Independent Peer Review Panel

A multi-agency panel of seismic hazard specialists established by the California Public Utilities Commission

CALIFORNIA GEOLOGICAL SURVEY, CALIFORNIA COASTAL COMMISSION, CALIFORNIA PUBLIC UTILITIES COMMISSION, CALIFORNIA ENERGY COMMISSION, CALIFORNIA SEISMIC SAFETY COMMISSION, COUNTY OF SAN LUIS OBISPO

IPRP Report No. 11

Summary of IPRP Public Meeting on September 15, 2016

BACKGROUND

In 2006, the California Legislature enacted Assembly Bill (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 Diablo Canyon Power Plant (DCPP), to a major disruption due to a major seismic event and other issues. In response to AB 1632, the CEC recommended that "PG&E should use three-dimensional geophysical seismic reflection mapping and other advanced techniques to explore fault zones near Diablo Canyon" and that studies should supplement Pacific Gas and Electric Company (PG&E)'s Long Term Seismic Program (LTSP) to "help resolve uncertainties surrounding the seismic hazard at Diablo Canyon".

The California Public Utilities Commission (CPUC) decision D 10-08-003 approved funding for the proposed seismic hazard studies and established the Independent Peer Review Panel (IPRP). The IPRP members represent the California Geological Survey, Coastal Commission, Seismic Safety Commission, County of San Luis Obispo, as well as the CEC and the CPUC. Since 2011, the IPRP has held public meetings and issued reports to comment on seismic hazard studies proposed by PG&E

Studies conducted in response to AB1632 are described in a series of reports collectively known as the Central Coastal California Seismic Imaging Project (CCCSIP). The CCCSIP report is divided into 14 chapters focused on individual studies intended to help constrain factors that are important to seismic hazard analysis. Although AB1632 predated the Tohoku earthquake and did not specifically address licensing of the DCPP by the U.S. Nuclear Regulatory Commission (NRC), the CCCSIP provided data that were used in evaluations of seismic hazard that were submitted to the NRC in September 2014.

Due to the large volume of information presented in the CCCSIP report, IPRP's review of the document was divided into IPRP Reports No. 7, 8, and 9. PG&E (2015) issued a response to the IPRP Report Nos 7, 8, and 9 on April 22, 2015, acknowledging that the IPRP process has provided valuable insight and guidance on the CCCSIP, and that

PG&E will use the IPRP comments as guidance for planning future seismic studies as part of the DCPP LTSP.

Following the completion of studies authorized by AB1632 and submission of the CCCSIP report to the NRC, the Legislature passed and the Governor signed AB361, which authorized continuation of the IPRP to review seismic studies of DCPP and the surrounding area through the term of the plant's operating license. This and future IPRP reports will include follow-up discussion of issues raised by the CCCSIP studies and discussion and recommendations for studies conducted under the Long-Term Seismic Program for DCPP.

This report summarizes IPRP's preliminary review of ongoing studies by PG&E based on documents currently available to the IPRP. We note that in-depth review of LTSP related studies is not yet practical because IPRP has not received detailed written descriptions of those studies.

REMAINING ISSUES FROM PREVIOUS REVIEWS

Some of the remaining issues where IPRP would like additional clarification or justification of PG&E conclusions are summarized in previous IPRP Reports. Examples are: (1) faults in Irish Hills need further investigation, and (2) consideration of proposed site terms in ground motion calculations require further investigation to rule out path effects.

With regard to the site velocity model, site amplification, and associated uncertainties PG&E noted that additional work is ongoing, which would address the comments raised by the IPRP. Following the CCSIP report, PG&E completed a report summarizing the methodology and results of an update to the three-dimensional (3D) velocity model, associated model uncertainties, and model validation (Fugro, 2015). PG&E performed one dimensional (1D) site response analysis (Pacific Engineering and Analysis, 2015) in response to a request from the NRC, following NRC required procedure. These two studies were the subject of a public meeting on September 9, 2015. Following that meeting, the IPRP issued Report No. 10 to summarize IPRP's preliminary review of these new studies. Report No. 10 indicates that based on documents available to the IPRP at that time: (1) considerable inconsistency remains between the 3D velocity model derived from tomographic and surface wave dispersion data and the downhole velocity measurements, and (2) 1D site response analysis for site terms may not be appropriate due to complex 3D geologic conditions beneath the Diablo Canyon site and lack of reliable data on damping characteristics in deeper layers. PG&E notes that these issues will continue to be addressed through its LTSP.

CONTINUATION OF LONG TERM SEISMIC PROGRAM

At the IPRP meeting on September 15, 2016, PG&E stated its continuing commitment to the LTSP (established in 1984) through the remaining lifetime of DCPP and decommissioning of the plant in 2024-25 to ensure seismic safety. The LTSP may also continue well into the future to support safe containment of nuclear wastes. PG&E gave a brief review of the history of the LTSP; its partnerships with U.S. Geological Survey (USGS), Southern California Earthquake Center (SCEC), California State University Monterey Bay Seafloor Mapping Laboratory, and Pacific Earthquake Engineering Research Center (PEER); and the integration of the LTSP with the AB1632 seismic studies and the comprehensive Senior Seismic Hazards Analysis Committee (SSHAC) level-3 hazard reevaluation per request from the NRC.

The AB1632 studies have narrowed the uncertainty ranges in seismic source parameters as illustrated by a PG&E tornado diagram. The results from these studies were used in the SSHAC level-3 seismic hazard reevaluation. Large uncertainties remain in ground motion characterizations, which will be the focus of the LTSP in the near future (5 years). PG&E's approach to ground motion characterization is moving toward more use of ground motions from physics-based numerical simulations as opposed to ground motions from empirical ground motion prediction equations (GMPEs) and developing non-ergodic ground motion models that work for a particular area and eventually a particular site.

Global models for ground motion characterization

Kinematic models for seismic wave propagation and amplification will continue to be validated using the SCEC broadband platform (BBP, a software system that generates broadband seismograms for historical and scenario earthquakes) with 13 additional earthquakes. These include three models that passed tests previously and two additional models (a Japanese model and John Anderson's composite source model). In addition to validation on median ground motions, there will be validations of ground motion variability on Fourier amplitude spectra and pseudo spectral accelerations using SCEC BBP. As an alternative to kinematic models that produce ground motions from prescribed fault rupture scenarios, dynamic rupture models are being developed at SCEC and USGS. In dynamic rupture models, rupture occurrence and propagation are controlled by fault frictional properties and crustal stress distribution. Therefore, these models are more fundamentally based on physics. They are also superior in dealing with complex rupture geometry.

Attempts will be made to develop new kappa scaling models that would work for hard rock sites with high kappa values such as the Diablo Canyon site and to address

discrepancies in kappa scaling using empirical and analytical approaches. Currently, correlations of kappa with high frequency ground motion amplitude based on an empirical approach are much weaker than those from analytical models. New directivity models for empirical GMPEs will be implemented. PG&E will continue to fund PEER to update empirical ground motion dataset.

Non-ergodic ground motion models

A GMPE with continuous regionalization will be developed, calibrated and tested in the next few years to achieve calculation of non-ergodic ground motions. Such a GMPE will have coefficients that vary smoothly in space (i.e., as functions of site coordinates). A number of tasks will be carried out to define spatial correlation of ground motions and variations of GMPE coefficients. Models for ground motion spatial correlations in California will be developed. Path effect terms for central coastal California will be determined using data collected from existing broadband ground motion stations and a temporary 50-station array added to reduce station spacing. PG&E will also fund SCEC and USGS to build new 3D crustal models for central California using two different approaches: a tomographic approach using micro-seismicity data and a geologic approach. SCEC will run 3D simulations for path effects using these new 3D crustal models with a goal of getting ground motions with frequency as high as 5 Hz. Dr. Abrahamson believes that the lack of spatially dense ground motion recordings is slowing the development and testing of non-ergodic ground motions models. The possibility of getting a denser observation network using redesigned electric Smart Meters with accelerometers is also being discussed. Using Smart Meters to collect ground motion data is a promising idea because Smart Meters are being redesigned presently, the prototype already has an accelerometer, and PG&E has the electric power and telemetry needed for data recording and collection. In addition, PG&E (in partner with others) has submitted a proposal to National Science Foundation to improve offshore seismic observations by adding more ocean bottom stations (there are four currently).

PG&E will also continue to support testing of 3D simulations in the Los Angeles Region (i.e., SCEC's Cybershake program, a physics-based computational approach to probabilistic seismic hazard analysis) and continue to support SCEC's core program of developing new methods and data for constraining path effects.

Hazard methodology

The PG&E hazard code is one of the 13 computer codes tested by PEER for seismic hazard calculations. Full non-ergodic ground motion models will be implemented in the code for future hazard calculations. Ground motion hazards near Diablo Canyon also will be constrained using precarious rocks.

IPRP REVIEW OF PG&E LONG TERM SEISMIC PROGRAM

The IPRP will continue its independent review of components of the LTSP applicable to assessing ground motion hazards at the Diablo Canyon site. Two immediate tasks are: (1) to reproduce the ground motion response spectrum at a control point that PG&E developed for safety assessment in order to gain familiarity with, and confidence in, PG&E's hazard codes, and to establish a point of comparison for future assessment of hazard sensitivity to key input parameters such as site terms and non-ergodic ground motions; and (2) to review NRC report anticipated to be release in December of this year on PG&E's SSHAC studies.

SUMMARY

Since 2011, the IPRP has focused on review of seismic hazard studies prepared in response to AB1632. IPRP comments and review helped evaluate the CCCSIP and its incorporation into seismic hazard evaluation submitted to NRC. Future work by the IPRP will continue to follow up on the results of the CCCSIP where significant uncertainties remain as well as review new work by PG&E under the LTSP.

REFERENCES

Fugro Consultants, Inc., 2015, *Update of the Three-Dimensional Velocity Model for the Diablo Canyon Power Plant (DCPP) Foundation Area*, Fugro Job No. 04.76140022, May.

Pacific Gas and Electric Company (PG&E), 2015, Pacific Gas and Electric Company's *Response to CPUC Independent Peer Review Panel Report Nos. 7, 8, and 9*, Letter to California Public Utilities Commission, April.

Pacific Engineering and Analysis, 2015, *Development of Amplification Factors for the Diablo Canyon Nuclear Power Plant*, Revision 1.