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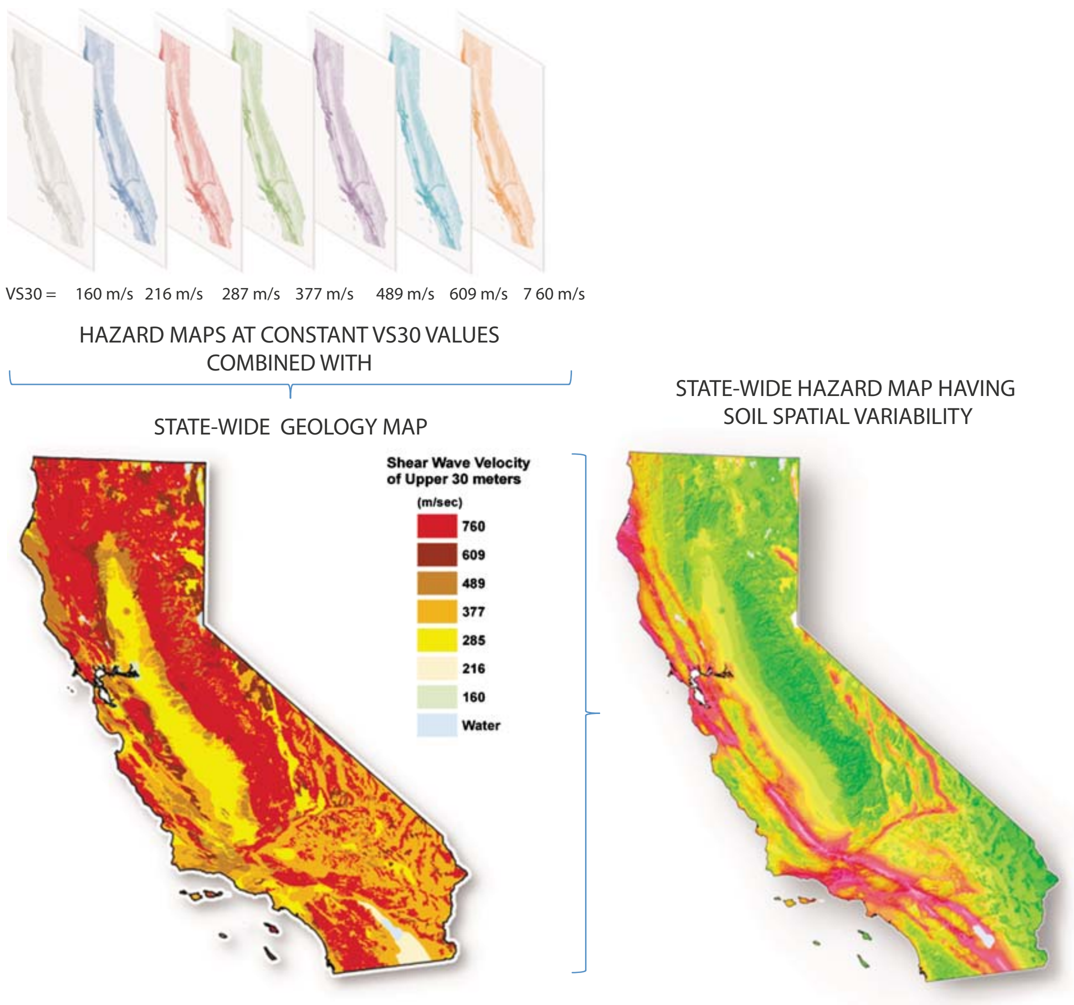

Hazard map for California that takes into account site effects

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Seismic Hazard Mapping of California Considering Site Effects

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In this paper, we have combined the U.S. Geological Survey's National Seismic Hazard Maps model with the California geologic map showing 17 generalized geologic units that can be defined by their V_{S30}. We regrouped these units into seven V_{S30} values and calculated a probabilistic seismic hazard map for the entire state for each V_{S30} value. By merging seismic hazard maps based on the seven different V_{S30} values, a suite of seismic hazard maps was computed for 0.2 and 1.0 s spectral ordinates at 2% probability of exceedance (PE) in 50 years. The improved hazards maps explicitly incorporate the site effects and their spatial variability on ground motion estimates. The spectral acceleration (SA) at 1.0 s map of seismic shaking potential for California has now been published as California Geological Survey Map Sheet 48. [DOI: 10.1193/1.3478312]

INTRODUCTION

The National Seismic Hazard Maps (Petersen et al. 2008) are the standard depiction of seismic hazard across the United States. These maps are intended not only for design of new and rehabilitation of existing structures but also for emergency planning, loss estimation, and risk assessment. These maps use a uniform set of input parameters and calculations that were developed through numerous workshops and conferences with the participation of seismologists, geologists, and engineers. In California, the 2008 National Seismic Hazard Maps are based on a seismic hazard model, the Uniform California Earthquake Rupture Forecast (UCERF), developed by the Working Group on California Earthquake Probabilities (WGCEP 2008) through a similarly open and inclusive process. The National Seismic Hazard Maps show the level of ground motion with a 2% probability of exceedance in 50 years, a value chosen for structural design in current building codes. These maps portray the spatial variability of seismic hazard by considering the potential earthquakes on faults with known slip rates.

For the National Seismic Hazard Mapping Program (NSHMP), ground motion is calculated by assuming that all sites are uniform "firm rock" and that the site conditions can be described by an average shear-wave velocity (V_{S30}) in the upper 30 meters as 760 m/s. In depicting the variability of earthquake hazard across a region, assuming a uniform "firm rock" condition across the area results in a pattern of ground motion that falls off smoothly from the major faults and misses the areas of high potential ground shaking due to amplification of seismic waves by the near-surface soils, which is commonly referred to as

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site amplification. During the 1985 Mexico City and 1989 Loma Prieta earthquakes, amplification due to near-surface soils resulted in significant damage to structures (Anderson et al. 1986, Holzer 1994). As a result, current building codes in the United States (e.g., ICBO 2007 and ICBO 2006) require consideration of site-amplification when estimating the seismic demand on a structure by modifying the "firm rock" ground motion by a set of factors representing generic site classifications (Borcherdt 2002). Recognition of the importance of site amplification has prompted efforts to map site conditions at regional and statewide scales. For example, Seekins et al. (2000) studied soil type and associated shaking hazard in the San Francisco Bay area, while Wills et al. (2000) and later Wills and Clahan (2006) mapped the geographic distribution of V_{S30} for the entire state of California.

For the hazards maps, we have incorporated the potential amplification by the near-surface soils to develop a more complete depiction of potential seismic shaking hazards throughout California. Seismic hazard maps incorporating the site effects were computed for 0.2 and 1.0 s spectral ordinates at 2% PE in 50 years. The 0.2 and 1.0 s periods are selected because they are used as corner spectral periods to construct a smooth design spectrum for structural design; an appropriate procedure to obtain a smooth design spectrum from a uniform hazard spectrum is given in the ASCE 41-6 guidelines (ASCE 2007).

The methodology used herein to prepare the resulting hazard maps is similar to one used for development of the national seismic hazard maps except it incorporates the impact of shallow geologic units. Comparison of the new hazard maps with the maps prepared by the NSHMP on the basis of uniform rock assumption indicates that incorporating site effects may escalate the ground shaking potential more than two times, especially in areas designated with low V_{S30}.

The new hazard maps presented in this article are useful for both building code applications and input to earthquake loss models. It may also serve as a reference for site-specific probabilistic seismic hazard analyses. The SA at 1.0 s map of seismic shaking potential for California has been published now as California Geological Survey Map Sheet 48 (Branum et al. 2008), which is intended to be accessible and understandable to the general public.

DEVELOPING THE EARTHQUAKE SHAKING POTENTIAL MAP

To show the potential for earthquake shaking, we applied the seismic hazard computer codes developed for the National Seismic Hazard Maps. These codes incorporate the UCERF and the Next Generation of Attenuation (NGA) relations for calculating ground shaking in a complete, consistent format where each aspect of the calculation has been extensively reviewed. For hazard computations in California, we have considered the hazard contributions due to the active faults in California, adjacent parts of Nevada and Oregon and the Cascadia Subduction zone.

The NSHMP codes calculate a grid of ground motion values with a specified probability at a chosen spectral period. Although the NSHMP codes calculate the ground shaking hazard for a "firm rock" site condition, it can be modified to calculate hazard for any value of V_{S30}. This requires a statewide V_{S30} map. To generate such a map for California, Wills and Clahan (2006) used the shear-wave velocity characteristics of geologic units updated from those described by Wills and Silva (1998) and applied them to a map that covers all of the sites where shear-wave velocity has been measured. In doing this, they created a new site conditions map for California where each site can be classified by a general geologic category (see Figure 1). To simplify calculations and production of the statewide hazard map, the most similar geologic categories could be combined and a composite V_{S30} value used for the combination. By reassembling geologic categories, we were able to simplify the map of Wills and Clahan (2006) from 17 geologic categories into seven V_{S30} "map groups." The table embedded in Figure 1 shows the simplified geologic units with calculated mean V_{S30} for that unit from Wills and Clahan (2006); further generalized groups used for calculation of the map grids here are described in the last column in Figure 1 and also mapped in Figure 2.

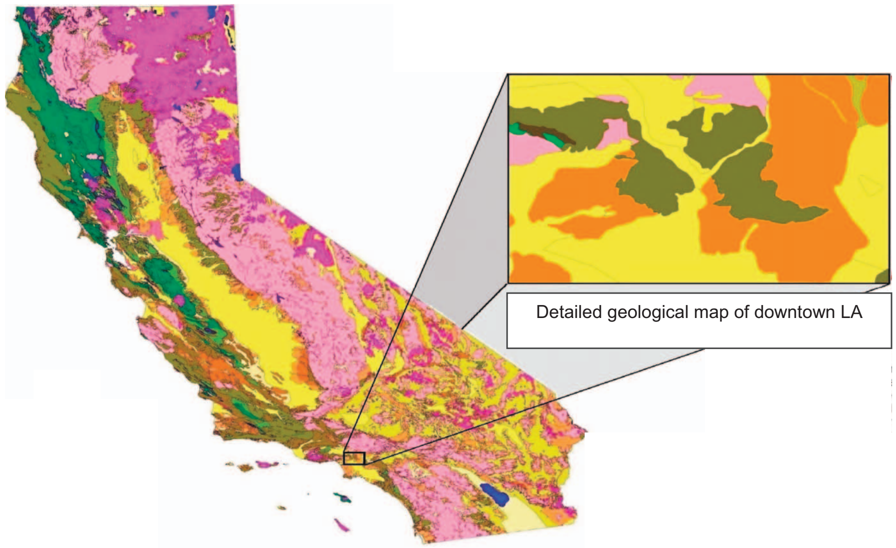
We used the NSHMP computer codes to calculate the seismic hazard with a 2% chance of being exceeded in 50 years for 0.2 and 1.0 s spectral periods for each of the seven V_{S30} values separately. The resulting grids show the seismic shaking hazard for the specified period (0.2 or 1.0 s) and V_{S30} (160, 216, 287, 377, 489, 609, or 760 m/s).

In the next step, we contoured each of the seven maps of gridded values for each period in a GIS environment to create polygons with a discrete range of values. The final map for each period was created by cutting the polygons defined from the grids by using polygons from the V_{S30} map (Figure 2), then assembling the final map using the polygons defined on the basis of the grid for a specific V_{S30} in place of the whole V_{S30} polygon. A schematic procedure for generating the statewide hazard map incorporating spatial variability of site conditions is demonstrated in Figure 2. Another approach to incorporate soil effects onto the hazard map would be assigning a V_{S30} value corresponding to each grid point by using the geology map as a reference. This approach requires a single probabilistic seismic hazard analysis (PSHA) based on a varying V_{S30} values on the grid. Although it seems to be computationally attractive, the resultant hazard values would mask the local peaks and valleys due to the smoothing process between grid points, initially spaced at 0.05°. It should be noted that the digitized boundaries are more precisely located than the grid; therefore the boundaries are shown more clearly using the polygons with different V_{S30} than using the grid.

In computing the seismic hazard for California, only three NGA relations were used (Campbell and Bozorgnia 2008, Boore and Atkinson 2008, Chiou and Youngs 2008). The Campbell and Bozorgnia and Chiou and Youngs relations require the basin depth as an input parameter. Currently, no statewide basin depth map is available to account for spatial variability of this value; therefore, a fixed value of 2.0 km was utilized using the Campbell and Bozorgnia relation. 2.0 km is selected because it averages the basin-depth effect on ground motion predictions (Harmsen 2009). For the Chiou and Youngs relation, basin depth is defined as depth to sustained $V_{S30}=1000$ m/s; this depth, Z1.0, is determined from V_{S30} using the default equation from Chiou and Youngs (2008).

SEISMIC SHAKING HAZARD MAPS

Figures 3 and 4 show the mean values of seismic hazard computed from PSHA for spectral acceleration (SA) at 0.2 and 1.0 s for 2% PE in 50 years. The distribution of cal-



Geologic Unit	Geologic Description	Unit V_{S30} (m/s)	Map Group V_{S30} (m/s)
Qi	Intertidal Mud including "bay mud"	160	160
Qal, deep, Imperial V.	Holocene alluvium in the Imperial Valley.	209	
aft/qi	Artificial fill over intertidal mud around San Francisco Bay.	217	216
Qal, fine	Fine grained Quaternary (Holocene) alluvium.	236	
Qal, deep	Quaternary (Holocene) alluvium in deep basins.	280	
Qal, deep, LA Basin	Quaternary (Holocene) alluvium in the Los Angeles basin.	281	287
Qs	Quaternary (Pleistocene) sand deposits.	302	
Qal, coarse	Coarse grained Quaternary (Holocene) alluvium	354	
Qal, thin	Thin (Holocene) alluvium underlain by contrasting material within 30m.	349	377
Qoa	Quaternary (Pleistocene) alluvium	387	
QT	Quaternary to Tertiary (Pleistocene - Pliocene) alluvial deposits.	455	
Kss	Cretaceous sandstone.	566	489
Tss	Tertiary sandstone.	515	
Tv	Tertiary volcanic rocks.	609	
Serpentine	Serpentine.	653	609
KJf	Franciscan complex rock.	782	
Xtaline	Crystalline; including granitic and metamorphic rocks.	748	760

Figure 1. Statewide map of Wills and Clahan (2006) shows 17 geologically defined shear-wave velocity categories with the V_{S30} values in the table. Right columns of the table shows simplified geologic units with calculated mean V_{S30} for that unit and further generalized (last column) for calculation of the map grids described here. A snapshot of the Los Angeles downtown area indicates the geological detailing of the map.

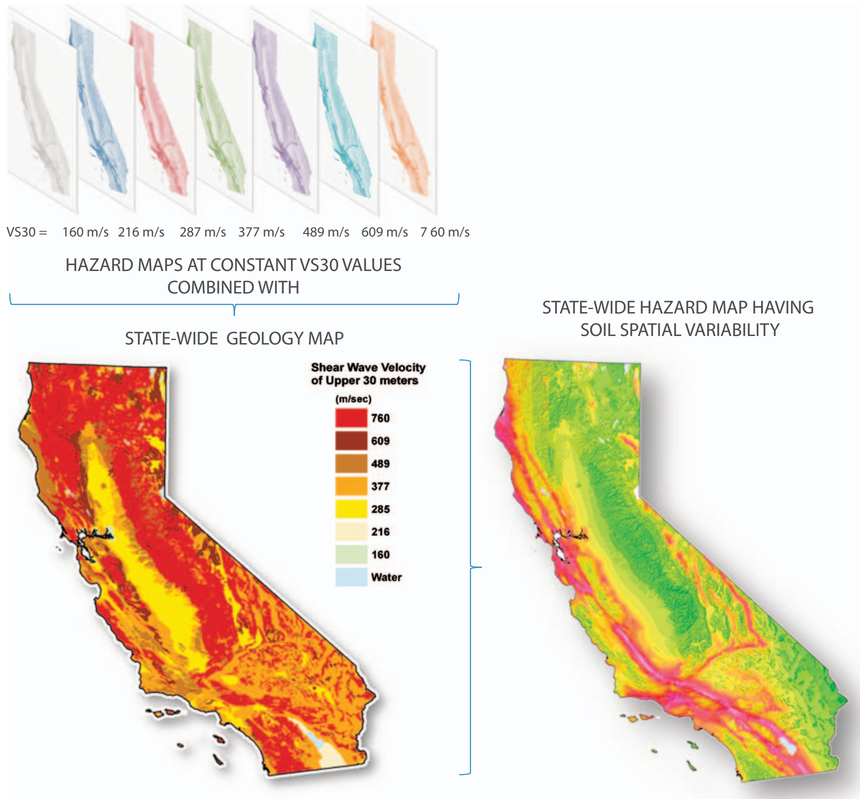


Figure 2. Schematic procedure for generating seismic hazard map for California incorporating spatial variability of site conditions.

culated SA values, shown by the color gradient, indicates higher acceleration values along the active fault lines. Peak values of SA reach 4.5 g at 0.2 s and 2.5 g at 1.0 s. The simple pattern of increased shaking hazard near the major seismic sources is clearer in the map of 0.2 s in Figure 3 because the surface soils have less effect on the short period shaking. The 1.0 s period shaking shows more pronounced influence of surface soils. The resulting map exhibits areas where high shaking hazard extends farther from a fault on one side than the other because of the increased shaking potential due to soft soils that are only found on one side of the fault lines (this effect is clear along the Hayward fault in the east bay area as well as others in the basin and range province of eastern California). The map also shows a few areas—for instance, the Sacramento-San Joaquin delta—where the soft near-surface soils increase the shaking hazard to levels comparable with areas with more frequent earthquakes.

To better demonstrate the influence of soil amplification on the hazard results, we examined the distribution of hazard in the San Francisco Bay and Los Angeles areas. In Figure 5, we compare the mean hazard values along the Hayward and northern branch of the San Andreas faults on the basis of a fixed V_{S30} (V_{S30}=760 m/s, i.e., uniform rock)

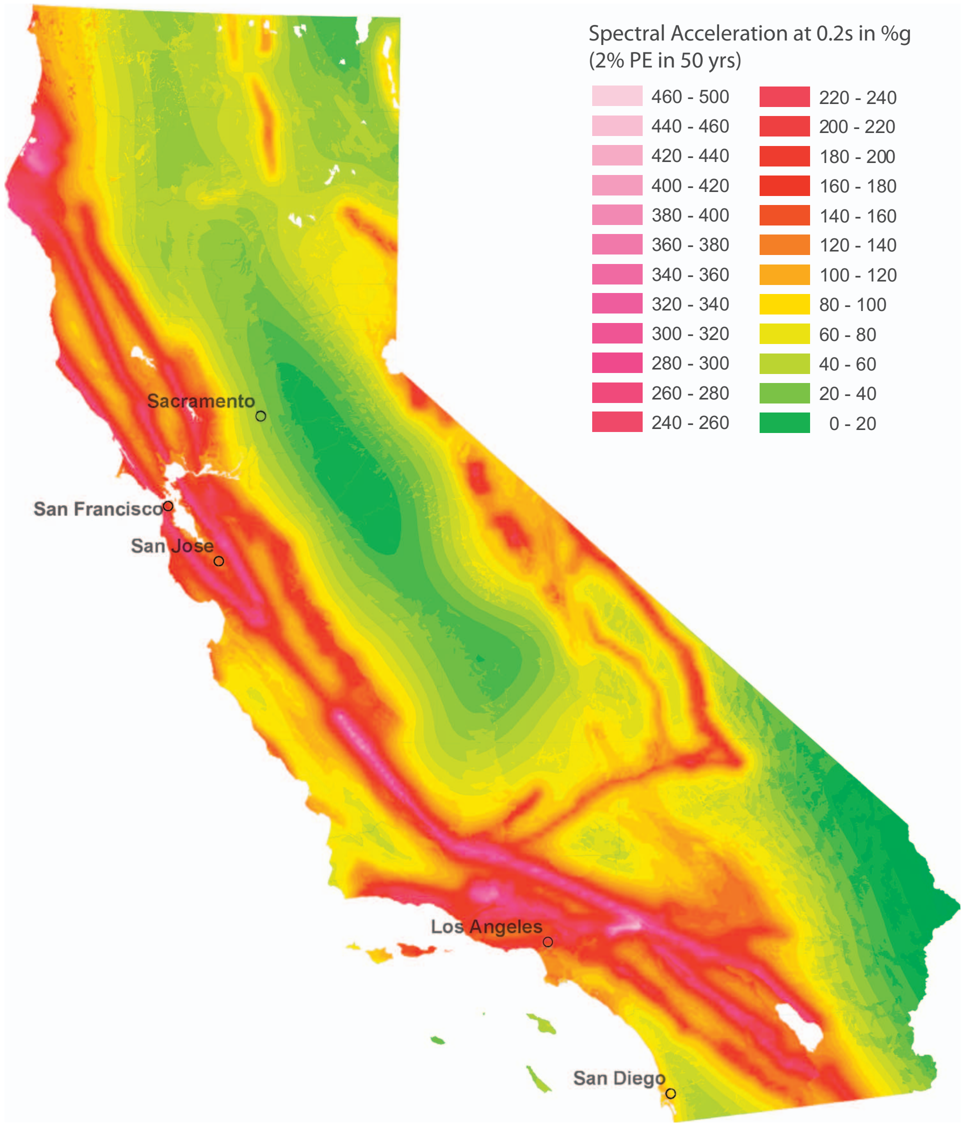


Figure 3. Spectral acceleration at 0.2 s map for California for 2% probability of exceedance in 50 years.

with hazard values by considering spatially variable V_{S30}. The ratio of the hazard values on the two maps shown in Figure 6 is the amount that the shaking hazard is amplified by the near-surface soils. From the map of this ratio, it becomes evident that there are extensive areas of Marin County and smaller areas on the San Francisco Peninsula where the near-surface soils do not significantly amplify the potential ground shaking (the ratio is near 1.0 because the near-surface material is "firm rock"). In most of the East Bay, however, there is

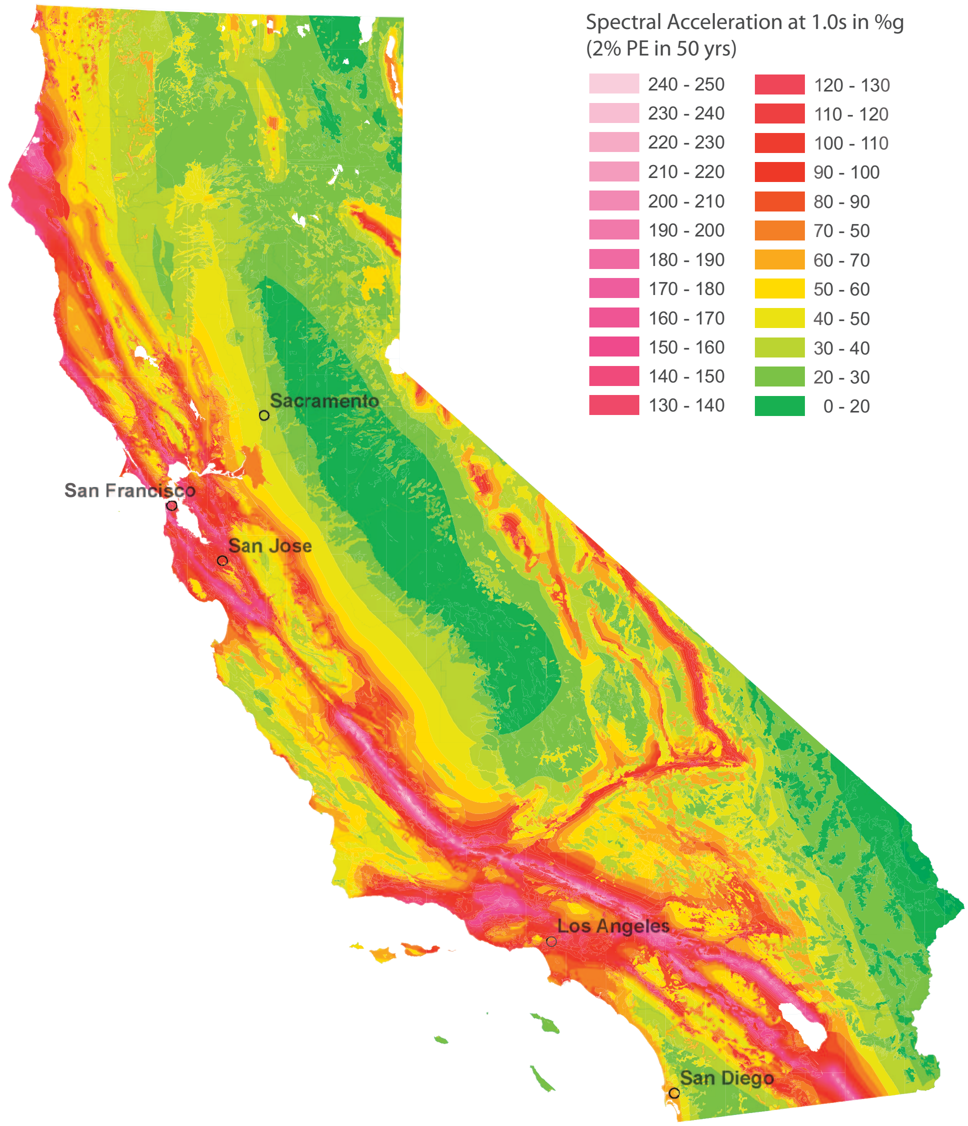
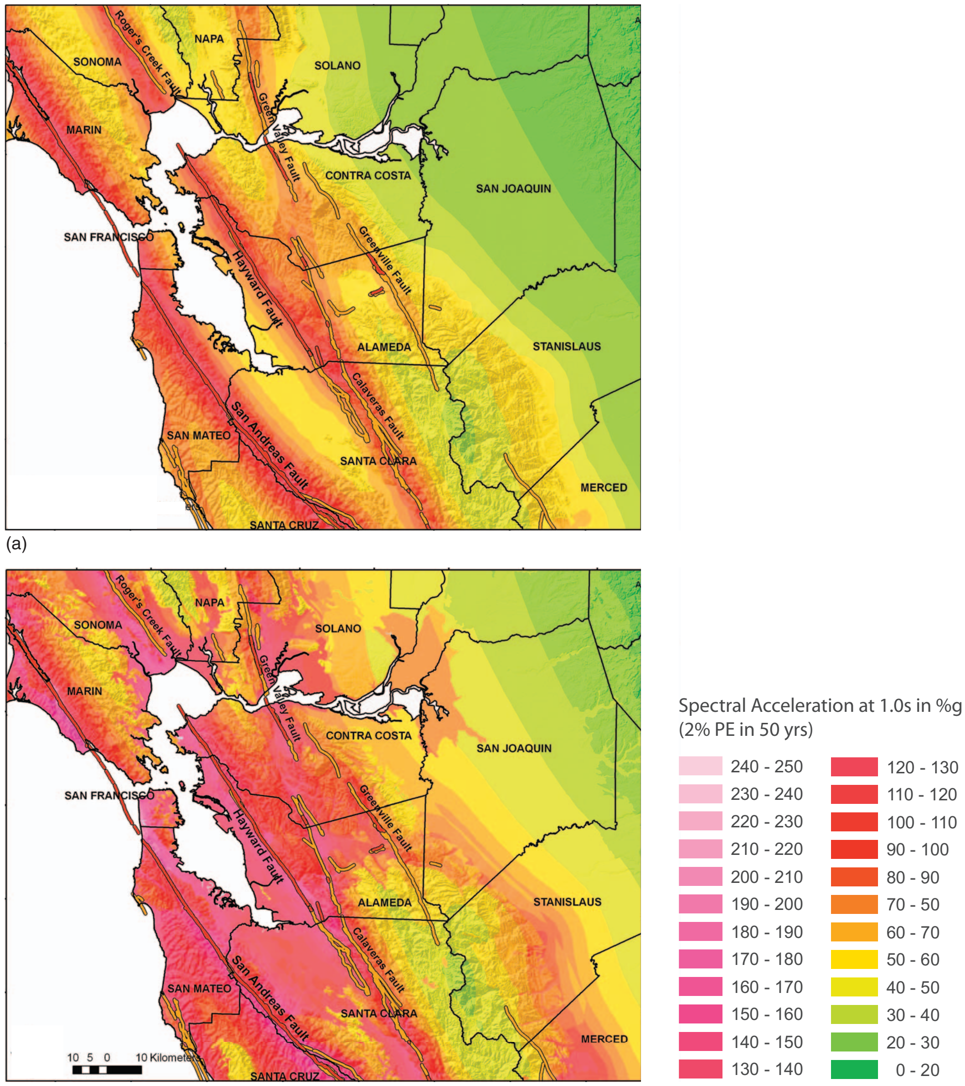


Figure 4. Spectral acceleration at 1.0 s map for California for 2% probability of exceedance in 50 years.

significant amount of site amplification. Site-conditions increase the shaking potential by 25% or more in much of the East Bay hills, because they are underlain by sandstone and shale with V_{S30} values lower than the 760 m/s of “firm rock.” Site amplification is greater in alluvial valleys and in bay mud. In alluvial sites, shaking potential is 50% to 100% higher than in “firm rock” sites. The bay mud and similar intertidal mud in the delta area more than double the potential shaking hazards from the values calculated for “firm rock” (further de-



(b)

Figure 5. Close up view of seismic hazard in the San Francisco Bay; maps show SA at 1.0 s with 2% probability of exceedance in 50 years. (a) V_{S30}=760 m/s; (b) Variable V_{S30}.

tailed in the next section). The pattern is complicated by the fact that the NGA relations utilize nonlinear soil correction (i.e., site amplification decreases with increasing ground-motion intensity as surface materials reach their strength limit and start behaving nonlinearly); along the fault lines in the near-field zone, they predict de-amplification on soft soil for large input (rock) SA at high frequencies.

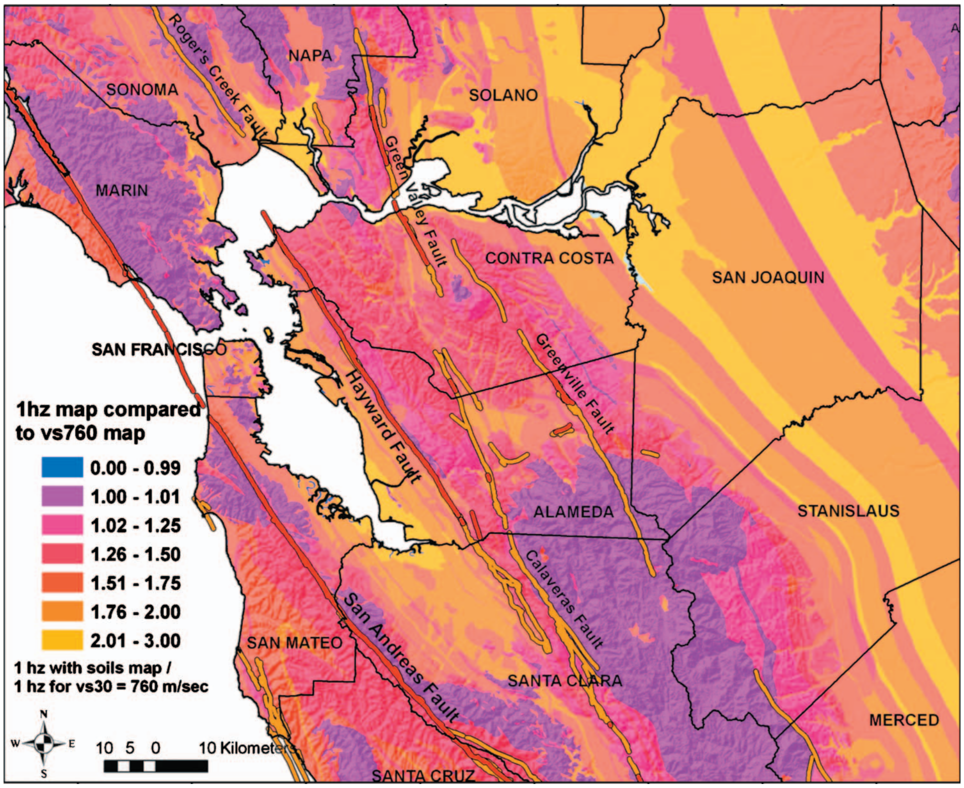


Figure 6. Bay Area soil amplification map with respect to V_{S30}=760 m/s. Map is for SA at 1.0 s considering 2% probability of exceedance in 50 years; it is obtained by taking the ratio of hazard values based on variable V_{S30} to those based on V_{S30}=760 m/s ("firm rock").

For the Los Angeles area, mean hazard values are compared in Figure 7, and their ratio is mapped in Figure 8. Similar to the San Francisco Bay, extensive areas of mountains surrounding the Los Angeles basin are underlain by "firm rock" that are not expected to significantly amplify ground motions. Other areas of "bedrock," including the Santa Susana and much of the Santa Monica Mountains and the Palos Verdes, Puente, and San Joaquin Hills are underlain by sandstone and shale with V_{S30} values that we simplified to either 377 m/s or 489 m/s. Amplification in these areas results in shaking potential up to 75% more than "firm rock." Within the Los Angeles basin, extensive areas are underlain by older (Pleistocene) alluvium with a mean V_{S30} of 377 m/s. These materials also result in shaking potential up to 75% more than "firm rock." The centers of the Los Angeles basin and the San Fernando and San Gabriel valleys are underlain by younger alluvium with a mean V_{S30} of 287 m/s. Amplification in some areas underlain by young alluvium is in the same range, 50%–75%, as for lower-velocity bedrock and for older alluvium. In other areas underlain by the same material, predicted amplification ranges from 75% to more than 100% of the value calculated for "firm rock." The similar predicted amplification across the Los

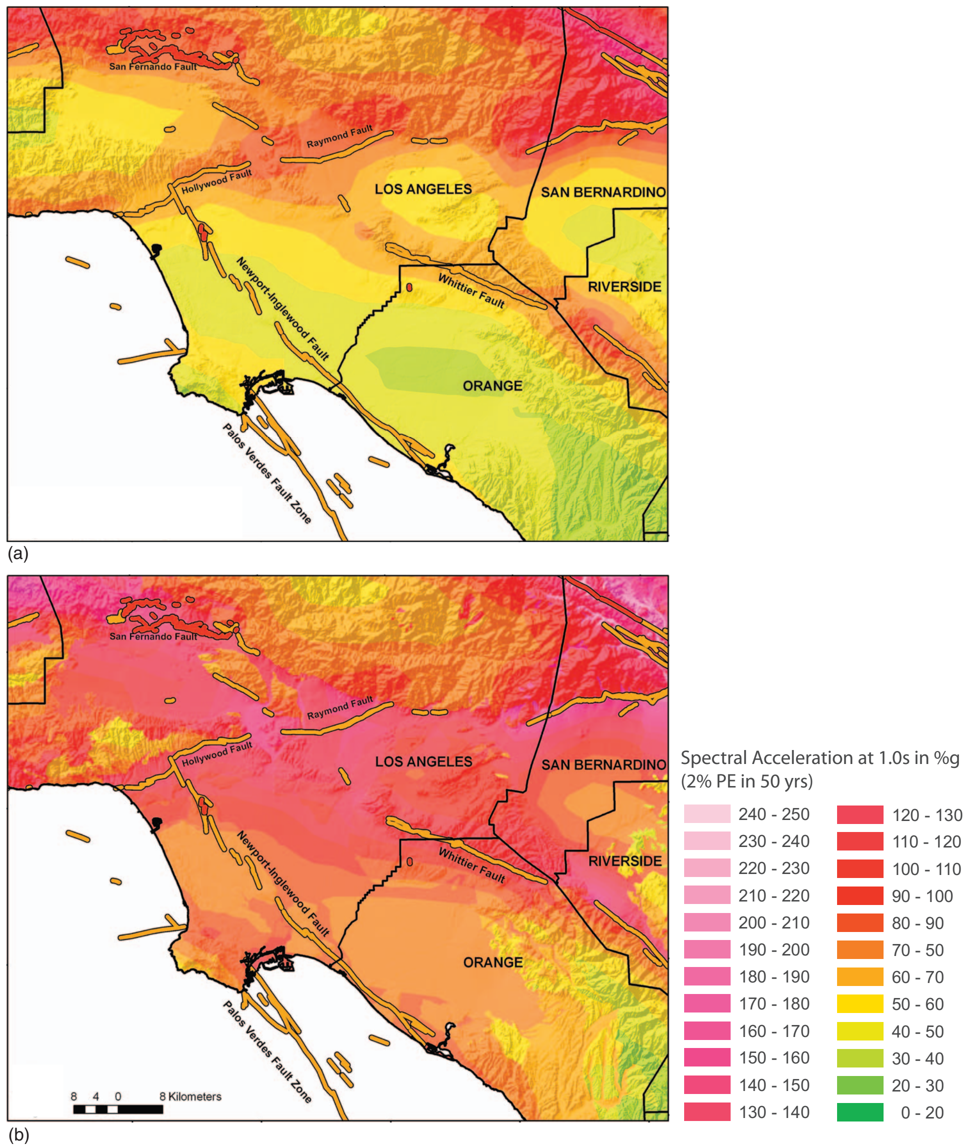


Figure 7. Close up view of seismic hazard in the Los Angeles; maps show SA at 1.0 s with 2% probability of exceedance in 50 years. (a) V_{S30}=760 m/s; (b) Variable V_{S30}.

Angeles area on materials with a wide range of V_{S30} shows the strong influence of the non-linear effect within the NGA equations. In the northern Los Angeles basin, where probabilistic ground motions are relatively high, young alluvium leads to amplifications of 50% to 100%. It is only in Orange County, where the probabilistic ground motions are lower, where amplification on material with the same V_{S30} is predicted to be greater than 100%.

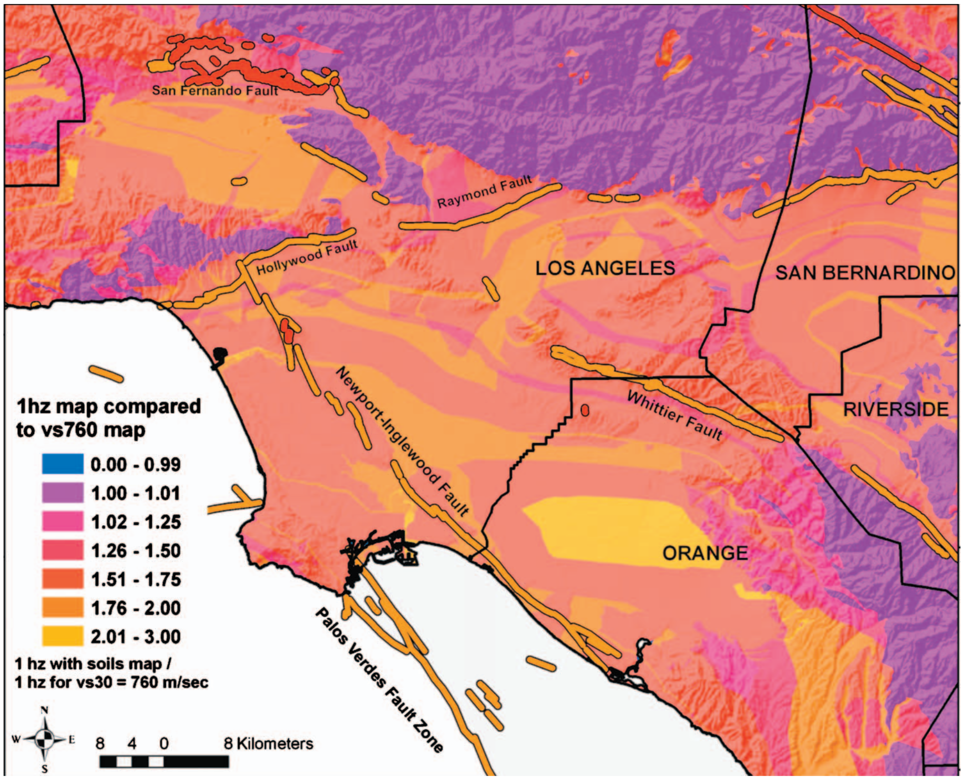


Figure 8. Los Angeles Area soil amplification map with respect to V_{S30}=760 m/s. Map is for SA at 1.0 s considering 2% probability of exceedance in 50 years; it is obtained by taking the ratio of hazard values based on variable V_{S30} to those based on V_{S30}=760 m/s ("firm rock").

Although, the NGA equations predict significant deamplification (25 to 35%) at for example V_{S30} of 1,200 m/s compared to 760 m/s, 760 m/s is considered here as an upper limit because not many boreholes are drilled into relatively hard rock and getting a good quantitative model of V_{S30} is difficult. It is also worth mentioning that there are known and suspected topographic amplification effects at/near hilltops [e.g., Tarzana Hill (Bouchon and Baker 2006)], and special hazard conditions due to widespread liquefaction and lateral spreading (Holzer et al. 2009). Their effects on probabilistic hazard estimates were yet to be included in the proposed state soil model.

EFFECTS OF SITE CONDITIONS ON HAZARD CURVES

Maximum considered earthquake (MCE) level is now a standard for building design practice in the United States. According to the ASCE 7-05, MCE ground motions are based on the lesser of:

(1) “probabilistic” ground motions defined by 2% PE within 50 years.

(2) “deterministic” ground motions defined as 1.5 times the median of the maximum magnitude event on the fault that controls hazard at the site of interest.

There is also a paradigm shift towards implementing performance-goal-oriented building-design procedures where different ground motion probability levels are considered to compute the seismic design loads. In order to show the ground motion estimate at different exceedance probabilities, a series of hazard curves for PGA, SA at 0.2 s and 1.0 s are generated for downtown San Francisco and Los Angeles. These two metropolitan areas are selected because they have high probabilities of major earthquakes. According to the UCERF, the probability of a magnitude 6.7 or larger earthquake over the next 30 years striking the greater Los Angeles area is 67% and in the San Francisco Bay Area it is 63% (Working Group on California Earthquake Probabilities 2008).

In Figure 9, 2% and 10% PE levels are indicated by horizontal dashed lines, and hazard curves are plotted for three different NEHRP site classes as Firm to Hard Rock (S_B, V_{S30}=760 m/s); Dense Soil—Soft Rock (S_C, V_{S30}=377 m/s) and Soft Clays (S_E, V_{S30}=160 m/s). The curves correspond to S_B site class are repeated on panels for S_C and S_E with gray color in order to demonstrate the impacts of site conditions on the hazard results. For both downtown areas, long period motions (SA=1.0 s) are most influenced by variations in site conditions as compared to ground motion estimate for PGA and SA at 0.2 s. Site condition is less influential for PGA. The effects of site conditions on the hazard results are more apparent for the Los Angeles downtown area than for the San Francisco downtown area. In Los Angeles, there is a significant increase of SA at 1.0 s (70% increase at 2% PE in 50 years) and reduction of SA at 0.2 s (33% reduction at 2% PE in 50 years) for V_{S30}=160 m/s relative to V_{S30}=760 m/s.

In examining these results, it should be noted that we did not consider the influence of deep basins, which is a complex multifaceted problem. If the basin effects are considered using the Z2.5 or Z1.0 depth parameter, long period (e.g., SA=1.0 sec) ground motion estimates would probably be higher than as computed for Los Angeles. This term for deep basin effects can be incorporated into hazard analyses as soon as a statewide basin depth map becomes available. Other features that lead to amplification in deep basins, such as three dimensional interference effects, soil-column resonances and/or kappa effects are much more difficult to include in a regional model. We do not anticipate these effects being included in a regional map in the near future.

MCE RESPONSE SPECTRA BASED ON MAPPED SA VALUES

In current building codes and guidelines in the United States (e.g., CBC2007, IBC2006, and ASCE 7-05), mapped values of spectral acceleration at 0.2 s (S_S) and 1.0 s (S_1) are used to compute the MCE response spectral acceleration parameters, S_{MS} and S_{M1} [$S_{MS}=F_a \times S_S$ and $S_{M1}=F_v \times S_1$, where F_a and F_v are the site-amplification parameters, respectively, for acceleration and velocity sensitive regions of the spectrum]. F_a and F_v are defined for each NEHRP site-categories; F_a and F_v are equal to unity for S_B site class since it is the reference site class used to map 0.2 s and 1.0 s spectra ordinates. In order to account

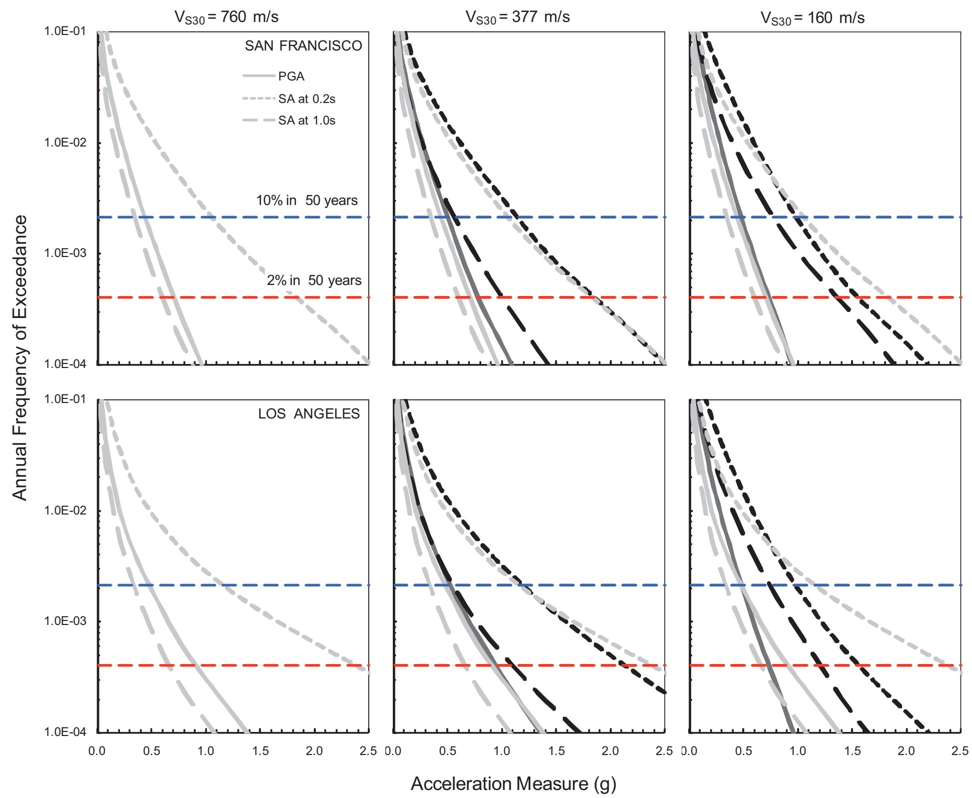


Figure 9. Hazard curves for downtown San Francisco (top row) and Los Angeles (bottom row) areas considering three different NEHRP site classes: [1] Firm to Hard Rock (S_B, V_{S30} $=760$ m/s); [2] Dense Soil—Soft Rock (S_C, $V_{S30}=377$ m/s); [3] Soft clays (S_E, $V_{S30}=160$ m/s). Hazard curves in gray correspond to S_B site class and plotted on panels for S_C and S_E site classes for direct comparison.

for soil nonlinearity under strong ground shaking, (when $S_S \geq 1.0$ g), F_a is set to 0.9 for site class, S_E. When F_a or F_v are less than unity, they result in de-amplification. Due to the same reason, the value of F_v becomes smaller as the level of S_1 increases.

Because we implicitly consider the spatial variation of site conditions in mapping S_S and S_1 values (i.e., SA at 0.2 s and 1.0 s), the resulting values can be compared with values adjusted from "firm rock" values using F_a and F_v (i.e., S_{MS} and S_{M1}). Note that S_S and S_1 values mapped in Figures 3 and 4 can be used directly to generate a MCE response spectrum for comparison with response spectra adjusted from "firm rock" values.

For downtown San Francisco and Los Angeles, we computed the response spectra using the SA at 0.2 and 1.0 seconds from the map and compared with those based on the ASCE 7-05. Figure 10 depicts these comparisons for three different NEHRP site classes. The MCE response spectra according to the ASCE 7-05 were computed using the USGS online

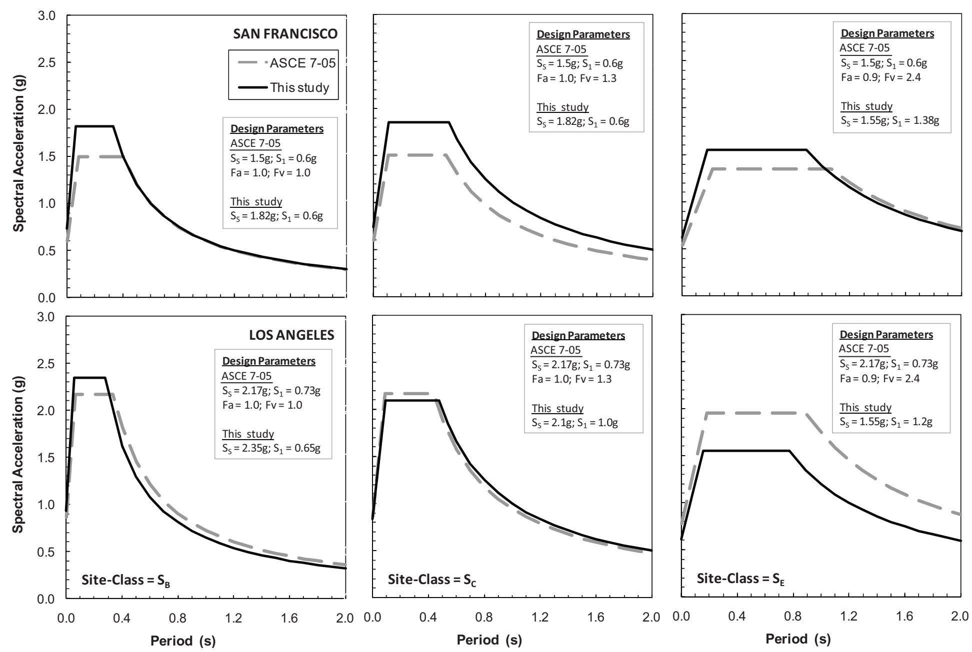


Figure 10. Comparison of MCE response spectra from this study and ASCE 7-05 for downtown San Francisco (top row) and Los Angeles (bottom row) areas considering three different NEHRP site classes: [1] Firm to Hard Rock (S_B, V_{S30}=760 m/s); [2] Dense Soil—Soft Rock (S_C, V_{S30}=377 m/s); [3] Soft Clays (S_E, V_{S30}=160 m/s).

calculator for seismic design values for buildings (http://earthquake.usgs.gov/research/hazmaps/design/). This figure shows that the differences between response spectra from this study and the ASCE 7-05 vary according to location. These differences are due to the site effects embedded in our map from the NGA equations. For S_B site class, the velocity sensitive region of the spectrum (flat region) from this study is 20% higher than that of the ASCE 7-05 spectrum for San Francisco, whereas it is only 8% higher for Los Angeles. When S_C site class is considered, the flat region of the spectrum becomes 25% higher than that of the ASCE 7-05 spectrum for San Francisco; in contrast it is only 5% lower for Los Angeles. The similar trend can be seen for S_E site class—the flat region of the spectrum is 11% higher for San Francisco than that of the ASCE 7-05 spectrum and 20% lower for Los Angeles.

We have also extracted site amplification parameters from our results for San Francisco and Los Angeles downtown areas by dividing the S_S and S_1 at lower V_{S30} values to those at V_{S30}=760 m/s. Table 1 compares F_a and F_v parameters from this study with those from the ASCE 7-05. When the spatial variability of site conditions is considered, F_a and F_v parameters become location dependent. We found F_a similar to those in the ASCE 7-05 for San Francisco and slightly lower for Los Angeles for both S_C and S_E site classes. The difference is more noticeable for F_v. As compared to the ASCE 7-05, we found F_v about 15% and 30% higher for S_C sites, whereas it is 4% and 25% lower for S_E sites for San Francisco

Table 1. Site coefficients F_a and F_v from this study and ASCE 7-05

	Site Coefficient, F_a			
	S_C		S_E	
	ASCE-7	This Study	ASCE-7	This Study
San Francisco	1.0	1.0	0.9	0.9
Los Angeles	1.0	0.9	0.9	0.7
	Site Coefficient, F_v			
	S_C		S_E	
	ASCE-7	This Study	ASCE-7	This Study
San Francisco	1.3	1.7	2.4	2.3
Los Angeles	1.3	1.5	2.4	1.8

and Los Angeles, respectively. It should be noted that site-amplification maps shown previously in Figures 6 and 8 are essentially the mapped values of F_v in the greater San Francisco Bay and Los Angeles areas considering spatial variability of site conditions. The peak value of F_v in these figures reaches as much as 3, whereas the peak value of F_v given in the ASCE 7-05 is 3.5 for locations where $S_1 \leq 0.1\ g$.

SUMMARY

This article describes the geographic distribution of V_{S30} in California and the potential for site conditions to locally amplify ground shaking hazard. The maps presented here differ from the maps prepared by the NSHMP only by their inclusion of amplification of seismic waves due to the near-surface soils. Around the San Francisco Bay and in the Los Angeles basin, that site amplification increases the seismic shaking potential by more than a factor of 2 in areas underlain by bay mud and by factors of more than 1.5 in areas underlain by Holocene alluvium. In both areas, the nonlinear effects in the NGA equations result in significant variation in amplification on materials with the same V_{S30}.

The new hazard maps presented in this article are not only useful for design applications but also serve as input to earthquake loss models and reference for site-specific hazard analysis. Maps created considering the special variability of site conditions provide a valuable comparison to the procedure in current building codes where ground motion for “firm rock” is modified using site-amplification parameters, F_a and F_v.

The SA at 1.0 s map of seismic shaking potential for California (Fig. 4) has been now published as California Geological Survey Map Sheet 48, which is intended to be accessible and understandable to the general public. That published map includes maps of the source data for the seismic hazard model, historic earthquakes and fault slip rates. It also includes maps described here: the seven V_{S30} categories, and 0.2 and 1.0 seconds SA shaking potential. These are described on the map as “high frequency” and “low frequency” seismic shaking. The map also explains that site conditions have a greater effect on the low frequency seismic hazards. Therefore, the low frequency hazard map is probably the best single descriptor of the overall hazard.

CGS Map Sheet 48 is intended to show seismic shaking hazard in a single graphically simple image that allows non-scientists to understand the overall distribution of seismic shaking hazards, including the effects of amplification by near-surface soils. Underlying the map is the most complete seismic hazard model developed through a broad-based consensus process and the most up-to-date, peer-reviewed estimate of the shear-wave velocity of the near-surface soils. The map itself can help planners and emergency preparedness officials evaluate the relative hazards across the state so that hazard mitigation efforts can be focused on the most hazardous areas.

DATA AND RESOURCES

Seismic hazard computations were carried out using the NSHMP codes available online at http://earthquake.usgs.gov/hazards/products/conterminous/2008/software/.

The hazard maps and gridded hazard values presented herein can be reached at: http://nsmp.wr.usgs.gov/ekalkan/California/index.html.

California Geological Survey Map Sheet 48 is available online at http://www.conservation.ca.gov/cgs/information/publications/ms/Documents/MS48_revised.pdf.

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