismic assessment report text, tables and figures and were peer reviewed by the PPRP and independent reviewers by the UCLA Garrick Institute of Risk Sciences during meetings, review of the draft and final reports.

PG&E agrees that the CHS offset could be evaluated further under the LTSP with a desktop analysis of existing data, or collection of additional chirp profiles to assess the consistency of the thickness of the blanketing unit.

3.2 Weighting of the Four Slip Rate Sites Used by PG&E for the Hosgri Fault

Context

The 2015 SSC model slip rate cumulative density function (CDF) for the Hosgri fault was based on developing slip rate CDFs at four sites along the fault within the general vicinity of the DCPP (PG&E, 2015, Chapter 8) (Figure 5-38 in the 2024 assessment). The sites include, from north to south, San Simeon, Point Estero (CHS), Southern Estero Bay, and Point Sal. At each slip rate site, the preferred values and uncertainty ranges of both the offset amount and the age of the offset feature were captured using one or more trapezoidal PDFs. As discussed in PG&E (2015, Chapter 8), the slip rate CDF represents the target slip rate (mean and uncertainty distribution) for the sections of the Hosgri fault source closest to the DCPP, which are the sections that contribute most to hazard at the return periods of interest (Section 5.1.2 in the 2024 assessment). The rupture sources and slip rate allocation models add additional slip rate to sections of the Hosgri fault source north of the DCPP due to the addition of rupture sources involved with the intersections of the Hosgri fault with the Shoreline and Los Osos faults (PGE, 2015, Chapter 8). This additional slip rate is consistent with the interpretation that the Hosgri-San Gregorio fault system slip rate increases from south to north as fault-parallel motion is transferred to the fault system from intersecting faults to the east.

Based on the findings in recent publications by Kluesner et al. (2023) and Medri et al. (2023), the 2024 TI Team interpreted the geologic slip rate at the CHS to be more reliable than it was during the 2015 SSC studies, and therefore the weights allocated to the four slip rate sites needed to be revised. Reweighting the four slip rates sites considers three main criteria, as follows:

- The age of the offset feature
- The location of the slip rate site along the Hosgri fault and its proximity to the DCPP
- The confidence that the interpretation of the site provides a reliable result

The weighting process considers the likelihood that each site represents the correct slip rate for the Hosgri fault to calculate site-specific hazard at the DCPP.

IPRP Comments and PG&E Response

Several IPRP comments focus on age ranges for fault data (e.g. offset features used for slip rate measurements) that are most appropriate for the site-specific hazard assessment for DCPP.

> *The Holocene age range (11.7 ka) has been established to be most representative for seismic hazards on high slip rate faults like the Hosgri fault because it includes enough earthquake recurrence intervals for a robust average, yet avoids the uncertainties associated with much older, several hundred thousand year, rates.*
>
> *While well-constrained slip rates over several time frames (e.g. Holocene, Late Quaternary, and Quaternary) would be ideal to demonstrate the stationarity or variability of fault slip rates through time, in the absence of such data, the use of faster, shorter-term rates is more conservative, unless there are serious and demonstrated concerns regarding the reliability of the shorter-term slip rates.*
>
> *We agree with PG&E's statement: "Given the complicated, multistage structural evolution of the central coast of California over the last 5 Ma, a slip rate over this time frame may not be applicable to the current tectonic framework". However, we would qualify their statement: "The relevant time frame of interest for site-specific seismic studies is the Late Quaternary". (Section 6.3.2, PG&E, 2024), as there is evidence that the most representative time frame for PSHA is the Holocene, especially when there is evidence that the slip rates have increased from the Quaternary to the Holocene time periods.*

PG&E is not aware of a documented standard that recommends use of only Holocene averaged slip rates for site-specific seismic hazard studies, has guidelines for time intervals to consider based on fault slip rate, or finds slip rates averaged over hundreds of thousands of years unreliable or low quality. On the contrary, NRC guidelines consider Quaternary fault data to be high quality and pre-Quaternary data to be low quality (NRC, 1997).

The IPRP notes that the Hosgri slip rate may have increased between the Pleistocene and Holocene based on the following observations: 1) mean slip rates calculated based on features that are hundreds of thousands of years or more are lower than the mean Holocene slip rate at the CHS site and 2) an independent slip rate calculated in an NRC-sponsored study that appears to increase over time (CNWRA, 2016). The TI Team considered these proponent models and while not developed further for the 2024 assessment, they are accounted for in the Hosgri fault slip rate CDF. Given that slip rate uncertainty between the CHS and other sites overlap with one another (Figure 2, Figure 5-41 in the 2024 assessment) and overlap with the Late Pleistocene rate for the CNWRA site, a slip rate increase is not a unique interpretation of the data. This is underscored by the CNWRA conclusion that highlights an alternate and perhaps preferred explanation for a potential slip rate increase at the site – that the apparent slip rate increase represents fault integration at a structural complexity. This alternative is not mentioned in the IPRP review.

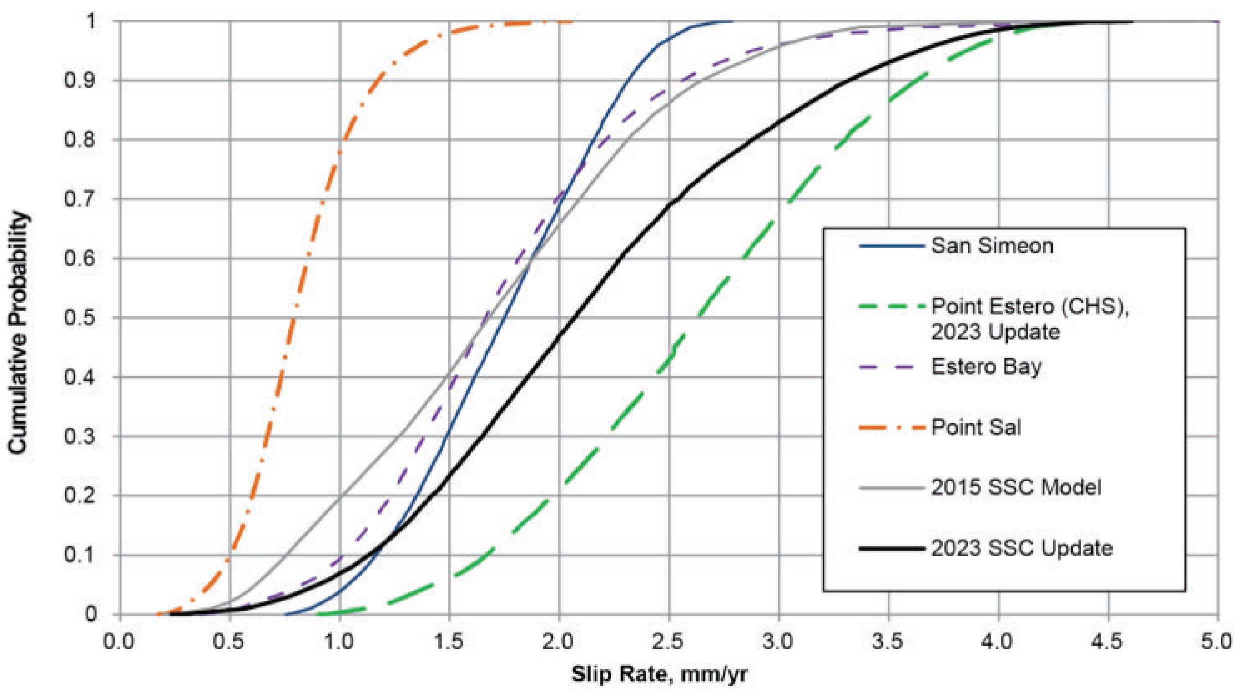

Figure 2. Hosgri fault slip rate CDFs (PG&E, 2024, Figure 5-41).

Because the charge of the TI Team is to capture the Center, Body and Range of Technically Defensible Information to develop a mean-centered model, Hosgri slip rates from older features were still included in the model because they represent a possible correct average fault slip rate for use in the PSHA. For a moderate slip rate fault such as the Hosgri fault, the number of recurrence intervals over hundreds of thousands of years may be more statistically meaningful than the number of recurrence intervals over 10,000 years. Slip rates averaged over hundreds of thousands of years may average out slip rate variations that can occur on the scale of thousands to tens of thousands of years due to complex fault interactions (e.g. Dolan et al., 2016) or sea level changes (e.g. Rockwell and Klinger, 2023).

> *Now that the CHS site has been improved by additional published studies, diluting the quality of the final weighted slip rate estimate by including less relevant site data is less defendable.*
>
> *We think it is best practice to use all data for overall screening, but it is not appropriate to include flawed data to calculate slip rate, and dilute the significance of the highest quality, most applicable slip rate determination for seismic hazards. If poor quality site data is included in determining the weighted slip rate on this section of the Hosgri fault, one may underestimate the hazard because all the poor- quality sites have much lower rates and, if overweighted, may bias the slip rate and hazard estimate too low.*
>
> *Further, if a site is ranked low in age applicability (e.g. Southern Estero Bay and Point Sal), why is it being considered for inclusion at all?*

Because no site is without some potential issues and uncertainties, the TI Team's approach is to evaluate each technically defensible site as a possible correct representation of the long-term slip rate in the current tectonic regime, and weight that site by its relative likelihood of being "correct." The philosophy is that including more information that is technically reasonable in the analysis has a better chance of approaching the correct result. Attaching zero weight to alternative locations is a very strong statement and would require that the data or method used to develop the slip rate at the site is technically not defensible, or that the rate is demonstrably wrong. The process does not substitute what is "preferred" given the available data with what provides the possible "correct" answer.

> *We also question the utility of the slip rate site location criterion, given that all sites are within an anticipated rupture length distance from the DCPP. Because we only have confidence in the San Simeon and CHS sites, and the CHS is much closer, we would rank it higher.*
>
> *In addition, in the data presented, we find no evidence for decrease in the Hosgri fault slip rate from San Simeon to Point Sal in the Holocene. There appears to be very little well-constrained data, such as rates on other structures, that indicates slip rates are changing along strike of the Hosgri fault.*

The model estimates the rate of all Hosgri fault ruptures for the plant. PG&E agrees the decrease in the slip rate of the Hosgri fault from north to south is currently poorly constrained and could be tested further through future LTSP research. However, branching of faults to the east suggests there should be at least a limited decrease in slip rate southward along strike. This is, in part, why Pt. Sal has some weight (though very low); because the total change is not expected to be significant, the long-term average slip rate of this site MAY be the correct interpretation. Alternatively, the kinematic model for the Hosgri fault may not be complete, and there could be other reasons why the slip rate on the southern part of the Hosgri tapers faster than would be expected given branch faulting.

> *We would weight a mid-late Quaternary slip rate much lower than a Holocene rate.*
>
> *We therefore agree with PG&E (5.3.1.2., 2024): "Due to the more thorough documentation of the CHS age and stratigraphy (Kluesner et al., 2023, Medri et al., 2023), there is greater confidence now than in 2015 that the geological interpretation of the site is correct and that the slip rate estimated from the site is a reliable estimate of slip rate for the Hosgri fault source near the DCPP.*

Weighting in the PG&E model is consistent with the IPRP proponent model where the Holocene rate for the CHS site is given a higher weight than the other three slip rate sites. The difference in specific weights is based on differences in stated philosophies between the IPRP and PG&E. In their review, the IPRP prefer a rate that is “conservative.” They favor a model where the Hosgri slip rate is increasing through time and put 100 percent weight on the rate developed at the CHS. The weighting scheme used by the TI Team considers the potential that the slip rate at each site is the correct rate on its own merits.

> *Also, in Figure 2 the full uncertainty range of the Point Sal and Estero Bay sites are provided, and these rates confirm that the CHS slip rate of 2.5 mm/yr is within the range of technically defensible slip rates. Because all the lower slip rates are associated with older features, this may be evidence that the rates were actually slower in the past and hence are not representative of current rates.*
>
> *An alternative explanation is that these should be considered as minimum rates as the time of initiation on the individual fault strands may be significantly later than the age of the features. In either case, including them may yield an unrealistically low preferred and weighted slip rate.*

The IPRP’s reasoning does not capture the purpose of the weighting, which is to consider the merits of each site on its own using the criteria described above (age of offset feature, location along the fault, distance from the plant and confidence). The TI Team has concerns that the CHS site interpretation may be misleading. Because the calculated slip rate is very sensitive to the offset amount, the preferred method given the alternatives may not result in the correct displacement amount, and thus the slip rate could be incorrect. If the team believed the CHS rate was 100 percent accurate and precise, they would not be doing the weighting. Because most other geologic data explored in the Hosgri slip rate assessment suggest more probability mass towards lower slip rates, this probability mass should be factored in.

> *The geodetic and geologic deformation model results are consistent with the site-specific rate determined for the CHS. Three of the four models indicate a slip rate above 2.5 mm/yr (Table 2). These models emphasize that a slip rate in the 2.6 mm/yr range appears most representative of the current tectonic regime and that significantly lower slip rate determinations should be treated as outliers.*

The geodetic deformation models interpret a range of values. After evaluating the merits of these models, the TI Team gave them zero weight as alternative interpretations of the correct long-term rate.

3.3 Data That Was Not Considered in the Report

Context

The IPRP noted that two reports were not discussed in the 2024 hazard assessment. One report was an NRC-sponsored study that provided an independent slip rate assessment of the Hosgri fault using a vertical subsidence rate in a pull apart basin to calculate a horizontal slip rate on the Hosgri fault (CNWRA, 2016). The second report modelled deformation of a Late Pleistocene unit in the Santa Maria Basin to calculate fault geometry and slip rate for the Casmalia fault.

IPRP Comments and PG&E Response

> *A 2016 (CNWRA, 2016) study prepared for the NRC titled: "Independent Evaluation of the Hosgri Fault Slip Rate Based on a Structural Analysis of the Pull-Apart basin linking the Hosgri and San Simeon Fault Systems" reports slip rates that have increased significantly in the past 1 million years and are now in the 1.5 to 2.5 mm/yr. range.*

The project team was aware of the CNRWA study. The objective of this study was to do a confirmatory calculation on the Hosgri slip rate, and with the PG&E/SSHAC Team's help, CNWRA identified a target of opportunity 23-40 km north of DCPP. The study documents an increase in the Hosgri-parallel rates (mostly heave rates) for faults within the pull-apart basin (See their Table 3-1). The discussion and conclusions in the CNRWA report are clear in that they do not interpret the change in Hosgri-parallel rates within the graben to conclusively document a change in the Hosgri-San Simeon fault lateral slip rate:

"There are two alternative explanations for the apparent increase in slip rate. The increase in slip rates could simply represent an increase in activity on the Hosgri

fault in the late Quaternary. Alternatively, the increase in slip rate could represent increasing cooperation and fault-linkage between the Hosgri and San Simeon faults. This latter alternative is a common feature of the evolution of interacting strike-slip faults. As the faults propagate laterally so that their fault tips overlap, overall fault displacement is distributed across the intervening transfer zone, in this case, the developing half-graben. Eventually the fault tips link, at which point the fault-system-parallel slip rate on the linking Half Graben fault will equal that of the whole strike-slip fault system at this location."

The study was not used in the 2024 seismic assessment because it has many simplifying assumptions and sources of uncertainty that would need to be evaluated further before integrating into the PG&E model. The TI Team viewed it as a preliminary check, or verification, of the rate used in the 2015 study. It is interesting to note that the center of the 1.5 to 2.5 mm/yr rate developed in the CNWRA study is approximately equivalent to the weighted mean Hosgri slip rate (2.1 mm/yr) for the four sites used in the 2024 PG&E assessment.

> *The recent work by McGregor and Onderdonk (2021) reports a slip rate on the Casmalia fault that is a magnitude higher than previous estimates. The interaction of the Casmalia fault with the Hosgri fault offshore should be revisited, as it was considered by PG&E (2015) to affect the Hosgri slip rate.*

The project team was aware of this study. As discussed below, the fault is too far from DCPP to be hazard-significant. The potential relevance to the DCPP will be evaluated under the LTSP.

3.4 Irish Hills Los Osos Tectonic Model

Context

Since the 2015 SSC report, no new data have been developed to reduce uncertainty in Irish Hills and Los Osos fault geometry and tectonic models.

IPRP Comments and PG&E Response

> *The understanding of the three competing fault geometry models (OV, SV, and NE) remains unchanged from the 2015 report. We still don't know whether the Los Osos fault is a reverse-oblique fault or purely thrust-reverse. We don't know whether the Los Osos fault or San Luis Bay fault is responsible for uplift of the Irish Hills. This unresolved issue of fault geometry highlights the need for improved geologic characterization of the Irish Hills and the bounding faults. Without a single geologic model for the Irish Hills that is clearly supported by hard data, there is greater (perhaps unrecognized) uncertainty regarding the seismic hazard model. Given that the DCPP is located in the Irish Hills, the lack of fundamental understanding of fault geometry*

> *and the mechanism responsible for the uplift appears to limit the potential for meaningful seismic hazard analysis.*

The SSHAC process accounts for model uncertainties, such as those in the fault geometry models. Despite uncertainties in the geometry models, coastal terraces provide a strong constraint on uplift rates and are extremely useful for calculating seismic hazard. Sensitivity analysis in the 2015 report indicates that fault geometry is not a hazard significant source of uncertainty (Figure 1).

> *There are potential options to improve the characterization of the faults that bound the Irish Hills. For instance, offshore seismic reflection profiling has been very successful at determining slip rates for the Hosgri fault and the Shoreline fault. That method could also be used to investigate other faults. Limited offshore seismic reflection profiling by the U.S. Geological Survey indicates that the Los Osos fault is a broad fault zone characterized by local vertical faults and flower structures, indicating strike slip faulting. If this preliminary work can be followed up with more detailed low energy seismic reflection profiling of the offshore Los Osos fault (such as can be accomplished using Chirp or sub-bottom profiler equipment capable of high-resolution imaging extending tens of meters below the ground surface), it may become easier to evaluate the three competing models and identify a single fault geometry model supported by geologic data. It is our opinion that additional geologic investigation along the Los Osos fault and South Boundary faults, both onshore and offshore, is warranted to resolve the fault geometry issue.*

While sensitivities indicate that uncertainty in existing fault geometry models are not hazard-significant, the LTSP continues to assess ways to reduce uncertainty in existing models or identify data or methods that have not been considered in previous assessments. Between 2023 and 2024, PG&E sponsored the USGS assessing whether new techniques, including absolute age dating methods, thermochronology, basin wide erosion rates, and geomorphic indices could help inform fault geometries, deformation models and rates for faults beneath and around the Irish Hills. This work is ongoing.

Other topics that LTSP has considered for future research is reprocessing existing geophysics and seismic data using improved machine learning techniques developed in recent years. It is unclear how chirp would definitively resolve the geometries of faults that extend to the base of the seismogenic crust.

As with all LTSP research, projects are prioritized based on hazard significance and to a lesser extent, other factors, such as community interest and ongoing active research on the topic.

> *Previous efforts to characterize the Los Osos fault on land using vibroseis methods resulted in seismic images that were inconclusive (IPRP report #8). It appears that other tools to characterize fault geometry are worth consideration. Other options for investigation of the Irish Hills faults (on land) include trenching across mapped faults and fault scarps. Another option would be a transect of deep core borings or bucket auger borings across the mapped faults. We recommend that PG&E consider a range of surface and subsurface investigation methods to improve the geologic characterization of faults that bound the Irish Hills.*

It is unclear how the proposed work would significantly improve upon previous studies that used similar methods. The LTSP program considers, on an ongoing basis, whether additional research at previously unidentified sites and/or research using new methods at known study sites can reduce hazard uncertainties.

3.5 Data That Was Not Considered in Update: Implications of Recent Studies Related to the Casmalia Fault

IPRP Comments and PG&E Response

> *These findings are relevant to seismic source characterization, because the Casmalia fault is located approximately 27 km south of the DCPP (at the closest point), and the slip rate for this fault is higher than many other faults within 40 km of the site. The updated seismic hazard analysis for the DCPP should consider the Casmalia fault as a potential seismic source.*

The 2015 and 2024 assessments consider the Casmalia fault. The 2024 model used the same fault parameters for the Casmalia fault as the 2015 SSC model, which was based on the fault parameters from the USGS. The parameters were not updated in the 2024 model and do not consider the new study by McGregor and Onderdonk (2021). Sensitivity analyses indicate that the primary fault sources that contribute to hazard at DCPP are the faults closest to the plant. More distant sources, such as the Casmalia fault, have a hazard contribution of less than 1 percent in aggregate (PG&E, 2015). The hazard contribution of the San Andreas fault, which has a much higher slip rate than the Casmalia fault and is about twice as far from DCPP contributes ~3 percent to hazard. Even with the revised Casmalia geometry and slip rate from McGregor et al., 2021, there would likely be little impact on hazard.

> *The most important implication of the Casmalia fault study is as a possible analog and implications for slip rates on neighboring and linked faults. The Casmalia Hills and Irish Hills uplifts are similarly shaped, display a distinct parallel orientation, and are bounded by faults along the north and south flanks. Additionally, these bounding*

> *faults all merge into or are truncated by the high slip offshore Hosgri fault. Based on these clear similarities, the geologic structure of the Casmalia Hills might prove to be a useful analog for the Irish Hills.*

While there are some similarities between the two sites, there are also differences that preclude using Casmalia fault geometry directly: broad, open folding and continuous Neogene strata across the Casmalia fault is in contrast with tight synclinal folds of the Pismo syncline in the Irish Hills.

> *Furthermore, kinematically high slip rates in the Casmalia Hills may contribute to the slip rate budget of more poorly understood faults closer to DCPP that lack well-constrained slip rates. Thus, while structures underlying the Casmalia Hills may be less significant for the ground motion hazard at DCPP, the slip rate determined for the Casmalia fault should be considered in a regional model of structures related to faults in the Diablo Canyon vicinity.*

It is currently unclear how the findings of McGregor and Onderdonk (2021) relate to slip rate budgets for faults closer to DCPP. PG&E met with the Principal Investigators of the study, Ian McGregor and Nate Onderdonk to discuss their recent work on the Casmalia fault. PG&E learned that there may be some issues with the dating method used in the study that are being evaluated with follow-up studies. Dr. Onderdonk is interested in further assessing the transition in tectonic style from the Transverse Ranges to the southern Coast Ranges. This work could be the focus of future LTSP research efforts.

4 Ground Motion Characterization

4.1 New Ground Motion Data

IPRP Comments and PG&E Response

> *Issues noted in previous IPRP reports regarding site condition and site amplification remain (see IPRP comments on Site Characterization and Site-Specific Adjustments). These, however, do not invalidate PG&E's updated seismic hazard given broad uncertainty ranges considered in input parameters for the hazard evaluation. However, future effort to reduce uncertainty or improve its quantification would be worthwhile when new data become available.*

PG&E expects that as new data becomes vetted and available, additional future sensitivity studies will be conducted under the LTSP.

4.2 Site Characterization and Site-Specific Adjustments

Context

Previous IPRP reports (e.g. numbers 9, 10 through 13 and 15) note some projects and issues regarding site characterization and site factors that PG&E was to address or improve via its LTSP. These include: 1) the "3-year Kappa" project; 2) development of 3D site response methodologies and models, potentially augmenting the current empirical and 1D analytical approaches; 3) better understanding of the differences in the results from analytical and empirical site amplification approaches; 4) evaluation on validity of the deep 1D analytical approach given the complex 3D geologic conditions beneath the DCPP site and lack of reliable data on damping characteristics in deeper layers; 5) addressing considerable inconsistency observed between the 3D velocity model derived from tomographic and surface wave dispersion data and the downhole velocity measurements; and 6) assessment of path effects on the estimated empirical site amplification factors given that these factors were estimated from two earthquakes (2003 San Simeon and 2004 Parkfield) with limited azimuthal coverage.

IPRP Comments and PG&E Response

> *IPRP requests a status update regarding these issues or projects for continuity as there are no updates in PG&E (2024).*
>
> *Given there are no new site data, the decision not to update the analytical factors appear reasonable. However, we believe analytical site factors can be improved if the characterization for the target site can be improved by devoting resources to acquire more site-specific data, including improving Vs profile and kappa value estimates. We are dubious about PG&E's statement that the site data at the DCPP were extensive and provided a well-constrained velocity model for depths up to 3 km. We believe there is still potential to improve site data. Analytical site factors may also be improved by carrying out supplemental site response analyses using the more traditional approach of propagating acceleration time histories selected from controlling scenarios determined from hazard disaggregation through the control-point rock and soil profiles. In additional, we encourage continuing effort to reduce uncertainty in the empirical site factors in future studies.*

There is always potential to improve site data for any site. The effectiveness of possible additional data is important for considerations of the benefit/cost related to additional site data collection. There would be little benefit to perform additional analysis without significant new data to justify this effort. The LTSP includes elements to track developments in these areas and provide support for those that show beneficial promise.

Fugro (2015) developed a 3D velocity model for the area near the power block. The model was initially developed as part of the CCCSIP effort using seismic tomographic data. It was then revised in 2015 using surface-wave dispersion and active source data. The combined efforts provided rigorous characterization of the subsurface in the areas immediately adjacent to the plant, as well as the surrounding area. The level of effort undertaken by this survey is beyond the standard of practice of characterization of velocity beneath a nuclear power plant. In the supplement of the Fugro (2015) report, the 3D velocity structure is compared to the four borehole velocity profiles from Blume (1968; 1969), as well as other refraction data collected by Blume (1978). The IPRP report mention inconsistencies between the datasets, but this is to be expected given the different approaches used into the original investigations performed over 50 years ago due to differences in data collection, processing, and measurement techniques.

PG&E agrees that acquiring additional site data could be beneficial in better constraining the analytical site factors and reducing the uncertainty. However, PG&E does not see the value in performing a "traditional" site response approach. If the traditional approach suggested by the IPRP means a soil-over-rock site response method, the shortcomings of such approaches are well documented in Williams and Abrahamson (2021), which is why this approach is not the standard of practice in the nuclear industry.

There are issues with the analytically based site adjustment factors, which have been identified in numerous studies (e.g., Thompson et al., 2012; Afshari and Stewart, 2019; Pilz and Cotton, 2019; Tao and Rathje, 2020; Zhu et al., 2021; Bahrampouri and Marek, 2023; Pretell et al., 2023). Some of the differences found in these studies are exacerbated by the comparison between surface and borehole recorded time series. However, there are other conditions (e.g., complex velocity structure, non-vertical wave propagation, etc.) that are present in earthquake recordings, but not found in the simplified site response methodologies applied. One solution is to increase the complexity of the site response models. This is one avenue of research that PG&E is working towards (e.g., Kusanovic et al., 2023; Hallal and Cox, 2023). However, as model complexity increases so does uncertainty. An alternative approach is based on observations.

As part of the PG&E (2015) submittal, observations of ground motion near the plant were used to quantify an empirical site adjustment factor. This approach used ground-motion recordings from the 2003 San Simeon and the 2004 Parkfield earthquakes at station ESTA27 and a recording of the Parkfield earthquake at station ESTA28. Comparison between the empirical and analytical site adjustment factors are generally good. These adjustment factors were compared to site adjustment factors extrapolated from nonergodic ground motion models in the 2023 SB-846 update (PG&E, 2024).

The Electric Power Research Institute (EPRI) and PG&E study of the site attenuation parameter kappa (EPRI, 2021) can be found here: https://www.epri.com/research/products/000000003002020750.

> *The description of Vs profiles for the target site condition given in the 1st and 2nd paragraphs of Section 9.1 is inconsistent with profiles shown in Figure 9-3 in PG&E (2024). Which version is correct? We request a revision with corrections.*

This is a misunderstanding of the description of how the target Vs profiles were constructed in the 2015 study. Both the text and figure are correct and there is no inconsistency. The text describes the development of the target Vs profile in the ranges of 0-125 m, 125-3000 m, and below 3000 m. Figure 9.2 shows the profiles (median and median +/- 1.6 sigma) in the top 125 m while Figure 9.3 shows the final profiles from the ground surface down to 14 km. Below 3 km, the target profiles are based on the reference host profile. At depths greater than 4 km, the central and lower profiles coincide while the upper profile does not exceed 3500 m/s (source Vs). The text does not say that the target site Vs profile below 3 km is the same as the reference profile. It says that below 3 km, the target Vs profile is based on the reference rock profile.

5 Hazard Calculation

5.1 Hazard Calculation and Results

IPRP Comments and PG&E Response

> *It would be good to illustrate mathematically why hazard curves can be scaled by the same factor as the mean slip rate.*

The hazard integral calculates the occurrence rate of ground motions with ground-motion intensity measure (*IM*) greater than *im*:

$$\lambda(IM > im) = \sum_{i=1}^{n_{rup}} P(IM > im|rup_i, site) \cdot \lambda(rup_i)$$

The conditional probability P(*IM > im | rup$_i$, site)* comes from a ground-motion model and the rate of ruptures ($\lambda(rup_i)$) comes from the seismic-source characterization. Through inspection of the equation above, for a single source changes in the $\lambda(rup_i)$ directly scale the hazard. The hazard model for DCPP is slightly more complicated due to the partitioning of the slip rate onto different rupture topologies. PG&E is evaluating.

> *It would also be good to clearly state any underlying assumptions of this scaling approach and discuss why these assumptions are appropriate.*

The scaling approach used in the SB-846 document is only appropriate if the only changes to the model are changes to the slip rate. There are numerous other aspects to the model: magnitude-frequency distributions, fault geometries, ground-motion models, site adjustment factors, etc. that could not be captured by this scaling.

> *For the Hosgri fault, the rationale for multiplying the scaling factors for mean rate and for EPHR should be stated.*

The EPHR is influenced by the slip rate because of the impact of the slip rate on the long-term mean occurrence interval and the historic period of absence of events. PG&E (2015) and Biasi and Thompson (2018) developed slip rate dependent EPHR. Since the EPHR scales the rate, this change can also be accommodated through scaling.

> *Equation 10-2 does not look correct. The term "0.6*AR0.8" is not defined. It looks like a typo.*

This should be MAX(0.6 * AR ** 0.8, 1), where AR is the hazard ratio defined in Equation 10-3. This equation has been updated on the version of the document publicly available on our website.

5.2 Control-Point Hazard for Risk Assessment

IPRP Comments and PG&E Response

> *We note hazard results may be subject to revision if the seismic source characterization inputs are modified based on the comments in this report regarding slip rates on the Hosgri fault and models for deformation in the Irish Hills.*

PG&E agrees.

6 CONCLUSION

PG&E appreciates the IPRPs detailed technical review of elements of the 2024 seismic assessment.

Review of the SSC model in the report underscores that the PG&E model has captured the center, body, and range of technically defensible models and is consistent with SSHAC process. The 2024 PG&E model captures the IPRP's proponent views on slip rate uncertainty at the CHS site and the IPRPs preferred slip rate based on their proposed weighting of the four Hosgri slip rate sites. From a hazard and risk perspective, the mean slip rate in the PG&E model (2.1 mm/yr) is similar to the IPRP's proponent slip rate of 2.6 mm/yr, using only the CHS site, and is approximately in the center of the Hosgri slip rate distribution from the NRC-sponsored study to test the Hosgri fault slip rate used in the 2015 PG&E model.

PG&E will consider the IPRP's recommendation to evaluate the implications of new data on the geometry and slip rate of the Casmalia fault for faults around DCPP and for hazard at the plant under the LTSP. PG&E will also consider recommendations to reduce uncertainty in the 2015/2024 fault geometry model using new methods such as shallow offshore seismic data.

The IPRP review identified local site adjustment as an area for future work. This is consistent with PG&E's prioritization due to the impact of site adjustment on the seismic hazard. PG&E's approach is focused on collecting ground motion observations and improving the ground-motion modeling to improve partitioning between source, path, and site behaviors. Additionally, PG&E will look to use numerical simulations to improve understanding of local site conditions and fault geometries on the expected ground motions.

The IPRP review did not identify any significant technical issues with PG&E's 2024 Updated Seismic Assessment Report. The assessment satisfies the covenant for the performance of a seismic update associated with the State of California SB-846 plant license extension. Any work to further explore or reduce uncertainty in the 2024 model or model components will occur under the PG&E Long Term Seismic Program.

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