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# Testing Seismic Hazard Models Against the Historical Record of Ground Motions in Southern California

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## Introduction

A serious deficiency that has long faced probabilistic seismic hazard (PSH) methodology is that no methods are available to formally test or validate the resulting estimates of PSH. In the past year our SCEC-funded research has addressed this deficiency by developing site-specific tests for PSH models from the historical record of felt intensities (Modified Mercalli intensities, or MMI) in southern California, and then undertaking preliminary tests of the US Geological Survey (USGS) and California Geological Survey (CGS) PSH model (e.g. Frankel,1995) at these same sites. Development of these tests is ultimately geared towards providing a formal test for the SCEC Regional Earthquake Likelihood Models (RELM) and PSH models in general. In this annual report for 2003 we provide a précis of our efforts to develop these historically-based tests, the work largely achieved during August and September when the PI was based at the USGS in Pasadena.

## Methodology

Our general method has been to use the historical record of felt intensities at a suite of towns and cities around Southern California to develop historically-based hazard curves (annual rates of exceedance for a suite of MMI levels) and then compare these historically-based curves to the hazard curves calculated for the sites from the PSH models. Our basic premise has been that the felt intensity data can be used in this manner as these data and PSH models are essentially independent of one-another. Specifically, the felt intensity data have not been used directly in the PSH models, only indirectly through the use of the intensity data to estimate magnitudes for some early earthquakes.

We have developed historically-based tests at 27 towns and cities distributed uniformly across southern California from areas of very high seismotectonic activity and seismic hazard in the west of the state to areas of low activity in the east (Fig. 1). For these sites we searched historical databases on the web and in the literature (primarily the USGS's NGDC website http://www.ngdc.noaa.gov:8800/seg/plsql/eqi.main) to estimate the historically-based rate of exceedance for various MMI levels at each site. Our data search resulted in the careful selection of MMI data and construction of three MMI "sub catalogs" for which a complete record of the following was assumed to exist on the basis of discussions with knowledgeable USGS personnel: (1) MM7 and above from the incorporation (founding) year of each town/city to the end of 1930; (2) MM6 and above from 1931 to the end of 1985 (the main period covered by the NGDC database), and (3) MM6 and above from 1985 to the present day (data for the latter not available for all 27 sites, and mainly derived from the USGS's SHAKEmap; http://www.trinet.org/shake/). The MMIs were then converted to the equivalent peak ground accelerations (PGA) by way of the equations of Wald et al (1999) and Trufunac & Brady (1975) to enable the comparison of the historical data directly to hazard curves derived from the PSH models. The Wald et al. (1999)

equation was considered to be most relevant to modern earthquake data and the Trifunac & Brady (1975) equation most relevant to the older data due to differences in the response of newer versus older manmade structures to earthquake shaking. Comparison of the historically-based rates of exceedance to PSH models was then accomplished simply by plotting both on the same graph (Fig. 2). The USGS/CGS model (e.g. Frankel, 1995) was used for this comparison as RELM PSH models were unavailable at the time of this work.

While our tests are limited by the short historical record of southern California, they have a major advantage in being able to be simultaneously applied to a large number of sites from different tectonic environments. The shortcomings of the historical record are therefore compensated for by the ability to make comparisons at a large number and great diversity of sites.

**Results**

The six graphs in Figure 2 provide examples of the comparisons made at the 27 sites. The graphs show the historical rates of exceedance for various levels of PGA (converted from MM Intensity by way of Wald, 1999 and Trifunac & Brady, 1975) along with hazard curves derived from the 1996 USGS/CGS seismic hazard model (e.g. Frankel, 1995). The tendency is for the historical hazard to be higher than the hazard derived from the USGS/CGS model. In fact for 9 of the 27 sites the historical rates of exceedance of PGA levels (the test) are at least an order of magnitude higher than the hazard calculated from the USGS/CGS PSH model. The discrepancies are greatest in areas away from the plate boundary where earthquake rates are low and hazard is dominated by background earthquake sources (see. "Needles" graph in Fig. 2 and location of Needles in Fig. 1), and least in the high-hazard areas dominated by fault sources (see. "San Bernardino" graph in Fig. 2 and location of San Bernardino in Fig. 1). The discrepancies may be due to the standard procedure of spatially distributing or smoothing background seismicity rates in PSHA, the tendency being to "spread" or "dilute" the historical earthquakes near individual sites away from those sites. If so, this could represent a deficiency in PSH methodology for the characterisation of seismic hazard in low-seismicity areas. The discrepancies may also be explained in some cases by the PSH models inderestimating strong site response in areas of soft ground and deep basins (e.g. "Los Angeles" graph in Fig. 2). We have found that the 9 largest discrepancies are so large that they cannot be accounted for by uncertainties in determination of MMI in the historical data and/or conversion from MMI to PGA.

The PI is carrying out a complimentary study on about 30 cities across the continental USA with Mark Petersen of USGS Golden, and on a further 30 towns and cities in New Zealand. The southern California-specific work and broader continental USA work will all be formerly documented in a paper for the RELM special issue of BSSA. SCEC-funded work in 2004 will focus on analysis of the statistical significance of the discrepancies between the historical and PSH model hazard, and further understanding the causes of the discrepancies. Ultimately we anticipate this work leading to formal adjustment and validation of PSH estimates. The historically-based tests will be implemented in OpenSHA for testing RELM PSH models in this manner.

**Conclusions**

Our preliminary tests of the USGS/CGS PSH model against the historical rate of exceedance of specific MMI levels at 27 towns and cities around southern California show a tendency for the PSH model to underestimate the historical hazard. The discrepancies are most marked in the areas of lowest seismicity and seismic hazard, and where strong site response is likely to be observed during large earthquakes.

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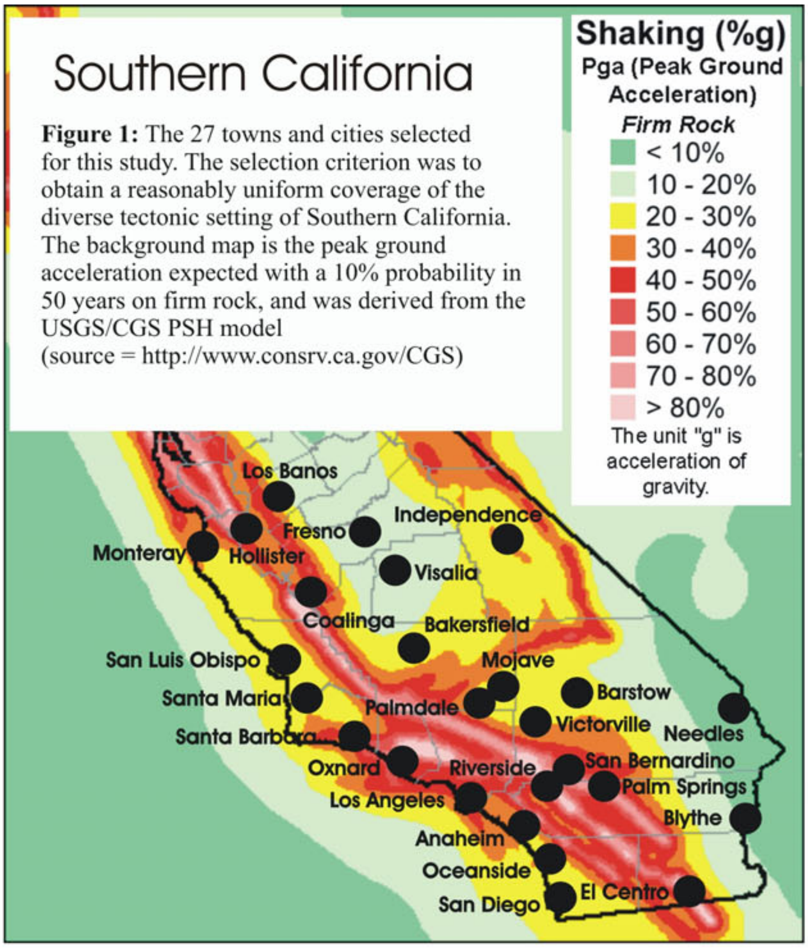


**Figure 1:** The 27 towns and cities selected for this study. The selection criterion was to obtain a reasonably uniform coverage of the diverse tectonic setting of Southern California. The background map is the peak ground acceleration expected with a 10% probability in 50 years on firm rock, and was derived from the USGS/CGS PSH model (source = http://www.consrv.ca.gov/CGS)

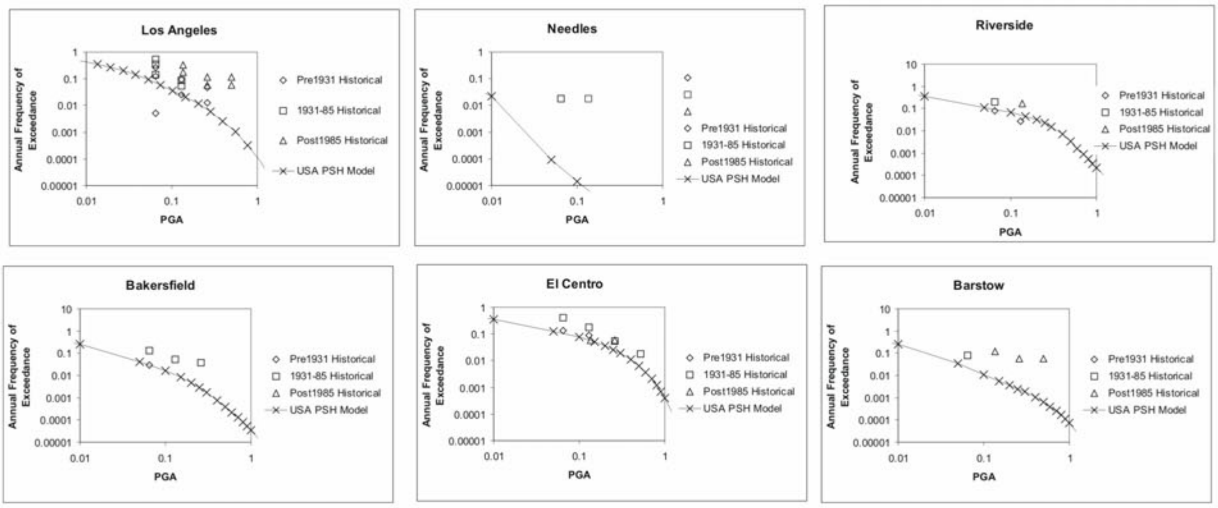


**Figure 2:** A sample of six of the 27 towns and cities focused on in this study. The graphs show the historical rate of exceedance for a suite of peak ground acceleration levels, plotted with the hazard curves for the USGS/CGS PSH model. Note the tendency for the historical hazard to be higher than for the PSH model, especially in the areas of lowest seismicity and hazard (ie. Needles and Bakersfield).