NEW MAP OF AVERAGE SHEAR WAVE VELOCITY IN THE UPPER 30M FOR ESTIMATING POTENTIAL SEISMIC AMPLIFICATION

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Background

(text from Wills and Silva, 1998)

Local geologic conditions play an important role in the strength of earthquake shaking and the intensity of damage. Describing the 1906 earthquake, Soule (1907) wrote "The destruction wrought by the earthquake amounted to little or nothing in well-built structures resting upon solid rock and, all other things being equal, increased in proportion to the depth and incoherent quality of the foundation soil."

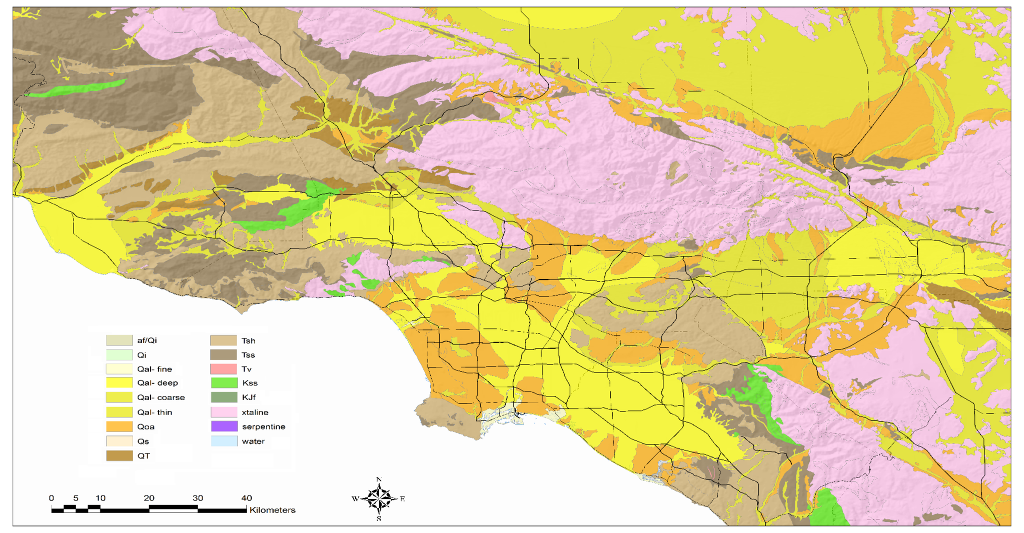
In recent years, shear wave velocity has become the primary measure of the "quality of the foundation soil" for determining the strength of earthquake ground shaking. Shear-wave velocity (V_s) is an appropriate measure of rock or soil conditions for ground motion calculations because it directly affects ground motion amplification. As a seismic wave passes through material of decreasing V_s, the resistance to particle motion decreases and the amplitude of the seismic wave increases. Besides being a direct indicator of the potential for amplification of shear waves, V_s is effective in categorizing geologic units for calculating shaking because it is dependent on basic physical properties of the material, such as density, porosity, cementation of sediments and hardness and fracture spacing of rock (Fumal, 1978).

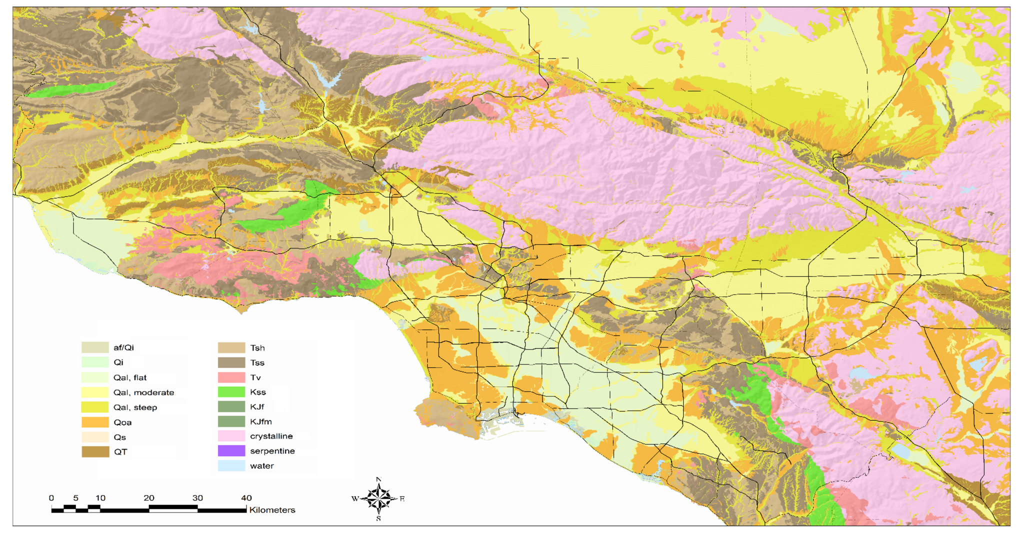
Correlations between geologic units and shear-wave velocity form the basis of a series of maps developed over the past 15 years to estimate the time-averaged shear-wave velocity in the upper 30 m (V_{s30}), a proxy for seismic amplification. A new map by Wills et al. (2015) shows simplified geologic units and corresponding V_{s30} values and applies a system to subdivide the younger alluvium based on surface slope.

Creating an improved map of site conditions

Step 1: More detailed geologic maps.

More detailed maps of V_{s30} categories should take advantage of the most detailed geologic maps available. The previous statewide map used generalized 1:250,000 scale source maps. Much more detailed, 1:24,000 scale, geologic maps are available for many areas. The use of more detailed source maps can make a significant difference in the resulting map of estimated V_{s30}.





These two maps of the Los Angeles area show the differences in applying the V_{s30} categories to detailed, versus generalized regional maps. The map on the left is the version described by Wills and Clahan (2006) the map on the right is an excerpt from the new statewide map. Two changes based on the detailed maps appear to be significant. First, in the older map all younger Tertiary sedimentary rocks were assumed to be shale. In the more detailed map, much of that area is actually sandstone, and therefore V_{s30} estimates are higher. Second, the generalized maps do not show the young alluvium in many small valleys. These valleys probably contain relatively thin alluvium and have intermediate V_{s30} between the surrounding bedrock and the deep alluvium of the nearby basin. That intermediate velocity is shown on the new map because small valleys in these hilly areas have relatively steep surface slopes.

Step 2: Better rules for the variability of V_{s30} in young alluvium.

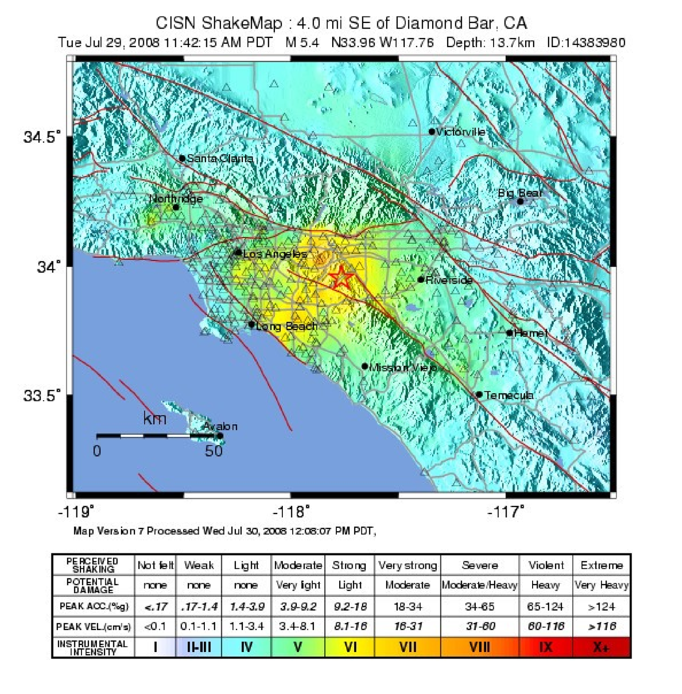
Most of the population of the Los Angeles region (and urban centers around the world) lives on recently deposited alluvium. These deposits tend to have low V_{s30}, but can be highly variable. Due to generally low velocities, improved estimates of V_{s30} in these materials have the greatest potential for improving seismic hazard estimates. We have applied the method described by Wills and Gutierrez (2010) to **correlate V_{s30} with slope to define three classes of young alluvium.** These three classes replace the five classes defined by Wills and Clahan (2006) with no increase in variability of V_{s30} within the classes, using a method that is much more easily applied to other areas.

Geologic Unit	Geologic Description	Number of Profiles	Mean V_{s30} (m/sec)	Std. Dev.
adf	Artificial dam fill.	NA	NA	NA
Qi	Intertidal mud, including mud around the San Francisco Bay and similar mud around the Sacramento/San Joaquin delta and Humboldt Bay.	19	176.1	47.6
af/Qi	Artificial fill over intertidal mud around the San Francisco Bay and similar areas.	95	225.6	113.3
Qal1	Quaternary (Holocene) alluvium in areas of very low slopes (less than 0.5%)	117	228.2	48
Qal2	Quaternary (Holocene) alluvium in areas of moderate slopes (0.5 - 2.0%)	161	293.5	73.5
Qal3	Quaternary (Holocene) alluvium in areas of steep slopes (greater than 2%)	114	351.9	112.2
Qoa	Quaternary (Pleistocene) alluvium.	181	386.6	145.1
Qs	Quaternary (Pleistocene) sand deposits, including the Merritt Sand in the Oakland area.	13	307.6	33.7
QT	Quaternary to Tertiary (Pleistocene - Pliocene) alluvial deposits, including the Saugus Formation of Southern CA, the Paso Robles Formation of the central Coast Ranges, and the Santa Clara Formation of the San Francisco Bay area.	17	444	159.7
Tsh	Tertiary shale and siltstone units, including the Repetto, Fernando, Puente, and Modelo Formations of the Los Angeles area.	32	385.1	129.4
Tss	Tertiary sandstone units, including the Topanga Formation in the Los Angeles area and the Butano Formation in the San Francisco Bay area.	62	468.4	212.6
Tv	Tertiary volcanic units including the Conejo Volcanics in the Santa Monica Mountains and the Leona Rhyolite in the East Bay Hills.	11	518.9	172
serpentine	Serpentine	3	571.6	87
Kss	Cretaceous sandstone of the Great Valley Sequence in the central Coast Ranges.	19	502.5	227.9
KJf	Franciscan complex rocks, including mélange, sandstone, shale, chert, and greenstone.	41	733.4	340.1
crystalline	Crystalline rocks, including Cretaceous granitic rocks, Jurassic metamorphic rocks, schist, and Precambrian gneiss.	35	710.1	393.8

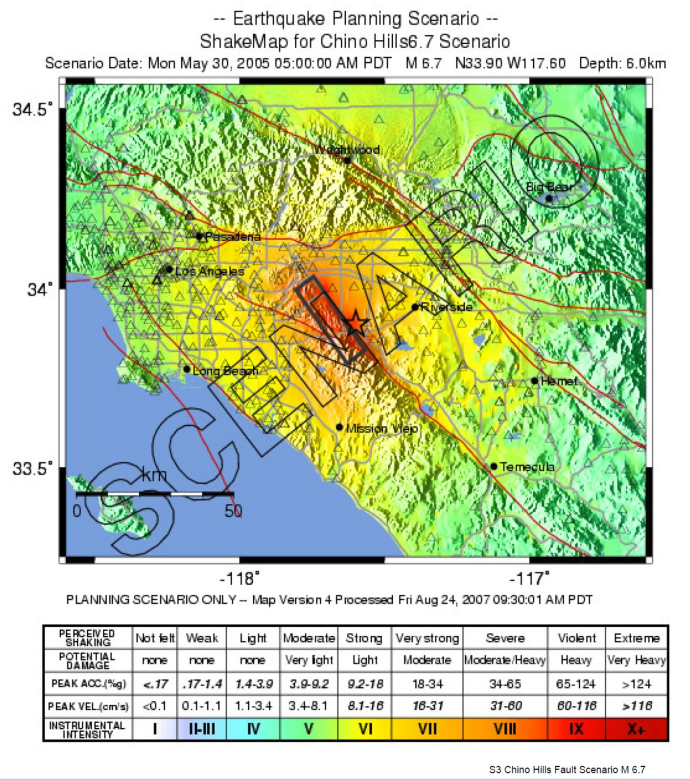
So What?

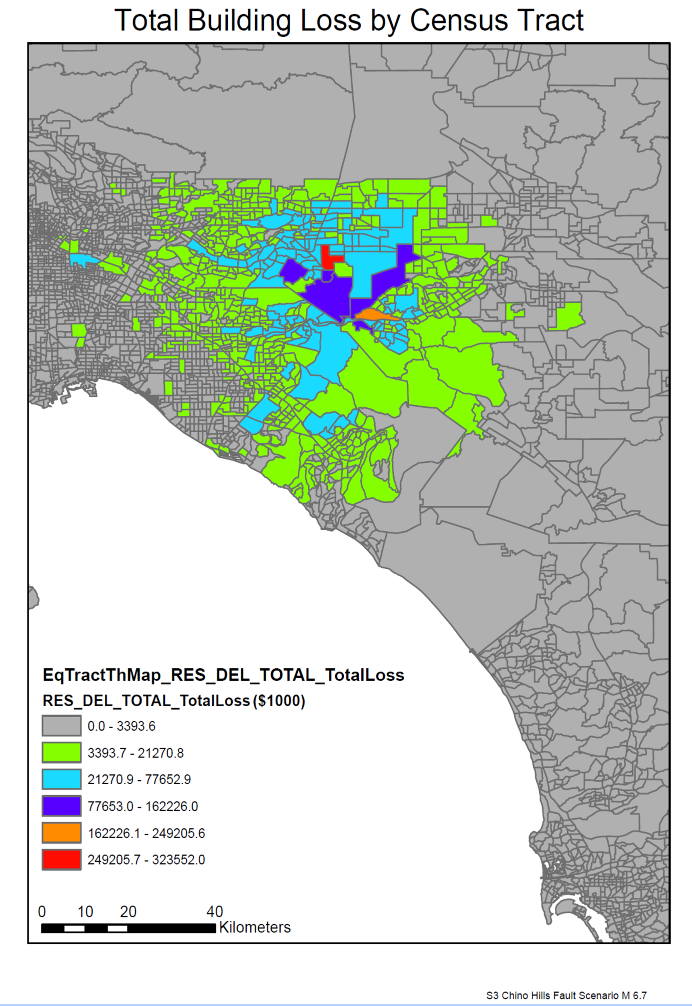
The simplified geologic map at left, assembled by geologists from geologic data, provides seismologists what they need: an estimate of V_{s30} that can be used as a proxy for site amplification. All current ground motion prediction equations use V_{s30} as the "site-conditions" term in calculating earthquake ground motion.

Previous versions of this map have been used for projecting earthquake ground motions between locations where it is measured (as in ShakeMap below) and in estimating damage from hypothetical future earthquakes using the HAZUS program developed for FEMA.



Effects of amplification in near-surface soils can be seen in ShakeMaps from earthquakes like the M5.4 Chino Hills earthquake of 7/29/2008 (left) and in projection of ground shaking and losses for larger earthquake scenarios (below). Improved maps of V_{s30} result in improved estimates of earthquake shaking and damage.





Details of development of this map were recently published in BSSA. PDF and GIS files of the map itself are available in electronic supplements to the same article:

Wills, C.J., Gutierrez, C.I., Perez, F.G., and Branum D.M., 2015, A Next Generation *VS*$_{30}$ Map for California Based on Geology and Topography: Bulletin of the Seismological Society of America, December 2015, v. 105, p.3083-3091. .