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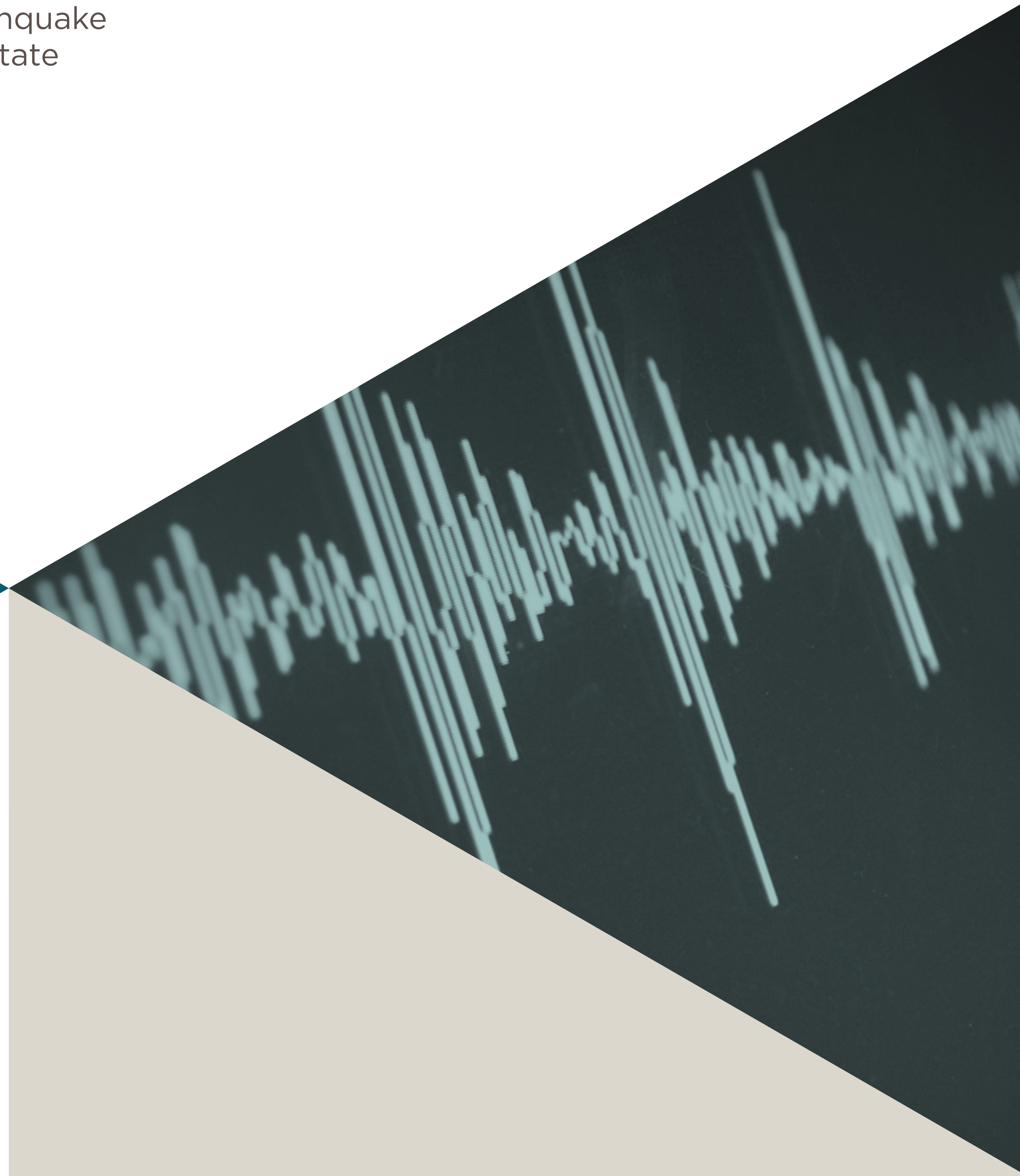
Seismic Risk in California Is Changing

The Impact of New Earthquake Hazard Models for the State



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Introduction

On June 1, 2016, CoreLogic® released a new earthquake catastrophe risk model for the United States that provides estimates of potential financial losses from earthquakes. The U.S. Earthquake Model by CoreLogic is the first-to-market incorporating a full implementation of the U.S. Geological Survey (USGS) updated seismic hazard model for the U.S. (Petersen et al., 2014, 2015) and the new time-independent and time-dependent seismic hazard models for California, known collectively as Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3; Field et al., 2014, 2015; Powers and Field, 2015). The difference between these two latter hazard models is that in the time-independent model the probability of an earthquake occurring sometime in the future does not change with the passage of time (known as Poisson occurrences). On the other hand, in the time-dependent model the probability of an earthquake occurring in the future changes with the passage of time, and increases rather substantially as the average recurrence time of the earthquake is approached. The time-dependent model accounts for the long-known fact (e.g., Reid, 1911) that strain slowly accumulates on a fault, meaning that the greater the elapsed time from the last damaging earthquake, the closer it is to the next. The UCERF3 models were developed by a distinguished group of USGS, California Geological Survey, and university scientists, referred to collectively as the Working Group on California Earthquake Probabilities. The rapid implementation and release of the CoreLogic model once the USGS models became public was possible because of the long-standing relationship and involvement of scientists in the CoreLogic earthquake Model Development Group with the USGS National Seismic Hazard Mapping Project.

Changes in California Earthquake Hazard

Although much has changed in specific areas across the U.S. in the new U.S. Earthquake Model, some of the most significant changes that affect potential earthquake losses are in California. Seismological insights from recent earthquakes worldwide, such as the 2011 magnitude (M) 9.0 Tohoku-oki, Japan earthquake and the 2010 M7.1 Darfield, New Zealand earthquake, prove that earthquake faults are more interconnected at depth than previously thought. The surface traces of faults that appear to be disconnected can give a false impression of their possible connectivity at seismogenic depths. In retrospect, this fact was also demonstrated in California by the 1992 M7.3 Landers earthquake, which ruptured across four different faults that had been previously identified at the surface (Hauksson et al., 1992) and created a fifth, previously unknown, fault during the earthquake.

The new UCERF3 fault model applies these lessons-learned from recent earthquakes by allowing longer fault ruptures and larger earthquakes to occur along the fault systems in California than had been previously considered impossible in the geologically segmented UCERF2 fault model. For example, it is now possible for earthquake ruptures on the San Andreas Fault to cross the Creeping Section of the fault north of Parkfield, California, which blurs the distinction between what were formerly known as northern and southern segments of the San Andreas Fault. Both of these segments were previously thought to be seismologically isolated from one another by the Creeping Section of the fault, but nevertheless capable of rupturing in great earthquakes, such as the 1906 M7.8 San Francisco earthquake on the northern part of the San Andreas Fault and the 1857 M7.9 Fort Tejon earthquake on the southern part of the San Andreas Fault. The possibility of earthquakes rupturing through the Creeping Section of the fault has since been shown to be possible using computerized earthquake simulators and physics-based ground-motion simulations.

The Implication

The implication of allowing longer fault ruptures and larger earthquakes to occur on California faults in the UCERF3 fault model is shown in Figure 1. This figure compares the modeled UCERF3 state-wide magnitude-frequency distribution (MFD) with that of the UCERF2 model and with a traditional Gutenberg-Richter MFD (Gutenberg and Richter, 1944) derived from California historical seismicity. From this comparison it can be seen that the modeled frequency of catastrophic-loss earthquakes of M7.5–8.5 has increased in the UCERF3 model by about 37 percent on average; whereas, the frequency of large-loss earthquakes of M6.5–7.5 has decreased by about 35 percent on average. The so-called UCERF2 bulge issue noted in the figure was a significant concern to the UCERF2 Working Group on California Earthquake Probabilities and was partially addressed using an ad-hoc method, although it could not be totally resolved at the time that the model was constructed.

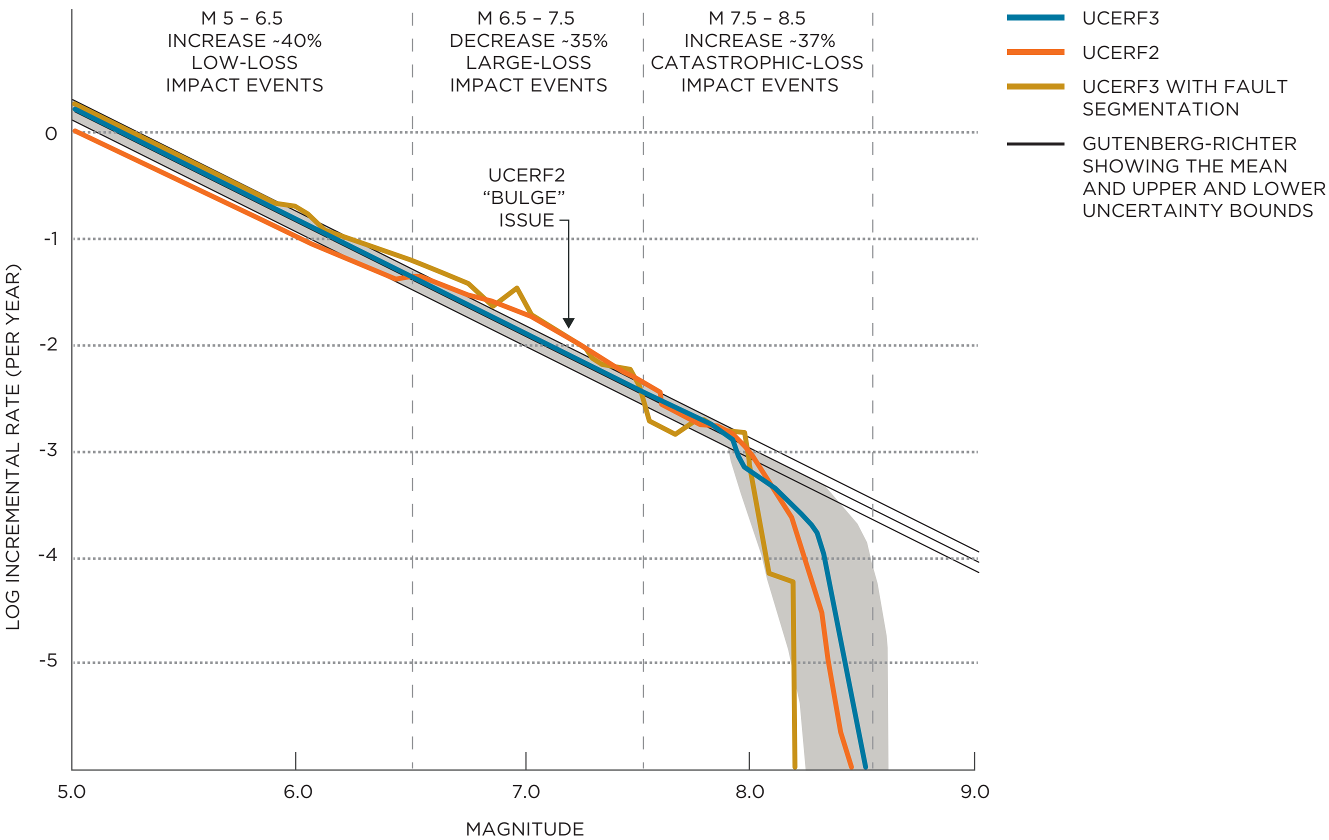

Figure 1. Comparison of the state-wide magnitude-frequency distributions for California (modified from Field et al., 2013).

The UCERF3 model resolved the discrepancy of the UCERF2 bulge issue as indicated by its agreement with the historical Gutenberg-Richter MFD. However, that could only be accomplished by relaxing the prescribed segmentation of faults in the UCERF2 model. This model change forecasts larger, unsegmented ruptures to occur that can jump across gaps to continue rupturing along nearby faults. The yellow curve in Figure 1 is the MFD of the UCERF3 model, but with strict fault segmentation applied as in the UCERF2 model. This curve shows that the unwanted bulge once again appears and that the frequency of the largest earthquakes decreases rather substantially from that predicted by the MFD of the UCERF3 model. This test validates the notion that it was the fault segmentation model of UCERF2 that inflated the frequencies of M6.5–7.5 earthquakes above that observed historically. It can also be seen from Figure 1 that the frequencies of M5.0–6.5 earthquakes increase by about 40 percent on average in the UCERF3 model compared to the UCERF2 model. However, these are generally low-loss impact earthquakes and do not cause an increase in damage.

Impact of UCERF3 Changes on Hazard Distribution

An important component in modern seismic risk assessment is the stochastic event set. In the CoreLogic RQE platform, the stochastic event set is a geographically referenced set of potential earthquake scenarios, each uniquely defined by an earthquake magnitude, recurrence frequency, and ground motion footprint. Each individual location of the footprint is defined by the mean, epistemic (modeling) uncertainty, and aleatory (random) variability of the ground motion derived from the underlying probabilistic seismic hazard model and accounts for the correlation with other footprint locations. Given the longer fault ruptures forecast in the UCERF3 model, footprints of stochastic events representing the larger earthquakes in California have correspondingly increased in length. As an example, Figure 2 compares ground-motion footprints for similar magnitude earthquakes between the UCERF2 and UCERF3 models for a ~250-year loss event along the Hayward-Rodgers Creek Faults and for a ~500-year loss event along the southern San Andreas Fault. The loss-impact area is substantially larger for the longer UCERF3 fault-rupture lengths.

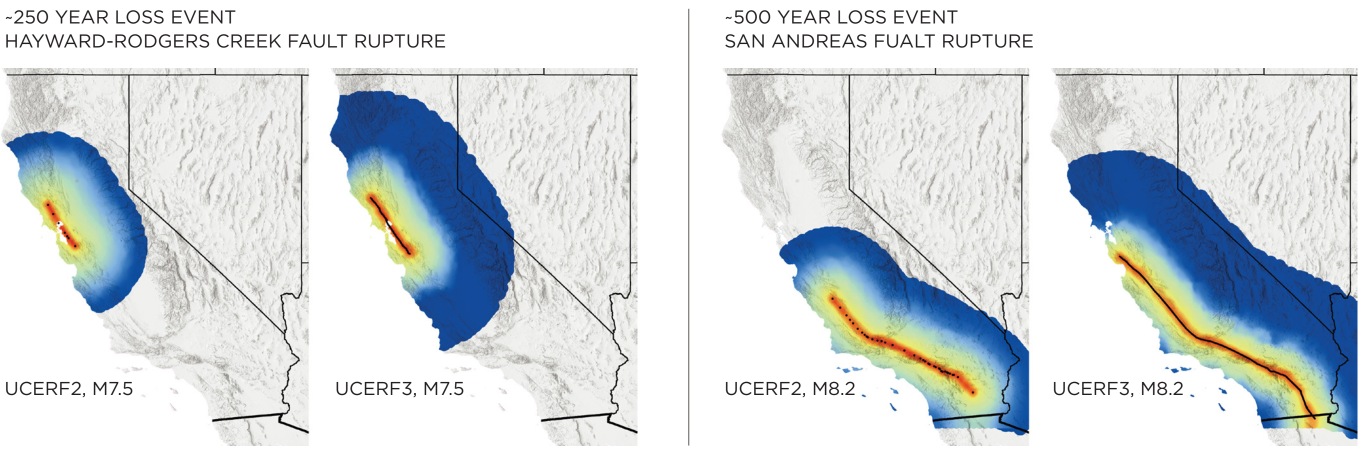

Figure 2. Example comparison of UCERF2 and UCERF3 modeled fault-rupture ground-motion footprints for similar magnitude earthquakes.

In addition, the spatial correlation of losses from individual large earthquakes in the UCERF3 model has increased dramatically. Figure 3 compares zip codes in California that are impacted by large-loss events in the Los Angeles and Oakland, California areas. A far greater area of the state shows a loss impact for similar magnitude earthquakes in the UCERF3 model compared to the UCERF2 model, once again due to the longer fault ruptures forecast in the UCERF3 model.

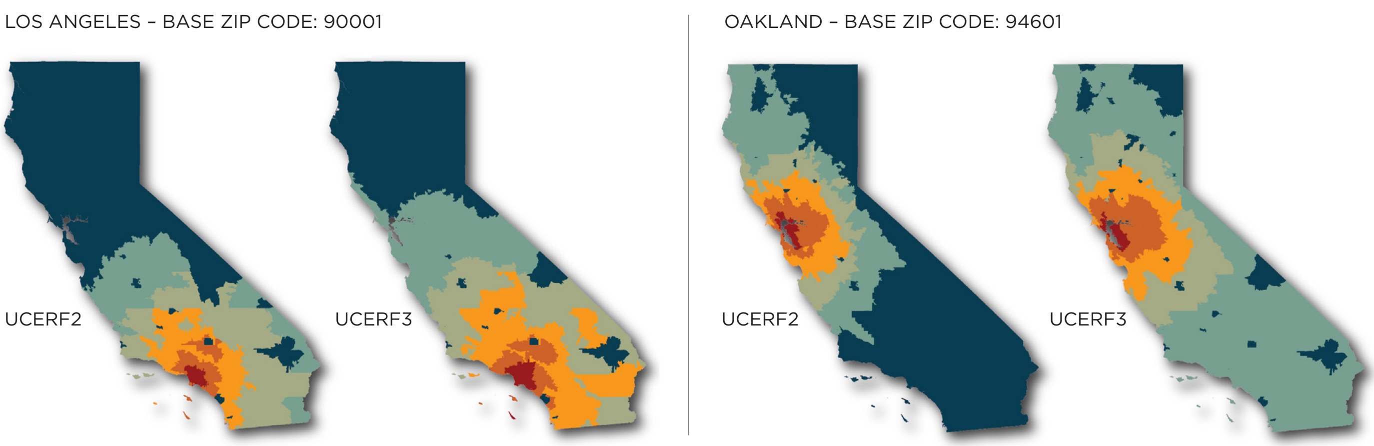

Figure 3. Comparison of the spatial correlation of loss between the UCERF2 and UCERF3 models for a large earthquake in the vicinities of Los Angeles and Oakland.

The Changing Drivers of Risk

The differences in the hazard distribution between the UCERF2 and UCERF3 models directly impacts the earthquake magnitudes driving the risk on a state-wide basis. Figure 4 compares the earthquake magnitudes that drive the risk between these two models for the shorter return periods on the loss-exceedance curve, which are important for estimating the Average Annual Loss (AAL; top pie charts), and for the longer return periods that are important for estimating the 500-year Tail Value at Risk (TVAR; bottom pie charts).

At the AAL level, the impact of M6.5–7.5 earthquakes is reduced in the UCERF3 model, but the impact of smaller earthquakes below M6.5 has increased. This is directly attributable to the changes demonstrated in the MFDs of the UCERF3 and UCERF2 models in Figure 1. At the TVAR level, the greater impact from catastrophic-loss earthquakes with magnitudes greater than M7.5 is pronounced in the UCERF3 model. This is due not only to the higher recurrence frequencies of these earthquakes but also to the longer fault ruptures that result from a more connected California fault network than was permitted in the more-segmented UCERF2 model.

The implication of these changes in the drivers of risk is that the UCERF3-based loss-exceedance curve for California has become steeper, resulting in higher losses at long return periods and lower losses at short return periods as compared to the UCERF2-based loss-exceedance curve.

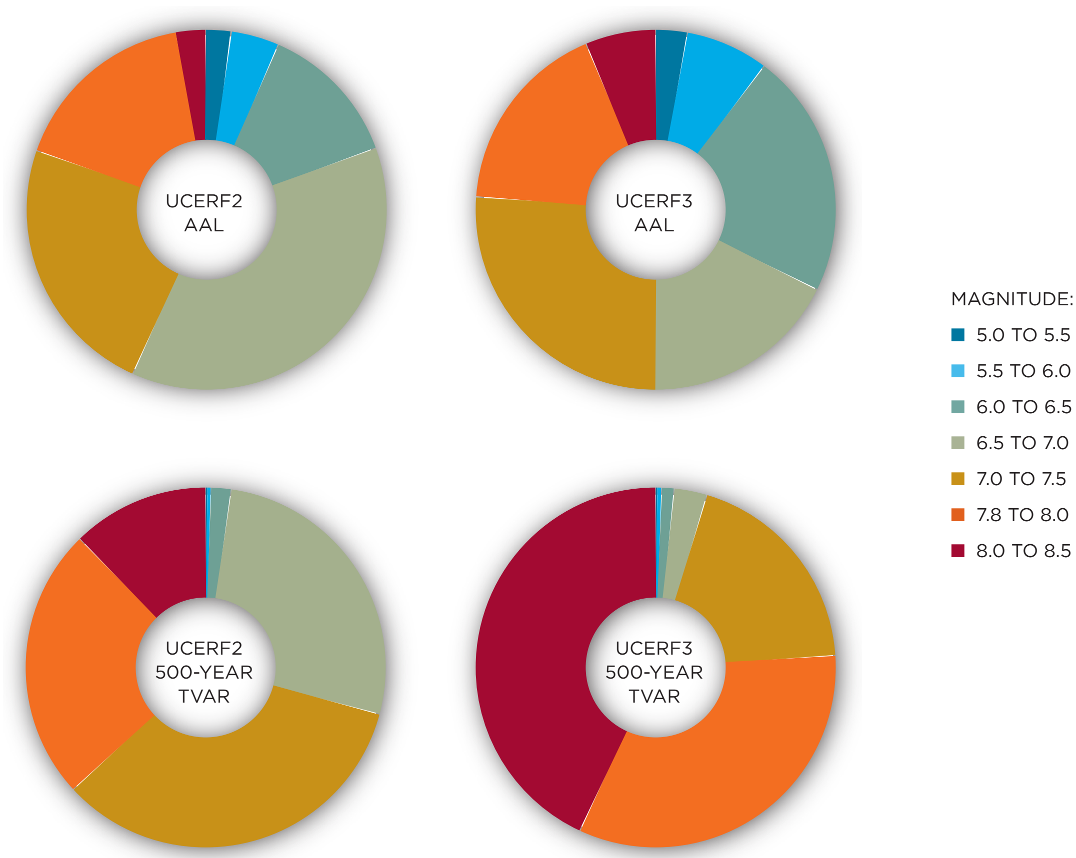

Figure 4. Comparisons of the earthquake magnitudes driving the risk for the State of California between the UCERF2 model (left column of charts) and the UCERF3 model (right column of charts) for the AAL (top row of charts) and the 500-year TVAR (bottom row of charts).

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