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SeismicWaves

How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Forecasting What's Coming Up from Down Below

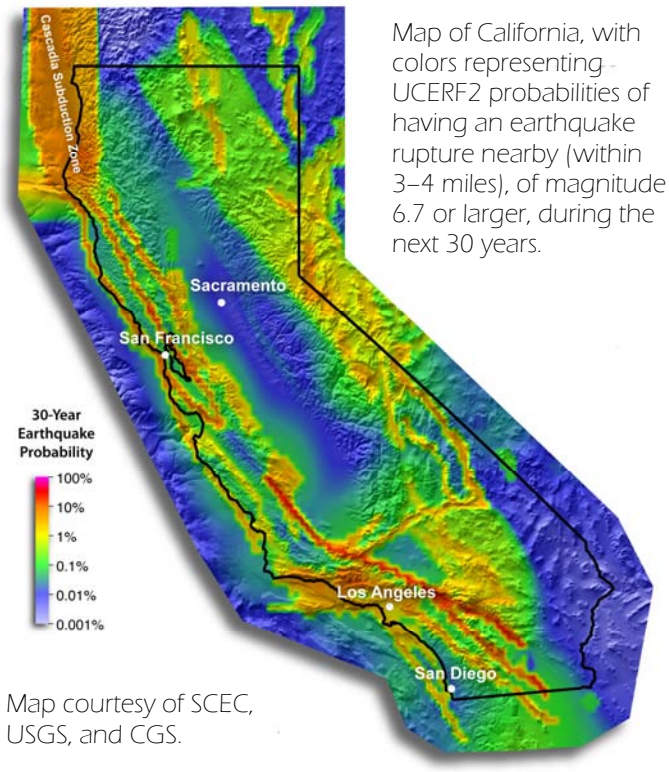
The Uniform California Earthquake Rupture Forecast

California has a greater than 99 percent probability of experiencing one or more highly damaging magnitude-6.7-or-larger earthquakes during the next 30 years. The two faults most likely to generate a major earthquake during that period are the southern segment of the San Andreas Fault and the San Francisco Bay Area's Hayward Fault. These are among the findings of the first-ever statewide earthquake rupture forecast developed for California. A team of federal, state, and university scientists and engineers named the Working Group on California Earthquake Probabilities (WGCEP) issued this forecast in April 2008, building upon earlier forecasts generated for selected areas of the state. The group incorporated the latest data, methods, and expert opinion to develop a state-of-the-art forecasting methodology and an unprecedented set of earthquake probabilities that are advancing earthquake safety in several important ways.

Forecasting and Working Groups

Until the 1980s, earthquake hazard assessment in California was largely *time-independent*. The likelihood that an earthquake of a given magnitude would occur on a fault or in a particular region was based on how frequently such quakes had occurred there in the past. As scientists have learned more about California's major faults, they have supplemented this approach with *time-dependent* forecasting. It is based on the concept of earthquake cycles, in which elastic strain energy slowly accumulates on a fault, is released when the fault ruptures, and then begins to accumulate again. The likelihood of earthquakes depends on where faults are in these cycles.

The WGCEP was the fifth such team to be organized in California since 1988. Each succeeding group has advanced earthquake forecasting with broad input from the earthquake science and engineering communities. The first four groups, however, adapted their forecasting methodologies to selected faults or regions only. The primary impetus for this WGCEP came from the California Earthquake Authority (CEA), the largest provider of residential earthquake insurance in the state. State law requires that the CEA use the best available science in adjusting its rates from year to year and region to region. To do this, the CEA needed statewide, time-dependent forecasts developed through a uniform methodology.



Map of California, with colors representing UCERF2 probabilities of having an earthquake rupture nearby (within 3–4 miles), of magnitude 6.7 or larger, during the next 30 years.

Map courtesy of SCEC, USGS, and CGS.

The First Statewide Forecast

The WGCEP was organized in September 2005 by the Southern California Earthquake Center (SCEC), U.S. Geological Survey (USGS), and California Geological Survey (CGS). (SCEC is an earthquake research collaboration funded by USGS and the National Science Foundation.) Comprising nearly 50 scientists and engineers from these organizations, the working group was supported with funds from the CEA and substantial in-kind contributions from the organizers.

The group's two major products—California's first statewide earthquake forecasting methodology and the earthquake rupture forecast it generated—successfully addressed the needs of the CEA, the WGCEP organizers, and others for updated, statewide time-dependent and time-independent forecasting. The working group integrated the latest data from the fields of geodesy, geology, seismology, and paleoseismology into the methodology, and evaluated hundreds of competing theories about how these data should be interpreted and used. They modeled

uncertainty through a consensus-building approach in which alternatives were weighted by expert opinion gathered at open meetings and workshops.

The methodology was implemented in modular, open-source software that can be updated as new data and methods emerge. Components include a time-independent earthquake rate model, developed in close cooperation with the USGS National Seismic Hazard Mapping Project (NSHMP), and a time-dependent earthquake probability model, which produced the earthquake rupture forecast.

The WGCEP issued the forecast in a report entitled "The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF2)."[1] The forecast estimates the magnitude and probability of all earthquakes with magnitudes greater than or equal to 5 ($M \geq 5$) that may occur in California during the 30-year period beginning in 2007. Some of the eye-opening earthquake probabilities in UCERF2 are shown below. A magnitude of 6.7 was used as the threshold for many of the probabilities because this was the size of the 1994 Northridge (CA) earthquake, which caused more than 70 deaths, thousands of injuries, and from $40 billion to $80 billion in losses.

Probability of One or More Earthquakes of Magnitude M During the Next 30 Years

Area	M	Prob.
Statewide*		
Somewhere in California	M ≥ 6.7	99.7%
Somewhere in California	M ≥ 7	94%
Somewhere in California	M ≥ 7.5	46%
Somewhere in California	M ≥ 8	4%
Regions		
Southern California	M ≥ 7.5	37%
Northern California*	M ≥ 7.5	15%
Urban Areas		
Greater Los Angeles	M ≥ 6.7	67%
San Francisco Bay Area	M ≥ 6.7	63%
Major Faults		
Southern San Andreas	M ≥ 6.7	59%
Hayward-Rodgers Creek	M ≥ 6.7	31%

* Excluding the Cascadia Subduction Zone.

Impact on Earthquake Safety

The development of UCERF2 and the statewide forecasting methodology has had a quick and multifaceted impact on earthquake safety. UCERF2 provides persuasive new data for use in promoting earthquake preparedness and mitigation in the state. Findings from UCERF2 are being used, for example, to promote participation in the Great California ShakeOut earthquake preparedness event planned for October 15, 2009.

At about the same time that UCERF2 was issued, in April 2008, USGS released its new 2008 National Seismic Hazard Maps. Due to the close coordination between the WGCEP and the NSHMP, USGS was able to incorporate the California earthquake rate model developed for UCERF2 into these maps. The maps will form the basis of the seismic design maps included in the next editions of the *International Building Code* and *International Residential Code*, scheduled for publication in 2011, enabling engineers to more accurately identify the levels of earthquake protection required for structures in different parts of California.

Over the past year, UCERF2 findings have also been incorporated into the software systems used by the CEA and other insurers to estimate future property losses from earthquakes. Insurers use these estimates to determine how much reinsurance they need to buy as well as how much to charge property owners for earthquake insurance policies.

In developing UCERF2, the working group delineated several issues that researchers must address to further refine the UCERF methodology. Foremost among these is the need to incorporate scientists' growing understanding of earthquake clustering, triggering, fault-to-fault rupturing, and other phenomena that can impact estimates of earthquake rates and probabilities. These issues have recently led SCEC, USGS, CGS, and the CEA to make plans for a new working group that will build upon the WGCEP's accomplishments to create a next-generation statewide rupture forecast.

The UCERF2 report and related materials can be accessed via SCEC at http://www.scec.org/ucerf/.

[1] USGS Open-File Report 2007-1437 and CGS Special Report 203, available at http://pubs.usgs.gov/of/2007/1437/.