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# Preparing for a New View of U.S. Earthquake Risk

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## INTRODUCTION

**THE UNITED STATES GEOLOGICAL SURVEY (USGS)** released the latest version of its National Seismic Hazard Maps (NSHM) in April 2008. The maps, which were last updated in 2002, define the latest scientific view of earthquake hazard at varying probability levels across the United States. These maps along with the 2007 Uniform California Earthquake Rupture Forecast (UCERF) report have formed the foundation of the catastrophe model updates that will be introduced by the commercial modeling companies (AIR, EQECAT and RMS) in early 2009 and, ultimately, will have a significant impact on the risk modeled for property and workers compensation portfolios.

Three key themes have emerged from these studies that could have significant implications on the insurance industry:

1. The greatest magnitude changes in seismic risk have occurred in California, with significant but lesser changes in the Pacific Northwest.
2. Measurements from recent large earthquakes around the world indicate that tall buildings in California may experience less shaking in a large earthquake than was previously thought.
3. The vendor models (AIR, EQECAT and RMS), however, will be fully recalibrated and therefore the seismic hazard changes summarized in this article may be offset or amplified by changes to other modeling components, such as engineering or demand surge models.

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The table above summarizes the changes in seismic hazard between the 2008 and 2002 USGS' maps. The remainder of the article focuses the changes to the USGS' earthquake hazard in the California region for high rise (10-story) buildings.

**Changes in Seismic Hazard Between the 2008 and 2002 USGS' Maps by Region and Building Type**

| | 0.2 sec Spectral Acceleration (2-Story Building) | 1.0 sec Spectral Acceleration (10-Story Building) |
|---|---|---|
| | 475 Year Return Period | 475 Year Return Period |
| CALIFORNIA | Moderate to small decreases -15% to 0% | Large to moderate decreases -35% to -15% |
| PACIFIC NORTHWEST | Moderate to small changes -15% to +5% | Moderate to small decreases -25% to 0% |
| INTERMOUNTAIN WEST | Moderate changes -25% to +15% | Large to moderate decreases -35% to -15% |
| NEW MADRID | Moderate to small decreases -25% to -5% | Moderate to small decreases -15% to 0% |
| NORTHEAST | Moderate to small decreases -25% to -5% | Moderate to small decreases -15% to -5% |
| SOUTH CAROLINA | Moderate to small decreases -20% to -5% | Moderate to small decreases -15% to -5% |

## EARTHQUAKE HAZARD DEFINITIONS

Spectral acceleration (SA) is one of the hazard descriptors commonly used in the USGS hazard maps. The shaking experienced by a building is dependent on its height (which determines its resonant frequency). Spectral Acceleration (SA) is used to distinguish the hazard experienced by buildings of differing heights. SA is expressed in units of "g" at different periods, such as 0.2 sec or 1.0 sec; however, it is more intuitive to translate these periods into approximate building heights. As a rule of thumb, you can approximate the building height by multiplying the time period by 10–0.2 sec period ≈ 2 stories and 1.0 sec period ≈ 10 stories.

Maps presented in this article are for 1.0 sec SA (10-story) at 475 years (10 percent exceeding probability in 50 years), to give you insight into how the changes in seismic hazard vary for a representative building type. The maps

> "...model changes will affect underwritting guidelines, capital requirements and portfolio management strategies."

assume uniform soil conditions and assume a hypothetical, uniform distribution of buildings at every location. In reality, high-rise buildings will be concentrated in city centers, business parks, and other commercial areas. Therefore, the actual changes in seismic hazard experienced by the industry will be a blend of the 1.0 sec maps and other frequencies that are not presented here.

## NEXT GENERATION ATTENUATION (NGA) EQUATIONS

The changes in the USGS' seismic hazard estimates in California were primarily the result of implementing new groundmotion attenuation models called Next Generation Attenuation (NGA) equations. Attenuation equations predict how groundmotion decays with increasing distance from an earthquake's epicenter and are used to determine the size of the earthquake footprint. Attenuation equations vary based on the fault type, the fault rupture characteristics, and the ground-motion modifications that occur along the path between the source and the site (e.g., soil type). Following an expert panel's recommendations, the USGS considered three of the five NGA attenuation equations for calculating the ground motion from crustal earthquake sources in the western United States. The ground motion was calculated for each of the three attenuation relations separately, and then combined using a weighted logic tree approach.

The new NGA equations are significantly different from previous equations (especially for tall buildings). The following maps contrast a M=7.0 event footprint (for a hypothetical single-point rupture) for a 10-story building (1.0 sec SA) as predicted by the new and old attenuation equations for an earthquake scenario on the South San Andreas Fault.

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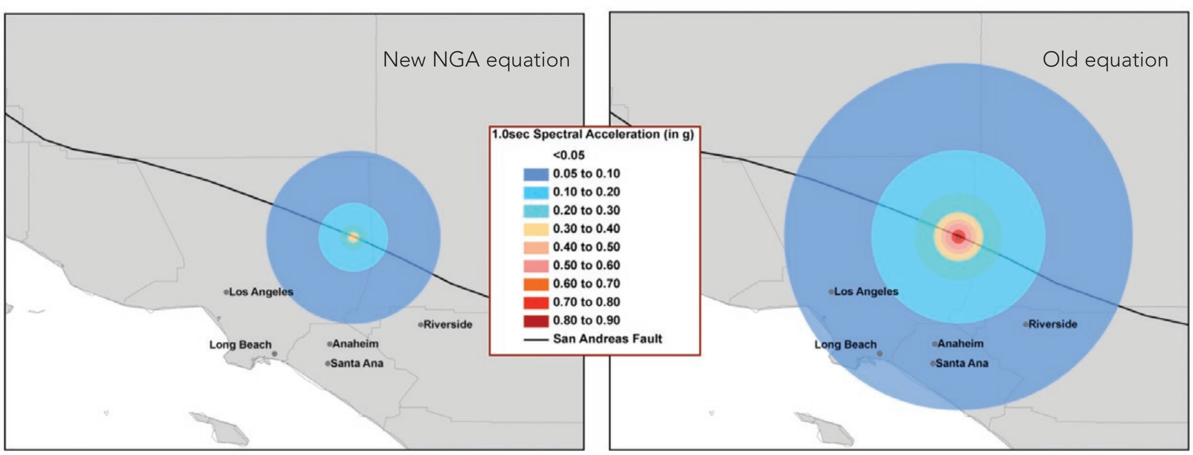


Comparison of Campbell & Bozorgnia 2003 attenuation equation with Campbell & Bozorgnia 2006, NGA. M7.0, strike slip faulting, soft rock site conditions.

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Estimates of shaking felt by high-rise buildings (10-story) using the new NGA equations is more than 40 percent lower compared to the estimates using old equations and the size of the damage footprint for high-rise buildings is significantly smaller in size for the new NGA estimates as compared to the old equations.

## CALIFORNIA REGION

The USGS' National Seismic Hazard Maps (NSHM) and Uniform California Earthquake Rupture Forecast (UCERF) are two studies that describe the latest view of earthquake risk in California. These studies use two different techniques to quantify the earthquake risk in California.

The USGS' NSHM for California is based on a *time independent* earthquake forecast in which the probability of each earthquake rupture is completely independent of the timing of all others. The NSHM describe the probability of shaking caused by these quakes ("seismic hazard") at a given location.

The Working Group on California Earthquake Probabilities (WGCEP) team develops the Uniform California Earthquake Rupture Forecast (UCERF) for California. The UCERF is based on a *time dependent* earthquake forecast, in which the probabilities of a future event is conditioned on known previous earthquakes have occurred. The latest time dependent model, the 2007 UCERF, was released in early 2008, where the earthquake forecast was expanded to cover the entire state of California using a uniform methodology. The UCERF study describes the probability of an earthquake of various magnitudes (M) occurring along various faults in California. However, this study does not describe the probability of shaking caused by these quakes ("seismic hazard") at a given location. This is an important distinction between NSHM and UCERF.

Time dependent model provides a more accurate representation of the probability of a California earthquake, since most faults have been well studied. Areas with a low probability of a local fault rupture, however can experience strong shaking and damage from distant, powerful earthquakes. For this reason, these two studies together will provide a complete view of the seismic risk in California.

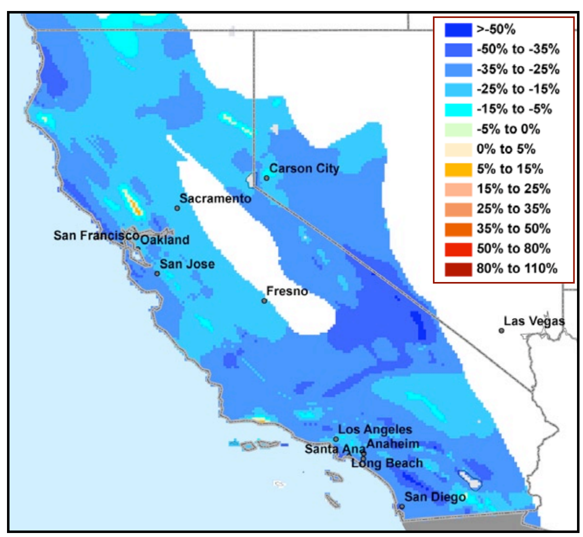
**Seismic Hazard (Time-Independent view)**

The new USGS seismic hazard maps for California are significantly different from the previous maps. The seismic hazard related to high-rise buildings in particular has decreased. The primary reason for the large decreases in the modeled hazard is due to the implementation of the Next Generation Attenuation (NGA) equations

The map below shows the spatial patterns of change in the amount of shaking experienced by high-rise (e.g., 10-story) buildings at the 475-year return period. Only those areas where hazard is significant enough to result in damage at these return periods are shown on this map. The areas along many of the fault traces are where changes in modeled damage could be lower than the changes in modeled hazard presented in the map. This conclusion is based on a representative building damage function. Outside these shaded areas, it is possible for the change in modeled damage to exceed the changes in modeled hazard.

**Change Between the 2002 and 2008 USGS Hazard Maps at 475 Year Return Period for 10-Story Buildings**

(+) increase/ (-) decrease



> "Adoption of NGA equations could mean risk managers need to update business rules based on the distance to a fault."

These significant changes to the seismic hazard could mean catastrophe risk managers will need to update their business rules and underwriting guidelines. Especially, business rules that are based on the distance to a fault, such as exposure aggregate thresholds, underwriting guidelines or insurance rates, will be significantly affected by these changes.

**Earthquake Probabilities (Time-Dependent view)**

The UCERF study describes the probability of an earthquake of various magnitudes (M) occurring across California. The results of the new study are similar to those in previous studies; however, the new probabilities calculated for the Elsinore and San Jacinto Faults in Southern California are about half of the previous predictions.

The new forecast indicates that California has a 99.7 percent chance to experience a M≥ 6.7 earthquake in the next 30 years and the likelihood of M≥ 7.5 earthquake in the next 30 years is 46 percent. The southern San Andreas Fault (near Los Angeles) has the highest probability (59 percent) in California of generating at least one M≥6.7 earthquake in the next 30 years, which is 23 percent higher than the time-independent probabilities.

In the northern California, Hayward-Rodgers Creek Fault (near Oakland) has the highest probability (31 percent) of generating at least one M≥ 6.7 earthquake in the next 30 years, which is 33 percent higher than the time-independent probabilities. The time-dependent probability for an M ≥ 6.7 earthquake to occur on the northern San Andreas Fault (near San Francisco) is about 13 percent lower than time-independent view.

## IMPLICATIONS OF NEW STUDIES ON VENDOR MODELS

The studies performed by the USGS and the WGCEP are very comprehensive, and have had wide scientific and catastrophe modeler adoption. These studies are the impetus for commercial catastrophe risk modeling companies to make periodic updates to their U.S. Earthquake models. The commercial modeling companies, however, cannot directly implement the National Seismic Hazard Maps and the Uniform California Earthquake Rupture Forecast into their models. This information must be translated into an event-based catastrophe model that is suited for the insurance industry. Therefore, although all modeling companies may start their development activities from a similar place, their implementation of these studies will result in different answers to the same question.

**How will changes to the commercial models differ from the USGS changes?**

There are three ways the changes in the commercial models will differ from the USGS:

1. The commercial models are broader in scope than the USGS.
   (e.g., site-specific amplification, basin effects, fire following, loss amplification, time dependency, etc.)
2. The commercial model developers will selectively differ in their scientific assumptions than the USGS.
3. The commercial modelers will recalibrate their models. It is plausible that changes to the engineering components of the models will offset or amplify changes to the seismic hazard.

Commercial models are broader in scope than the USGS' maps, but this point has significant implications for how we interpret the information in this article. For example, the modeled risk to the structure coverage for 10-story buildings may go down in the new models, however, new methods for modeling loss amplification may offset some of these changes. In addition, some of the modeling assumptions made in the new maps might have already existed in the current version of the vendor models. Therefore, the changes in the USGS' seismic hazard maps cannot be used to precisely predict changes that will occur in the vendor models.

In addition, commercial modelers often take the opportunity to upgrade many other model components, in addition to seismic hazard. Ultimately, the insurance industry is most interested in the product of all these components working together to asses the full catastrophe risk of a portfolio—not by each component in isolation. Therefore, the modelers will recalibrate their models to ensure that the results are well validated, whilst ensuring that each component is scientifically defensible. As such, changes in the seismic hazard component of the model may lead to refinements in the damage/ vulnerability

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model. These multiplicative changes could result in offsetting or amplifying effects.

## CONCLUSIONS

We can not exactly predict how the commercial models losses will change based on the USGS hazard changes. However, the USGS modeled hazard decreases for high-rise buildings are so substantial, significant decreases in modeled losses are likely to occur if the vendors fully adopt the NGA equations. One way we can get more insight into these changes is by studying the spatial patterns of change in hazard estimates and understanding the loss sensitivities from changes to the hazard. By virtue of the shape of a building damage function for earthquakes, the amount of damage a building incurs rapidly decreases as the ground motion attenuates from the fault (all other components remaining constant). Therefore, as an example, a 20 percent decrease in hazard can equal a 30-50 percent decrease in expected damage. This means that modeled damage for 10-story buildings may decrease by a much larger amount than the change in modeled hazard shown in the maps presented in this article. The exception to this rule is the immediate vicinity of faults where marginal changes in hazard have little effect on modeled damages.

At this point, we can conclude that model changes will be significant for many portfolios, and the patterns of change will be complex and multifaceted. These changes will affect underwriting guidelines, capital requirements, and portfolio management strategies. Also, these changes will affect the downstream risk to Workers Compensation portfolios. Changes to portfolio loss estimates in the Western United States will be highly influenced by the new NGA equations, especially for mid-rise and high-rise buildings and business rules that are based on the distance to fault will be significantly affected. Changes to loss estimates in the Central and Eastern United States will be relatively low compared to changes to the Western United States.

This article is a shortened version of a report by authors, released by Willis in 2008 entitled: “Preparing for a New View of U.S. Earthquake Risk.” This article focuses on the critical changes to the view of earthquake risk in California region. We encourage readers to refer to the original document for information on other regions, which is available at *http://www.willisre.com/html/reports/catastrophe/Willis_Report_Preparing_for_a_New_View_of_US_EQ_Risk.pdf* ✦

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