Final Project Summary — PEER Lifelines Program

Project Title—ID Number	*Validation of Probabilistic Seismic Hazard Computer Programs*—**607**		
Start/End Dates	11/1/01 – 4/30/04	Budget/ Funding Source	$93,692 / Caltrans
Project Leader (boldface) and Other Team Members	**Wong (URS)**		

1. Project goals and objectives

Despite its relatively widespread use both nationally and internationally, only a few publicly available and proprietary probabilistic seismic hazard analysis (PSHA) computer codes have been developed. In large part, this is because PSHA calculations are still being done by a relatively small proportion of the professional community. Because of the importance of PSHA in seismic design, the PEER Center's Lifelines Program sponsored a Working Group to validate both the numerical approaches and computer software used in PSHA.

The objective of the project was to develop a set of standard exercises that can be used by current and future PSHA software developers to validate their codes. The validation process will also provide the means for the PEER Lifeline Program sponsors (CALTRANS, PG&E, and the CEC) to insure that work done for them by others, including consultants, is done using qualified software.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

In the past three decades, the approach to estimating earthquake ground shaking hazard, particularly of critical and important facilities, has slowly evolved from the traditional deterministic earthquake scenario analysis to PSHA. A prime example is the very comprehensive PSHA that was performed to evaluate both ground shaking and fault displacement hazards at Yucca Mountain, the site of the nation's first nuclear waste repository. The National Seismic Hazard Maps developed by the U.S. Geological Survey, which form the basis of building codes in the U.S. (e.g., International Building Code) are based on PSHA.

Results from PSHA also form the basis for: (1) design ground motions specified in structural codes and standards (e.g., AASHTO for bridges); (2) site-specific design of important and critical facilities such as all U.S. Department of Energy facilities (e.g., national laboratories and Yucca Mountain); (3) site-specific design for nuclear power plants and interim nuclear waste storage sites; (4) safety analysis evaluations of important/critical facilities such as U.S. Bureau of Reclamation dams; (5) loss estimation to establish insurance rates; and many other uses. PSHA is now being used by Federal and state agencies, which have traditionally only used a deterministic approach for estimating ground motions. Examples of such agencies are the U.S. Army Corps of Engineers and the California Division of Safety of Dams. Thus PSHA has become the primary tool in estimating seismic hazards in the U.S. and is gaining widespread use worldwide.

3. Brief description of the accomplishments of the project

This project provided an opportunity for the developers of the most important PSHA codes in the U.S. to validate and in some cases, revise the numerical approaches used in their codes. The project, test cases, and their answers will be published in a PEER final report, posted on the PEER website (http://peer.berkeley.edu), and documented in publications that will provide widespread distribution to PSHA software developers interested in validating their codes. This will be of value to the other engineering centers and to other countries in their development or use of PSHA codes.

4. Describe any instances where you are aware that your results have been used in industry

Results not available yet.

5. Methodology employed

The Working Group tested both publicly available codes as well as proprietary codes that have been used extensively in hazard evaluation in the U.S. and worldwide. Members of the Working Group consisted of code developers from government agencies and engineering firms. The focus of the project was the numerical verification of the codes and analysis and comparison of their various features. The validation exercises consisted of two sets of cases that tested fundamental aspects of the codes including how they modeled (1) faults, areal sources, and complex fault geometries, (2) recurrence models and rates, and (3) attenuation relationships and their uncertainties. The test cases ranged from the simplest to more sophisticated. The simplest cases have analytical

solutions, but the more complex cases do not. "Acceptable" answers to the test cases were defined either through analytical solutions or consensus results from the Working Group.

The test case sets (e.g., Figure 1) were developed by the PIs and were distributed to each member of the Working Group. Each member ran the test cases and sent their results back to the PIs. The results were compiled for the whole Working Group and sent back to each participant without identifying the names of the codes except for their own code. This initial feedback allowed for each code developer to identify numerical errors, errors in interpretations, or limitations in their codes and the opportunity to correct them. In some cases, this resulted in modifications of the codes. For each test case set, the above steps were followed and a workshop was held to discuss the group results, to identify discrepancies and the reasons for them, particularly if differences were due to differences in assumptions, numerical solutions, and hence features of the codes. A third and final workshop was held to discuss the results of each test case and to select the "acceptable" answers for each test case. Recommendations of minimum standards for meeting the benchmark results (e.g., 10% in probability level) were also defined to qualify the hazard codes.

6. Other related work conducted within and/or outside PEER
None.

7. Recommendations for the future work: what do you think should be done next?
The current state-of-the-practice in PSHA is to assume earthquakes behave in a Poisson manner. In the near future, time-dependent probabilistic seismic hazard analyses will be performed as the required seismic source data become available A topic of future work will be development of time-dependent models as employed in PSHA codes. These will also require validation as such codes become increasingly used.

8. Author(s), Title, and Date for the final report for this project
Ivan G. Wong, Patricia A. Thomas, and Norm Abrahamson "The validation of software used in probabilistic seismic hazard analysis," December 2004.

Figure 1. Fault and Site Geometry for Test Case Set #1