Earthquake ShakeMap Scenario Selection for California Governor's Office of Emergency Services

Project Report

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Abstract

California Governor's Office of Emergency Services (Cal OES) contracted the California Geological Survey to select at least 91 earthquake scenarios from the United States Geological Survey's ShakeMap website, identify significant earthquake faults, list identified scenarios for each California county, and provide earthquake occurrence rate information for identified faults and scenarios. In this report, we document a stepwise approach consisting of identification of resources and appropriate ShakeMap catalogs, manual selection based on rupture extent and shaking intensity, and analytical verification and augmentation of scenario selection based on numerical analysis of shaking intensity and population density using ArcGIS spatial analysis tools. Selected scenarios are tabulated along with rupture names and occurrence rates estimated using moment rates. Fault section magnitude-frequency distributions and moment rates are taken from Unified California Earthquake Rupture Forecast Version 3. For each county, scenarios are listed for three shaking intensity levels and are sorted by affected population.

Contents

1 Introduction

California Governor's Office of Emergency Services (Cal OES) requested the California Geological Survey to select earthquake scenarios from the ShakeMap collections developed by the United States Geological Survey (USGS). Cal OES intends to estimate potential losses from these scenarios for their earthquake library project using Hazus, a geographic information system (GIS)-based natural hazard loss estimation software developed by the Federal Emergency Management Agency (FEMA). As specified in the contract, the project goal is to select at least 91 scenarios and provide digital ShakeMap files suitable for Hazus loss estimation. Specific tasks include: (i) identify significant earthquake faults, (ii) present magnitude-frequency distributions for the identified faults and indicate the occurrence rates of the identified scenarios, and (iii) list identified scenarios for each county. Ideally, this process identifies and selects the scenarios that are potentially the most damaging for each county in California.

We document a stepwise scenario selection approach and process in Chapter 2. A decision was made to select scenarios from the 2014 Building Seismic Safety Council (BSSC) catalog. The selection process results in two groups of scenarios: recommended scenarios presented in Table 1 and supplementary scenarios presented in Table 2. These tables also include scenario rupture names from which earthquake faults can be identified readily because ruptures are named by the faults and fault sections. Estimation of occurrence rate, magnitude-frequency distribution and other important data are discussed in Chapter 3.

We note scenarios that we select from the 2014 BSSC Catalog are characteristic earthquakes as discussed in Luco et al. (2015) and in Chapter 3 of this report. These scenarios are deterministic in nature with magnitude (**M**) determined from rupture area. Their occurrence rates are estimated with assumptions and should be used only as a qualitative indicator of how often such events may occur. Magnitude-frequency distributions for identified faults (fault sections to be precise; see discussions in chapter 3 of this report) are taken from the Uniform California Earthquake Rupture Forecast Version 3 (UCERF3, Field et al., 2013) and are presented in Table A-5.

We recommend 4 scenarios outside the 2014 BSSC Catalog. These scenarios are discussed in Section 2.4, in which relevant literature and web links for Hazus files are also provided.

Our scenario selection and ranking of the potentially most damaging scenarios for each county are based on shaking intensity and population density and do not consider vulnerability or other ground motion parameters such as peak ground acceleration or spectral accelerations. Therefore, we should not be surprised if Hazus loss estimation results in different ranking of these scenarios in terms of economic losses for each county.

2 Scenario Section Method and Process

There are hundreds of ShakeMap scenarios in five catalogs on the USGS Scenario ShakeMap website (https://earthquake.usgs.gov/scenarios) that affect California. These are:

1. The 2014 BSSC Catalog,
2. Northern California Legacy Catalog,
3. Southern California Legacy Catalog,
4. **M** 9 Cascadia Earthquake Scenarios, and
5. Global Legacy Catalog.

For the Cal OES loss estimation project, we select scenarios mainly from the 2014 BSSC Catalog, which is an authoritative USGS collection of nearly 800 ShakeMaps for the continental US. We believe the 2014 BSSC Catalog is the most appropriate catalog to use for scenario selection for the following reasons:

1. The BSSC Catalog is derived from the 2014 update of the National Seismic Hazard Maps (Petersen et al., 2014), which is based on the most recent and comprehensive fault source models and ground motion models (GMMs). Specifically, scenario ruptures in the 2014 BSSC Catalog are a subset of ruptures in UCERF3.
2. Shaking parameters in the 2014 BSSC Catalog establish the standards for the deterministic component of ground motion hazard assessments required by the building codes (Luco et al., 2015; BSSC, 2015), making the catalog the best choice for establishing an earthquake library and the most relevant in terms of community seismic safety.

We do not consider the Southern and Northern California Legacy Catalogs because these catalogs are based on older fault models and GMMs. Scenarios in these catalogs are largely superseded by those in the 2014 BSSC Catalog. We also do not consider the **M** 9 Cascadia Earthquake Scenario catalog because this catalog is based on ground motions from a set of thirty numerically simulated **M** 9 Cascadia earthquake rupture scenarios. Instead, for Cascadia subduction zone, we suggest using the Cascadia scenario in the 2014 BSSC Catalog which uses GMMs for ground motion calculations and is more appropriate for comparison with other scenario ground motions.

The Global Legacy Catalog contains a few well-known emergency response planning and exercising scenarios in California. We recommend four of these scenarios for Cal OES to include in their loss estimation. These Scenarios are discussed in Section 2.4. Potential losses from these scenarios are well studied and can provide valuable comparison with Cal OES loss results.

2.1 SELECTION METHOD

A stepwise approach was taken to select scenarios from the 2014 BSSC Catalog. In the initial step, we identified resources from which scenario selections could be made effectively and efficiently.

Each ShakeMap scenario has a rupture with predefined geometry (location, dip angle, length, and width). Each scenario has a **M** estimated from rupture area and shaking intensities calculated using GMMs for the given rupture geometry and **M**. Available shaking intensity measures include Modified Mercalli Intensity (MI), peak ground acceleration, peak ground velocity, and spectral accelerations at 0.3 second, 1.0 second, and 3.0 seconds.

We examined distributions of epicenters and ruptures of all scenarios in the 2014 BSSC Catalog on a map view available at the catalog website (https://earthquake.usgs.gov/scenarios/catalog/bssc2014/) and thought that the epicenter and rupture data layers are likely useful if ArcGIS shapefiles of these data layers can be obtained. The website, however, only provides maps for visualization; no usable datafiles can be downloaded. Instead, we acquired shapefiles from Erik Thompson (USGS) who established the 2014 BSSC Catalog.

After initial analyses of epicenter and rupture distributions of all catalog events in ArcGIS, we found the epicenter file not useful for two reasons: 1) the epicenter is assumed to be in the middle of the rupture for all scenarios, and 2) for a given rupture, shaking is a function of closest distance to the rupture, not to the epicenter (i.e., all sites having equal distance to the rupture have the same shaking intensity if site conditions are similar). Epicenter location would be important if near source effects such as directivity and directionality were included in ground motion calculations, which is not the case for scenarios in the 2014 BSSC Catalog.

In the rupture shapefile, each scenario has a rupture plane depicted as an ArcGIS polygon feature representing the surface projection of the rupture area and is attributed with the USGS ShakeMap scenario identification number (ID), rupture name, and **M**.

The most useful shaking intensity measure for scenario selection is MI because it correlates with perceived shaking and damage better than other intensity measures. The ShakeMap MI shapefiles contain polygons of MI contours. Each polygon is attributed with the MI scale that is standard for all ShakeMaps for both scenarios and real-time earthquakes. The ShakeMap shaking intensity scale is reproduced in Figure 1 for easy reference. For scenarios, the *Instrumental Intensity* is the MI. MI shapefiles are a large, complicated dataset due to significant overlaps of MI contour polygons from multiple scenarios. The dataset needs to be simplified for it to be useful for scenario selection.

The initial visual analyses of the rupture and the MI shapefiles for all catalog scenarios led to the establishment of a 4-step scenario selection process:

1. Select all ruptures contained within or extending into California and its surrounding areas defined by a buffer zone of 100 km from the state boarder,

2. Eliminate ruptures completely contained or nearly completely contained in other larger ruptures in the same fault zone,
3. Eliminate other smaller ruptures if deemed appropriate, see criteria in Section 2.2.3,
4. Refine scenario selection based on shaking intensity and population density

Steps 1 through 3 are based on rupture extent and are described in Section 2.2. Step 4 is described in Section 2.3 and consists of a manual refinement stage and an analytical verification stage. These steps gradually reduce the total number of selected scenarios.

2.2 SELECTION BASED ON RUPTURE EXTENT

2.2.1 Step 1 – Selection by State Boundary

In this first step, we used an ArcGIS *Selection by Location* tool to select all scenarios with rupture polygons falling within or extending into California and its surrounding areas defined by a buffer zone of 100 km from the state boarder line. This simple first selection step resulted in a total of 432 scenarios.

2.2.2 Step 2 – Selection by Fault Zones

For many fault zones, there are multiple scenarios with varying magnitudes and rupture extents because these fault zones have multiple segments, and UCERF3 allows single segment rupture as well as different combinations of multiple segments to rupture together in a single scenario. Larger **M** corresponds to larger rupture area and longer rupture. If the area of a smaller rupture is completely or nearly completely contained in a larger rupture, its shaking intensity will certainly be smaller than the larger rupture at all locations. It is, therefore, reasonable to eliminate these shorter ruptures, which is what we do in step 2. We tried to find a polygon analysis approach in ArcGIS to perform this step automatically but were not successful due to the complexity of the rupture shapefile and short duration of this project. In the interest of time, this step was performed manually by carefully comparing rupture polygons visually in ArcGIS and deleting smaller ruptures.

For large multi-segment strike-slip fault zones, the 2nd largest/longest ruptures in the northern and southern parts or eastern and western parts of the fault zone are kept to capture scenarios that are more likely to occur than the full length rupture scenario in which all segments rupture together. Full rupture has the largest **M** but a smaller chance of occurring. Affected faults include the Northern and Southern San Andreas, Hayward-Rodgers Creek, Calaveras, Elsinore, San Jacinto, and Garlock faults. An example is shown in the Figure 2, in which 3 scenarios are selected from a total of 9 scenarios for the Hayward-Rodgers Creek fault zone.

For large faults with only partial ruptures that do not overlap significantly, all scenarios are kept. Those faults are usually less active than faults that have full and partial ruptures. Great Valley, Death Valley, Fish Lake Valley, Black Mounts Frontal faults are examples.

For ruptures with alternative dip angles or depth extents, the larger polygon (larger **M**) is selected, unless the differences are large, in which case multiple scenarios are kept.

Step 2 resulted in resulted in 307 scenarios.

2.2.3 Step 3 – Elimination of Other Small Ruptures

In step 3, rupture polygons of the 307 scenarios selected from step 2 are examined in greater detail and remaining small ruptures are eliminated if they fall into the following three categories:

1. Ruptures outside the state border: eliminate smaller ruptures that are near other larger ruptures and are further away from the state border than the larger ruptures, which also applies to offshore ruptures;
2. Small ruptures that are very close to other much larger ruptures, even if they are not in the same fault zone, usually where there are complex networks of small faults;
3. **M** < 7 scenarios near very large fault zones such as the San Andreas, Hayward-Rodgers Creek, etc.

Examples of these three types of excluded ruptures are shown in Figure 3. Step 3 resulted in a preliminary selection of 173 scenarios. Figure 4 compares rupture maps of the total of 432 polygons in and near California (Figure 4-A) and the 173 selected scenario ruptures after step 3 (Figure 4-B). It is apparent from these figures that ruptures eliminated are very small and would not be the top damaging scenarios for any counties. Eliminating these small ruptures makes the subsequent analyses more efficient and save both computational time and human labor.

2.3 SELECTION BASED ON SHAKING INTENSTITY AND POPULATION DENSITY

Step 4 was carried out to further reduce the number of selected scenarios. Three groups of data were acquired and analyzed: i) ShakeMap files; ii) 2020 US census data, and iii) population density data.

2.3.1 ShakeMap File Bulk Download

Normally, ShakeMap files are downloaded from the ShakeMap website for each individual event on the event-specific webpage. However, it would be a tedious and time-consuming process to download files for 173 selected scenarios. We explored alternative approaches and used the USGS python library and command line tools (Libcomcat) (https://github.com/usgs/libcomcat) on GitHub to batch download all files automatically. Libcomcat is a powerful resource from which two zip directories are downloaded for each of the 173 scenarios. The process to download the ShakeMap files includes the following steps:

1. Follow the instruction on installation of libcomcat at https://github.com/usgs/libcomcat
2. Download and edit a python script, *get_scenarios.py*, by making the following changes:
    a. Enter space delimited list of desired products (i.e., selected scenario IDs) in the variable "products"
    b. Enter the directory name where "products" are to be stored in the variable "data_dir"
    c. Enter the name of the file that contains the list of scenarios in the variable "scenario_list"
3. Run Python script to start the download by issuing "python get_scenarios.py" in command line prompt

These steps automatically download ShakeMap files and place them in the "data_dir" directory as subdirectories. Each subdirectory contains zipped shapefiles for a scenario. Subdirectories and files are named by scenario IDs. Once unzipped, the Shapefiles can be imported into ArcMap or QGIS for further analysis. The directory having a name ending with *_hazus* contains files needed for Hazus loss estimation.

2.3.2 Census and Population Density Data

We note that earthquake loss is determined by seismic hazard, as well as property exposure and vulnerability. It is difficult to rank scenarios by their potential damage for each county without carrying out loss estimation. Our selection uses MI as proxy for seismic hazard. We use population density as proxy for exposure. We have no information on vulnerability.

In the US., the most granular spatial units of population enumeration are census blocks which make up census tracts. In California, census blocks have an average land area of roughly 0.8 km^2 and a population of about 75 people each. However, Census block land area can vary significantly, and population isn't uniform. For example, in sparsely populated regions, their areal extents tend to be much larger, consisting of large open, unpopulated spaces. Assuming uniform population distribution across a block often poses significant limitations. To address these limitations, population estimates need to be disaggregated to finer scales using a broad class of techniques known as 'dasymetric' mapping.

Through a literature search, we identified a recently developed suite of population grids, known as 'CA-POP', for the State of California produced using dasymetric mapping methods by Depsky et al. (2022). These grids provide population at a pixel resolution of 100 meters using the 2020 census blocks as source zones. The geo-TIFF files of these population grids are available at the public CA-POP repository (github.com/njdepsky/CA-POP). We downloaded the geo-TIFF files and converted them to shapefiles for analysis in ArcGIS.

To analyze shaking intensity and exposed population in each county, we need a shapefile that defines county boundaries. The shapefile of California counties is obtained from the United States Census Bureau (2021) TIGER/Line Shapefiles webpage (https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2020.html#list-tab-BG8ZITUQ783GX73G14).

2.3.3 Step 4 – Selection by Shaking Intensity and Population Exposure

This step refines the preliminary selection and creates a final selection of 114 scenarios, separated into two groups (see Tables 1 and 2) through a manual refinement process and an analytical verification/augmentation process.

Manual Refinement

We symbolized the MI contours in ArcGIS for each of the 173 scenarios in the preliminary selection from Step 3 and plotted county boundaries and population density on top of the MI contours. We then visually examined and compared spatial extents of various MI contours in each county to eliminate less influential scenarios and to select appropriate MI levels for analytical verification. This is a tedious and judgment-based process. To facilitate the process, counties were group into 10 regions, then visual inspection was carried out region by region, starting from the northwest corner of California to the southeast corner. Grouping of counties was adopted from California Earthquake Authority in their risk assessment (https://www.earthquakeauthority.com/California-Earthquake-Risk/Faults-By-County). These regions are: North Coast; Shasta Cascade; Delta, Sierra and Greater Sacramento Areas; Greater Bay Area; Inyo and Mono; Central Valley South; Central Coast; Southern California Coast; Inland Southern California; and San Diego County. These processes resulted in the selection of 92 scenarios from the 173 scenarios in the preliminary selection.

Manual selection has many limitations. It relies on our personal interpretation and professional judgement, can be difficult to reproduce, and is prone to mistakes. An analytical process is, therefore, carried out to supplement manual selection and to provide numerical bases for ranking the potentially most damaging scenarios for each county.

For the subsequent numerical analyses, we chose three grouped MI levels based visual inspection of the symbolized MI contours, particularly those of large events. The three grouped MI levels are MI ≥ 7, 6, and 5; corresponding to at least moderate, light, and very light damages, respectively (see Figure 1). In terms of perceived shaking, these levels correspond to light, moderate, and strong, respectively. The grouping creates shapefiles that are much simpler than the original MI contour polygons, making analyzing MI information numerically an achievable task.

Analytical Verification

To aid analytical verification, we created 3 new shapefiles (MI-7, MI-6, and MI-5) from the 173 MI shapefiles of all scenarios in the preliminary list. This is accomplished using a model built in QGIS. Just like the rupture polygon shapefile, each new shapefile has 173 polygon features, one feature per scenario. Each polygon in the MI-7 file combines all polygons with MI ≥ 7 for each scenario and delineates spatial extent of MI ≥ 7 for that scenario. Similarly, the MI-6 and MI-5 shapefiles delineate areas of MI ≥ 6 and 5, respectively. Figure 5 shows the distribution of these shaking intensity levels. All California counties are nearly completely covered by MI ≥ 5, which corresponds to very light potential damage (see Figure 1 for MI scales), except for four counties in the Great Valley: Calaveras, Tuolumne, Mariposa, and Madera which have the least shaking hazards from scenario earthquakes among all California counties.

The polygons of MI ≥ 7 were spatially joined with the county polygon file using ArcGIS spatial analysis tools to produce a new polygon layer that delineates areas of MI ≥ 7 in each county by each scenario. We call the new layer "MI-7 by county". Total area in km^2 covered by MI ≥ 7 from each scenario in each county was calculated using ArcGIS field calculator. The MI-7 by county layer was further joined by the population grid to aggregate total population in the MI-7 areas for each scenario in each county. Finally, the rupture polygon file was queried to attach rupture name and **M** for each scenario for easy reference. The results are exported as Table A-1 in Appendix A in the common-separated-value format (*.csv*).

Figure 6 is a screenshot of the first 3 counties (in alphabetic order) in Table A-1. For each county, this table gives the total land area in km^2 with MI ≥ 7 from each scenario that produces this level of shaking (column named *area_sq_km*). Total population in the area is given in the last column (named *Pop_Count*), which is aggregated from the population grid. The affected population and area size are used to verify and augment scenario selection.

Table A-1 is sorted first by county names in alphabetic order, then by affected population in descending order. Because we use affected population as a proxy for potential exposure and damage, for each county, the sorted population column (*Pop_Count* in Table A-1 and in Figure 6) also indicates scenario ranking in terms of potential damage from the most damaging to the least damaging. For example, based on population, *Calaveras: CN+CC+CS+CE* and *Calaveras: CN+CC+CS* are the top two potentially most damaging scenarios in Alameda County (see Figure 6 or Table A-1). Similarly, *Great Valley 03 Mysterious Ridge* and *Bartlett Springs* are the top two potentially most damaging scenarios in Colusa County.

It is apparent from Figure 5, not all counties are covered by MI ≥ 7. Also, for some counties (e.g., Butte County in Figure 6), only one scenario produces MI ≥ 7 shaking level. For such counties, analyses of lower shaking level(s) are needed to identify the 2nd or 3rd potentially most damaging scenarios. Therefore, we also carried out polygon analyses on shapefiles MI-6 and MI-5.

Analyses of MI-6 provide square-km areas of MI ≥ 6 and affected population from each scenario in each county. The results are presented in Table A-2 in Appendix A. Table A-2 is much longer than Table A-1 because more counties are affected by MI ≥ 6 than by MI ≥ 7 and, in general, there are more scenarios with MI ≥ 6 than with MI ≥ 7. Analysis of MI ≥ 5 for all counties not only will produce a much longer list than Tables A-1 and A-2, but also is unnecessary, Therefore, similar polygon analysis for MI ≥ 5 is only carried out for 10 California counties which MI ≥ 6 does not cover completely. For these counties, intensity 5 level may have some influence on scenario selection and ranking. Results are presented in Table A-3. Both Tables A-2 and A-3 are also sorted first by county, then by affected population and are in *.csv* format.

For each county, we first look at scenarios with the top 2 population affected by MI ≥ 7 (by sorting table A-1 by county, then by population, the *Pop_Count* column) to be sure they are included in the list of 92 scenarios from manual refinement. They are added to the list if not already included. We then look at the scenarios with the top 2 MI ≥ 7 square-km land area (by sorting table A-1 by county, then by area, the *area_sq_km* column). Verify them against the list. Same process is repeated for Tables A-2 and A-3 for MI ≥ 6 and 5, respectively. These processes added 14 scenarios to the list and left 29 unverified scenarios which we moved to a separate list, resulting in two separate lists presented in Tables 1 and 2, respectively. We recommend estimating losses using scenarios in Table 1, supplemented with those in Table 2 if needed (see discussions in the last paragraph of Chapter 3).

2.4 OTHER RECOMMENDED SCENEARIOS

Besides scenario catalogs, USGS also collects ShakeMaps for ongoing and past ShakeOut exercises, drills and three-dimensional simulations. We suggest Cal OES also include some of these scenarios in their earthquake library project, particularly the ones that have comprehensive loss estimations which can serve as a point of comparison with Cal OES loss estimation. Groups of scenarios affecting California include:

- "Ardent Sentry" Southern California ShakeOut – **M** 7.8 on the Southern San Andreas Fault (2012 update)
- Southern California ShakeOut – **M** 7.8 on the Southern San Andreas Fault (2008)
- Hayward Fault Scenarios
- Haywired Aftershock Planning Scenarios
- Global Legacy Catalog

In the following paragraphs, we first provide a brief discussion, our recommendation, and available literature. Then, we list the recommended scenarios along with web links where ShakeMap files for Hazus loss estimation can be downloaded.

The two Southern California ShakeOut **M** 7.8 scenarios appear to be the same scenario event, but ground motions for the 2012 version are updated using the newer GMMs. We recommend using the 2012 version. The southern California ShakeOut exercise is documented in a special issue of *Earthquake Spectra* in 2011 (Volume 27, issue number 2) (Porter et al., 2011).

We do not recommend the Hayward Fault Scenarios listed above because these are simulated ground motions and may not be appropriate to compare with scenarios in the 2014 BSSC Catalog. They are also older scenarios compared to the scenarios in the Haywired project discussed later. We also do not recommend scenarios in "Haywired Aftershock Planning Scenarios" because these aftershock scenarios are smaller and would not be the most damaging scenarios to the affected counties.

Five scenarios in the Global Legacy Catalog affect California: 2 Cascadia **M** 9.0 scenarios and 3 Haywired scenarios.

For the 2 Cascadia **M** 9 scenarios, we recommend the 2016 scenario which appears to supersede the 2011 **M** 9 scenario.

The 3 Haywired **M** 7.05 scenarios appear to have different epicenter locations along the Hayward fault, likely to account for rupture directivity effects. We recommend the scenario located in the middle of the fault because this scenario would represent an average directivity effect and therefore is more comparable to scenarios in the 2014 BSSC Catalog.

The Haywired project is documented extensively in a USGS factsheet (Hudnut et al., 2018), and other studies available on the project website: https://wim.usgs.gov/geonarrative/safrr/haywired_vol1/

The last scenario is the **M** 6.9 San Diego – Tijuana (SD-TJ) shakeout exercise scenario. It would be good to include this scenario for comparison. Related studies are documented in an Earthquake Engineering Research Institute project report (EERI, 2020).

In summary, we recommend four scenarios outside the 2014 BSSC Catalog as listed below. Links are provided for each scenario where ShakeMap files for Hazus analysis can be downloaded:

1. Southern California ShakeOut – **M** 7.8 on the Southern San Andreas Fault (2012 update): https://earthquake.usgs.gov/scenarios/eventpage/sclegacyardentsentry2015_se/executive
2. The 2016 Cascadia **M** 9 scenario: https://earthquake.usgs.gov/scenarios/eventpage/gllegacycasc9p0expanded_peak_se/executive
3. The Haywired **M** 7.05 scenarios (middle epicentral location): https://earthquake.usgs.gov/scenarios/eventpage/gllegacyhaywiredm7p05_se/executive

4. The **M** 6.9 SD-TJ shakeout exercise scenario: https://earthquake.usgs.gov/scenarios/eventpage/gllegacyshakeout_sdtj2015_hybridvs30_tj_se/executive

3 Data for Selected 2014 BSSC Catalog Scenarios

ShakeMap files for Hazus analyses are provided as electronic attachment and can be downloaded from this Box folder: https://doc.box.com/s/67a26jh72r9f19c04x4ij1khjoevg4xr. Files in Appendix A can also be found in the same folder.

There are two separate directories for scenarios in Tables 1 and 2, respectively. The directories contain zipped ShakeMap files, one file for each scenario. Zipped files are named by scenario ID (column labeled *id* in Tables 1 and 2), with *bssc2014* added before the scenario ID and _*hazus* after scenario ID.

Additional information provided in Tables 1 and 2 includes: scenario name (column labeled *name*), **M**, and average event rate or range of average event rate calculated from UCERF3 fault section moment rate assuming all energy is released by the repeat of the scenario event. Table A-4 in Appendix A provides UCERF3 fault section moment rate and Table A-5 provides magnitude-frequency distribution for fault sections.

The 2014 BSSC Catalog names each scenario by fault name plus the names or abbreviations or numbering of fault sections. Full names of abbreviated fault section names are provided in Table A-6. This table also spells out other abbreviations encountered in rupture names based on our inferences.

As we noted in the Introduction, scenarios in the 2014 BSSC Catalog are characteristic earthquakes. They are deterministic in nature with **M** determined from rupture area. Rupture location and geometry are fixed. They represent only a very small subset of UCERF3 ruptures that also correspond to characteristic ruptures in UCERF2 (Luco et al., 2015).

In UCERF3, there are 253,706 and 305,709 unique “viable” ruptures in its two alternative fault models, namely the FM 3.1 and FM 3.2, respectively (Field et al., 2013). Often, there is a suite of scenarios that defines the activity for a given fault. At a given location, multiple faults and, therefore, multiple suites of scenarios determine the total hazard. One scenario is only one sample among hundreds of thousands of scenarios. In subsequent hazard calculations using UCERF3, such as for the 2014 update of the National Seismic Hazard Maps (Petersen et al., 2014), hazards from all scenarios are added to obtain the total hazard. In another word, all scenarios contribute to the total hazard, with each scenario making up a very small contribution. Occurrence rates of individual scenarios are only meaningful in probability hazard calculations. They are not meaningful in assessing hazards or risks in a deterministic manner. For these reasons, we do not provide UCERF3 rate for the identified characteristic scenarios. Instead, we provide rate calculated assuming all energy is released by the repeat of the scenario earthquake using fault section moment rate.

For a given fault, moment rate and magnitude-frequency distribution vary from location to location. UCERF3 provides average moment rate for each fault section, which is provided in Table A-4 of this report and used to calculate the average occurrence rate (for ruptures involving only one fault section) or the range of average occurrence rates (for ruptures involving more than one fault sections) for selected scenarios. The rate of the selected scenario calculated from moment rate is presented in the last columns of Tables 1 and 2, labeled "Event Rate Based on Moment Rate."

UCERF3 magnitude-frequency aggregated on fault sections is provided in Table A-5. Note that all UCERF3 fault sections are included in Tables A-4 and A-5 for completeness. It is easy to find fault sections involved in a scenario because all these tables are listed by fault and fault section names in alphabetic order. Table A-4 also includes UCERF3 mean recurrence interval (MRI, inverse of occurrence rate) for $\mathbf{M} \geq 6.7$ events, which can be used in conjunction with scenario rate estimated from moment rate to better understand how likely the selected scenarios are to occur.

UCERF3 does not have moment or event rate information for faults not in the UCERF3 models. These include faults outside California and the Cascadia subduction zone.

As noted previously, the second group of scenarios in Table 2 is provided for Cal OES to consider only if additional scenarios (in addition to those in Table 1) for loss estimation are needed. Again, earthquake loss is a function of not only seismic hazards and exposure, but also vulnerability which we do not have. In the scenario selection, we used our professional judgement and selected scenarios based on the extents of ruptures and shaking intensity with qualitative reference to population density. As such, though we have confidence that our selection most likely includes the potentially most damaging scenarios for each county, we do not rule out the possibility that scenarios in the second group or other unselected scenarios may result in greater estimated losses than those selected in the first group. After all, our analysis cannot replace loss estimation, which will eventually determine damage levels of these scenarios.

4 Summary

In summary, we recommend Cal OES to estimate losses for the 83 scenarios listed in Table 1 and the 4 planning scenarios discussed in Section 2.4. If loss estimation for additional scenarios is needed to reach "at least 91" scenarios specified in the contract, we recommend either taking scenarios from Table 2 or picking them from Tables A-1 and A-2. Picking from Tables A-1 or A-2 is preferred, as scenarios in these tables are selected based on affected population and land area, whereas those in Table 2 are selected manually based on visual inspection. As we discussed in Section 2.3.3, the recommended scenarios (those listed in Table 1) are the ones with the top 2 affected population and the top 2 affected square-km land area for each county. Further selection, then, should pick the 3rd ranking population and, if needed, the 3rd ranking land area for all counties or for desired counties.

The Shapefiles of MI ≥ 7, 6, and 5 polygons are for the purpose of scenario selection. They are not intended for loss estimation. Hazus loss estimation requires a different set of ground motion parameters which we downloaded for Cal OES. In Hazus loss estimation for each scenario, the geographic extent of the loss model should include the entire region covered by the scenario ShakeMap. Ranking of the topmost damaging scenarios for each county, if needed, should be based on loss estimates of all selected scenarios affecting the county.

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Appendix A

Appendix A includes 6 tables found in a subdirectory named *Tables* in Box folder: https://doc.box.com/s/67a26jh72r9f19c04x4ij1khjoevg4xr

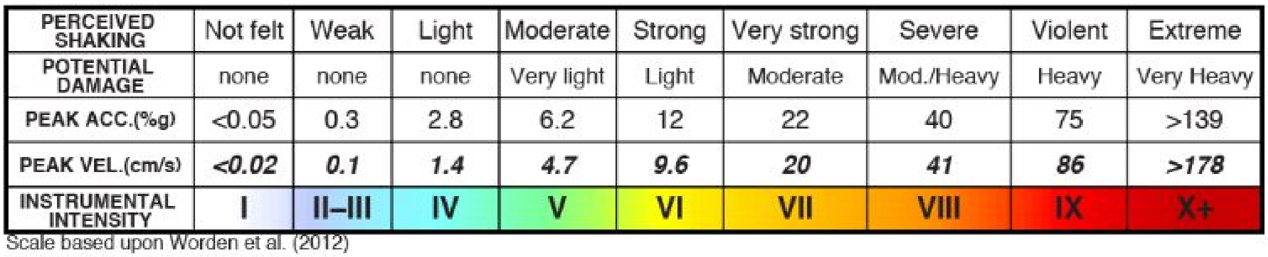
- Table A-1 Scenario list by county with total population and square-km area affected by shaking intensity level ≥ 7
- Table A-2 Scenario list by county with total population and square-km area affected by shaking intensity level ≥ 6
- Table A-3 Scenario list by county for ten central valley counties with total population and square-km area affected by shaking intensity level ≥ 5
- Table A-4 UCERF3 fault section moment rate
- Table A-5 UCERF3 fault section magnitude-frequency distribution
- Table A-6 Abbreviations in rupture names

Electronic Attachment

Zipped ShakeMap files for Hazus loss estimation are provided in three subdirectories in Box folder, https://doc.box.com/s/67a26jh72r9f19c04x4ij1khjoevg4xr:

1. *Recommended Scenarios*: files for recommended scenarios, i.e., those listed in Table 1
2. *Supplementary Scenarios*: files for supplementary scenarios, i.e., those listed in Table 2
3. *Scenarios excluded by shaking and population:* files for scenarios on the preliminary list (i.e., those selected by rupture extents), but excluded from analysis by county and population (i.e., those not included in Table 1 or Table 2).

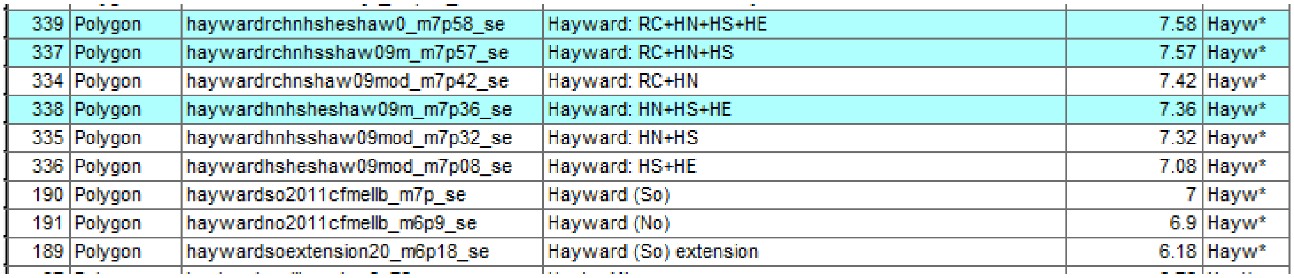
Figures



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Figure 1. USGS ShakeMap shaking intensity scale (based upon Worden et al., 2012)



339	Polygon	haywardrchnhsheshaw0_m7p58_se	Hayward: RC+HN+HS+HE	7.58	Hayw*
337	Polygon	haywardrchnhsshaw09m_m7p57_se	Hayward: RC+HN+HS	7.57	Hayw*
334	Polygon	haywardrchnshaw09mod_m7p42_se	Hayward: RC+HN	7.42	Hayw*
338	Polygon	haywardhnhsheshaw09m_m7p36_se	Hayward: HN+HS+HE	7.36	Hayw*
335	Polygon	haywardhnhsshaw09mod_m7p32_se	Hayward: HN+HS	7.32	Hayw*
336	Polygon	haywardhsheshaw09mod_m7p08_se	Hayward: HS+HE	7.08	Hayw*
190	Polygon	haywardso2011cfmellb_m7p_se	Hayward (So)	7	Hayw*
191	Polygon	haywardno2011cfmellb_m6p9_se	Hayward (No)	6.9	Hayw*
189	Polygon	haywardsoextension20_m6p18_se	Hayward (So) extension	6.18	Hayw*

Figure 2. Scenario selection for the Hayward-Rodgers Creek fault zone as an example showing how scenarios for large multi-segment fault zones are selected.

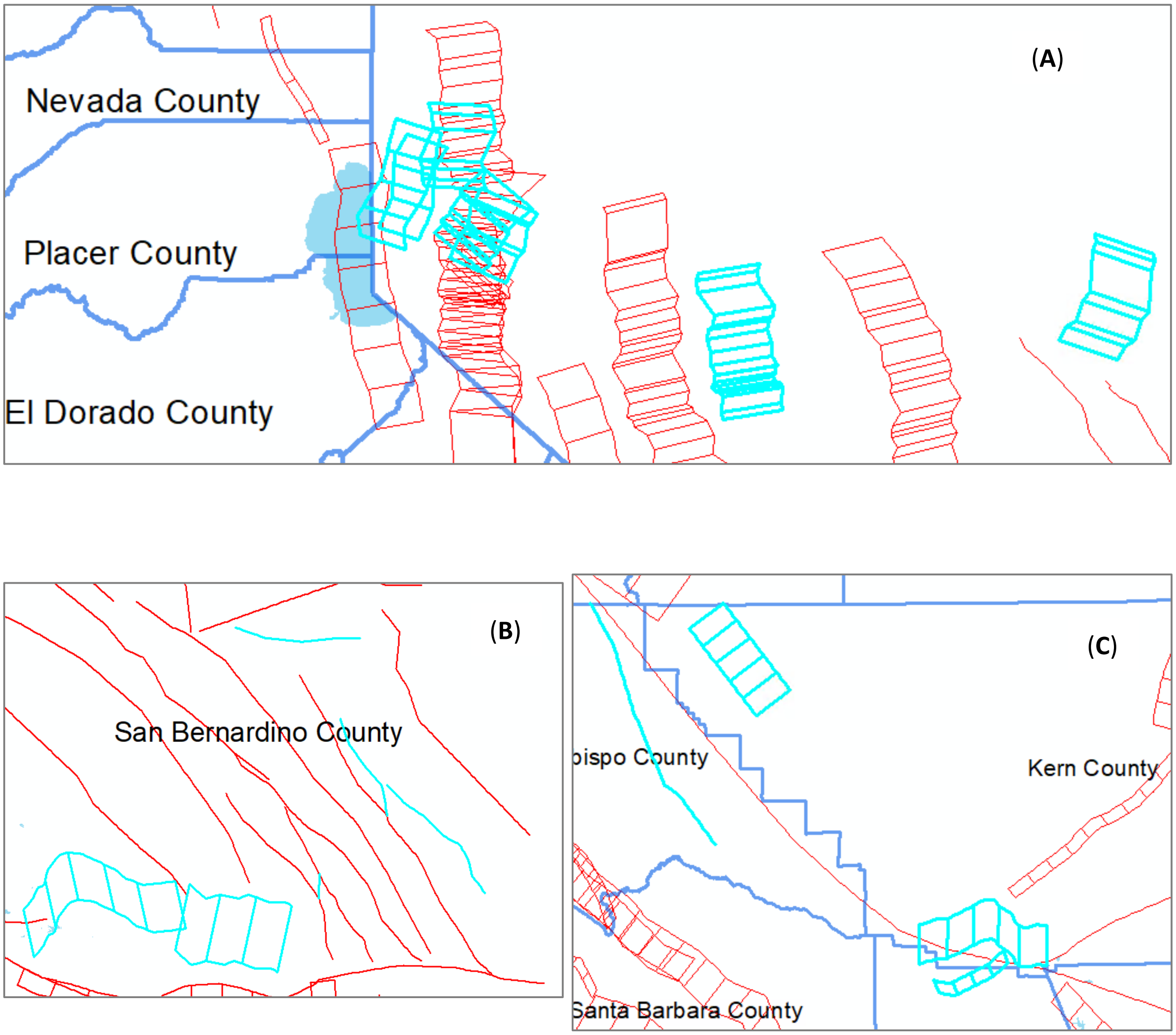


Figure 3. Examples of three types of excluded scenarios (highlighted in blue) based on rupture extent: A. Small ruptures outside California; B. Small ruptures next to large ruptures; and C. Ruptures with M < 7 that are next to very large strike-slip fault zones such as the San Andreas fault zone.

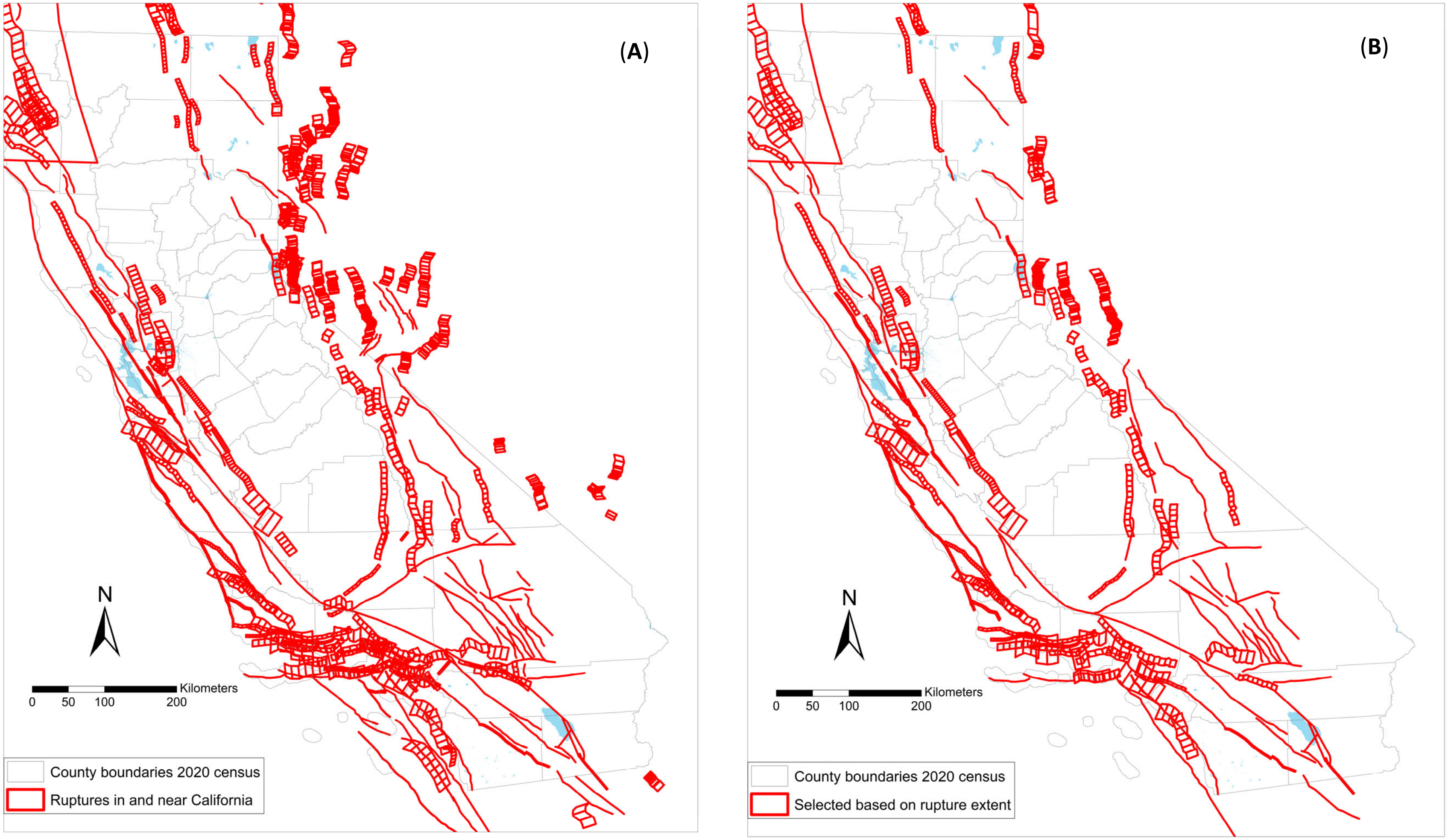


Figure 4. Maps of scenario ruptures: A. The total of 432 scenarios in the BSSC catalog in and near California; B. 173 scenarios selected based on rupture extent. Most eliminated scenarios have short ruptures (small magnitude). Some short-rupture scenarios are kept because they may be important to some counties.

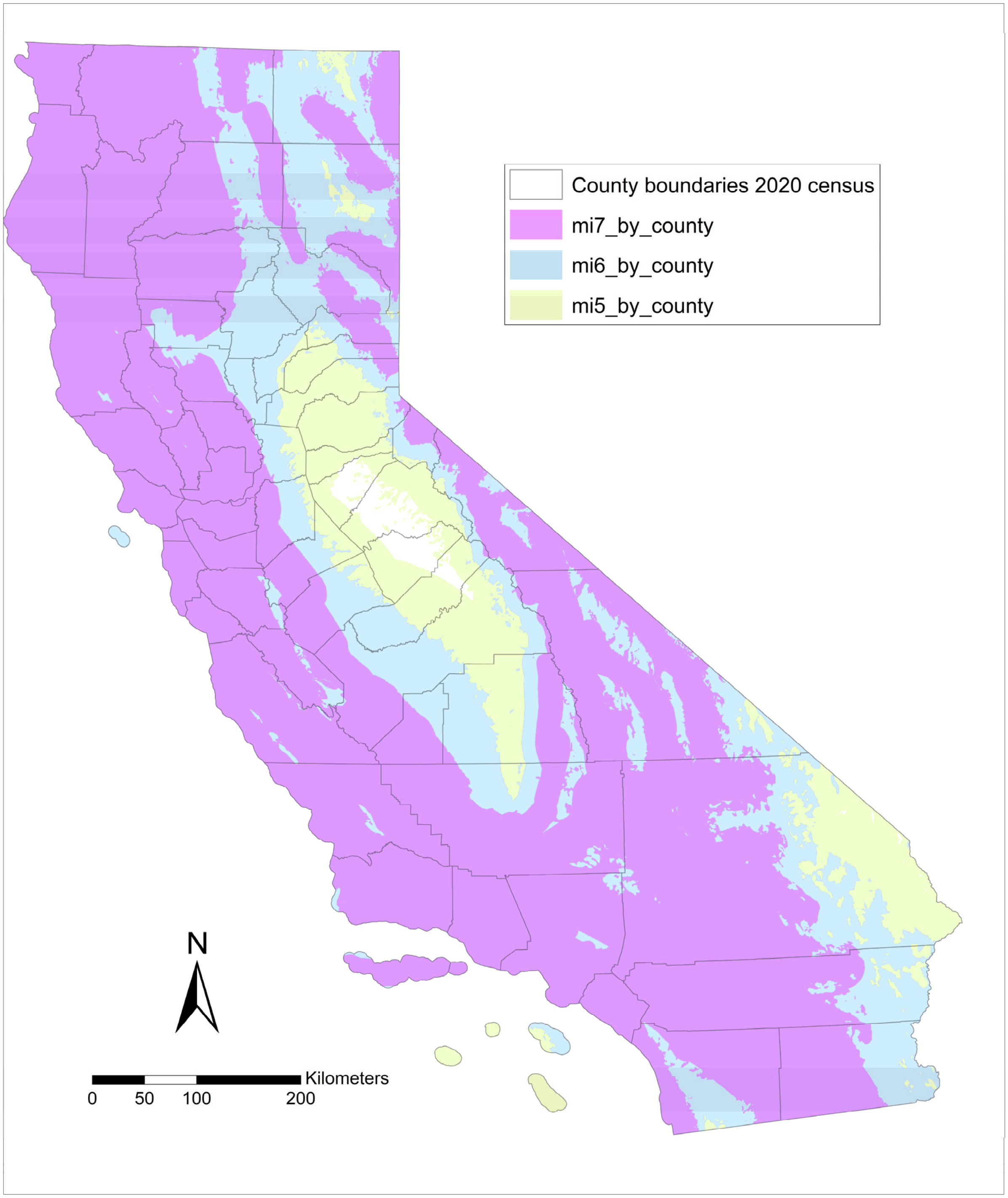
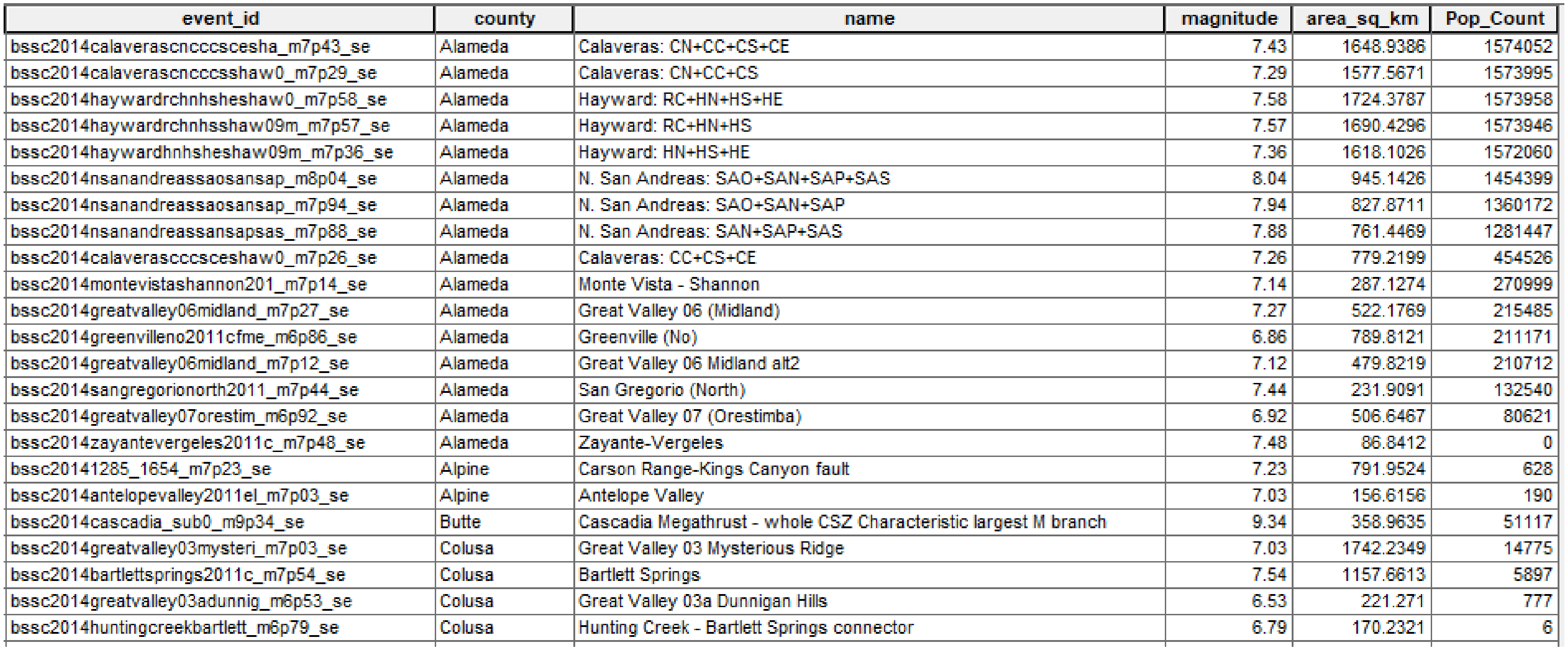


Figure 5. Three simplified shaking intensity levels (mi) for the 173 scenarios in the preliminary list. These mi levels are used to verify and augment scenario selection.



event_id	county	name	magnitude	area_sq_km	Pop_Count
bssc2014calaverascncccscesha_m7p43_se	Alameda	Calaveras: CN+CC+CS+CE	7.43	1648.9386	1574052
bssc2014calaverascncccsshaw0_m7p29_se	Alameda	Calaveras: CN+CC+CS	7.29	1577.5671	1573995
bssc2014haywardrchnhsheshaw0_m7p58_se	Alameda	Hayward: RC+HN+HS+HE	7.58	1724.3787	1573958
bssc2014haywardrchnhsshaw09m_m7p57_se	Alameda	Hayward: RC+HN+HS	7.57	1690.4296	1573946
bssc2014haywardhnhsheshaw09m_m7p36_se	Alameda	Hayward: HN+HS+HE	7.36	1618.1026	1572060
bssc2014nsanandreassaosansap_m8p04_se	Alameda	N. San Andreas: SAO+SAN+SAP+SAS	8.04	945.1426	1454399
bssc2014nsanandreassaosansap_m7p94_se	Alameda	N. San Andreas: SAO+SAN+SAP	7.94	827.8711	1360172
bssc2014nsanandreassansapsas_m7p88_se	Alameda	N. San Andreas: SAN+SAP+SAS	7.88	761.4469	1281447
bssc2014calaverascccsceshaw0_m7p26_se	Alameda	Calaveras: CC+CS+CE	7.26	779.2199	454526
bssc2014montevistashannon201_m7p14_se	Alameda	Monte Vista - Shannon	7.14	287.1274	270999
bssc2014greatvalley06midland_m7p27_se	Alameda	Great Valley 06 (Midland)	7.27	522.1769	215485
bssc2014greenvilleno2011cfme_m6p86_se	Alameda	Greenville (No)	6.86	789.8121	211171
bssc2014greatvalley06midland_m7p12_se	Alameda	Great Valley 06 Midland alt2	7.12	479.8219	210712
bssc2014sangregorionorth2011_m7p44_se	Alameda	San Gregorio (North)	7.44	231.9091	132540
bssc2014greatvalley07orestim_m6p92_se	Alameda	Great Valley 07 (Orestimba)	6.92	506.6467	80621
bssc2014zayantevergeles2011c_m7p48_se	Alameda	Zayante-Vergeles	7.48	86.8412	0
bssc20141285_1654_m7p23_se	Alpine	Carson Range-Kings Canyon fault	7.23	791.9524	628
bssc2014antelopevalley2011el_m7p03_se	Alpine	Antelope Valley	7.03	156.6156	190
bssc2014cascadia_sub0_m9p34_se	Butte	Cascadia Megathrust - whole CSZ Characteristic largest M branch	9.34	358.9635	51117
bssc2014greatvalley03mysteri_m7p03_se	Colusa	Great Valley 03 Mysterious Ridge	7.03	1742.2349	14775
bssc2014bartlettsprings2011c_m7p54_se	Colusa	Bartlett Springs	7.54	1157.6613	5897
bssc2014greatvalley03adunnig_m6p53_se	Colusa	Great Valley 03a Dunnigan Hills	6.53	221.271	777
bssc2014huntingcreekbartlett_m6p79_se	Colusa	Hunting Creek - Bartlett Springs connector	6.79	170.2321	6

Figure 6. Screenshot of the first 3 counties (in alphabetic order) in Table A-1. For each county, this table gives the total land area in km^2 with MI $\geq$ 7 from each scenario that produces this level of shaking in the county. Total population in the area is aggregated from the population grid and given in the last column (named *Pop_Count*). The affected area size (column named *area_sq_km*) and population are used to verify and augment scenario selection.

Tables

Table 1. Recommended Scenarios

id	name	Magnitude	Event Rate Based on Moment Rate	
			rate or upper bound of rate	lower bound of rate if applicable
almanor2011cfmellbge_m6p69_se	Almanor	6.69	1.319E-03	
anacapadumealt1ellbg_m7p2_se	Anacapa-Dume alt 1	7.2	1.513E-04	
antelopevalley2011el_m7p03_se	Antelope Valley	7.03	6.574E-04	
bartlettsprings2011c_m7p54_se	Bartlett Springs	7.54	1.371E-03	
biglagoonbaldmtn2011_m7p87_se	Big Lagoon - Bald Mtn	7.87	1.751E-04	
calaverascccsceshaw0_m7p26_se	Calaveras: CC+CS+CE	7.26	1.473E-03	6.271E-04
calaverascncccsshaw0_m7p29_se	Calaveras: CN+CC+CS	7.29	1.328E-03	1.328E-03
calaverascncccscesha_m7p43_se	Calaveras: CN+CC+CS+CE	7.43	8.191E-04	3.486E-04
1285_1654_m7p23_se	Carson Range-Kings Canyon fault	7.23	5.461E-04	
cascadia_sub0_m9p34_se	Cascadia Megathrust - whole CSZ Characteristic largest M branch	9.34		
cedarmtnmahoganymtns_m7p13_se	Cedar Mtn-Mahogany Mtn	7.13	1.717E-04	
collayami2011cfmellb_m6p7_se	Collayami	6.7	4.425E-04	
comptonellbgeol_m7p45_se	Compton	7.45	3.142E-04	
coronadobankalt2shaw_m7p38_se	Coronado Bank alt2	7.38	2.906E-04	
deathvalleynoshaw09m_m7p37_se	Death Valley (No)	7.37	1.213E-03	

eatonroughs2011cfmsh_m7p36_se	Eaton Roughs	7.36	9.381E-04	
elsinorecmjtsgishaw0_m7p69_se	Elsinore: CM+J+T+s+GI	7.69	2.579E-04	4.277E-05
elsinorecmjtsgiwshaw_m7p77_se	Elsinore: CM+J+T+s+GI+W	7.77	1.957E-04	3.244E-05
elsinorejtsgiwshaw09_m7p72_se	Elsinore: J+T+s+GI+W	7.72	2.325E-04	3.856E-05
greatvalley03mysteri_m7p03_se	Great Valley 03 Mysterious Ridge	7.03	7.436E-04	
greatvalley03adunnig_m6p53_se	Great Valley 03a Dunnigan Hills	6.53	3.507E-04	
greatvalley04atroutc_m6p6_se	Great Valley 04a Trout Creek	6.6	1.104E-03	
greatvalley04bgordon_m6p77_se	Great Valley 04b Gordon Valley	6.77	7.104E-04	
greatvalley06midland_m7p27_se	Great Valley 06 (Midland)	7.27	6.631E-05	
greatvalley06midland_m7p12_se	Great Valley 06 Midland alt2	7.12	7.353E-05	
greatvalley07orestim_m6p92_se	Great Valley 07 (Orestimba)	6.92	2.998E-04	
greatvalley08quintoe_m6p59_se	Great Valley 08 (Quinto)	6.59	3.116E-04	
greatvalley09lagunas_m6p57_se	Great Valley 09 (Laguna Seca)	6.57	1.458E-03	
greatvalley13coaling_m7p03_se	Great Valley 13 (Coalinga)	7.03	7.290E-04	
greatvalley14kettlem_m7p12_se	Great Valley 14 (Kettleman Hills)	7.12	4.901E-04	
hartleysprings2011cf_m6p77_se	Hartley Springs	6.77	5.444E-04	
hatcreekmcarthurmayf_m7p29_se	Hat Creek-McArthur-Mayfield	7.29	2.139E-04	
haywardhnhsheshaw09m_m7p36_se	Hayward: HN+HS+HE	7.36	1.313E-03	1.163E-04
haywardrchnhsshaw09m_m7p57_se	Hayward: RC+HN+HS	7.57	6.356E-04	5.122E-04
haywardrchnhsheshaw0_m7p58_se	Hayward: RC+HN+HS+HE	7.58	6.141E-04	5.440E-05
hiltoncreek2011cfmel_m6p92_se	Hilton Creek	6.92	1.043E-03	
honeylake2011cfmshaw_m7p03_se	Honey Lake	7.03	8.776E-04	
hosgrishaw09modgeol_m7p54_se	Hosgri	7.54	3.861E-04	
huntingcreekberryess_m6p69_se	Hunting Creek - Berryessa	6.69	3.966E-03	
independencerev2011e_m7p31_se	Independence rev	7.31	8.510E-05	
kerncanyonnorthkern2_m7p1_se	Kern Canyon (North Kern)	7.1	9.687E-05	
kerncanyonsouthkern2_m7p06_se	Kern Canyon (South Kern)	7.06	1.250E-04	
843bc_m7p36_se	Klamath graben fault system (east)	7.36		
likely2011cfmshaw09m_m7p16_se	Likely	7.16	1.935E-04	
maacama2011cfmshaw09_m7p55_se	Maacama	7.55	2.145E-03	
mohawkvalley2011cfme_m7p13_se	Mohawk Valley	7.13	3.218E-04	

monolake2011cfmellbg_m6p7_se	Mono Lake	6.7	7.336E-04	
montevistashannon201_m7p14_se	Monte Vista - Shannon	7.14	3.922E-04	
montereybaytularcito_m7p26_se	Monterey Bay-Tularcitos	7.26	2.325E-04	
nsanandreassansapsas_m7p88_se	N. San Andreas: SAN+SAP+SAS	7.88	1.570E-03	6.435E-04
nsanandreassaosansap_m7p94_se	N. San Andreas: SAO+SAN+SAP	7.94	1.276E-03	6.674E-04
nsanandreassaosansap_m8p04_se	N. San Andreas: SAO+SAN+SAP+SAS	8.04	9.034E-04	3.703E-04
oakridgeonshoreellbg_m7p16_se	Oak Ridge (Onshore)	7.16	1.955E-03	
oceanicwesthuasnasha_m7p21_se	Oceanic - West Huasna	7.21	2.592E-04	
ortigalitasouthshaw0_m7p01_se	Ortigalita (South)	7.01	6.769E-04	
owensvalleyshaw09mod_m7p38_se	Owens Valley	7.38	1.065E-03	
panamintvalleyshaw09_m7p38_se	Panamint Valley	7.38	9.865E-04	
pitaspointlowerweste_m7p21_se	Pitas Point (Lower West)	7.21	4.130E-04	
polaris2011cfmellbge_m6p79_se	Polaris	6.79	4.204E-04	
puentehillsellbgeol_m7p08_se	Puente Hills	7.08	2.579E-04	
redmountainshaw09mod_m7p41_se	Red Mountain	7.41	1.055E-03	
reliz2011cfmshaw09mo_m7p44_se	Reliz	7.44	8.333E-05	
rosecanyonshaw09modg_m6p99_se	Rose Canyon	6.99	7.263E-04	
roundvalleyellbgeol_m7p02_se	Round Valley	7.02	4.601E-04	
ssanandreasccbbnmsmn_m8p1_se	S. San Andreas: CC+BB+NM+SM+NSB+SSB+BG+CO	8.1	6.235E-04	1.059E-04
ssanandreaschccbbnms_m8p1_se	S. San Andreas: CH+CC+BB+NM+SM+NSB+SSB+BG	8.1	6.235E-04	1.059E-04
ssanandreaschccbbnms_m8p17_se	S. San Andreas: CH+CC+BB+NM+SM+NSB+SSB+BG+CO	8.17	4.896E-04	4.971E-05
ssanandreaspkchccbbn_m8p11_se	S. San Andreas: PK+CH+CC+BB+NM+SM+NSB+SSB+BG	8.11	6.023E-04	1.023E-04
ssanandreaspkchccbbn_m8p18_se	S. San Andreas: PK+CH+CC+BB+NM+SM+NSB+SSB+BG+CO	8.18	4.730E-04	4.803E-05
sancayetanoellbgeol_m7p16_se	San Cayetano	7.16	2.684E-03	
sangregorionorth2011_m7p44_se	San Gregorio (North)	7.44	1.377E-03	
sangregoriosouth2011_m7p24_se	San Gregorio (South)	7.24	7.825E-04	
sanjacintosbvsjvsacc_m7p72_se	San Jacinto: SBV+SJV+s+A+CC+B	7.72	6.614E-04	1.344E-04
sanjacintosbvsjvsacc_m7p76_se	San Jacinto: SBV+SJV+s+A+CC+B+SM	7.76	5.761E-04	1.171E-04
sanluisrangesomargin_m7p49_se	San Luis Range (So Margin)	7.49	2.515E-05	
bssc2014santaynezwestshaw09m_m7p11_se	Santa Ynez (West)	7.11	9.132E-04	

1291abc_m7p37_se	Smith Valley fault	7.37		
surprisevalley2011cf_m7p2_se	Surprise Valley	7.2	2.811E-04	
trinidadalt1ellbgeol_m7p46_se	Trinidad (alt1)	7.46	2.579E-04	
1605_m6p92_se	Warm Springs Valley fault zone	6.92		
westnapa2011cfmellbg_m6p97_se	West Napa	6.97	8.132E-04	
whitemountainsshaw09_m7p38_se	White Mountains	7.38	1.930E-04	
zayantevergeles2011c_m7p48_se	Zayante-Vergeles	7.48	6.671E-06	

Table 2. Supplementary Scenarios

id	**name**	**Magnitude**	**Event rate from UCERF3 Moment Rate**	
			rate or upper bound of rate	**lower bound of rate if applicable**
bluecutshaw09modgeol_m7p2_se	Blue Cut	7.2	2.789E-04	
brawleyseismiczoneal_m6p1_se	Brawley (Seismic Zone) alt 1	6.1	1.824E-02	
brawleyseismiczoneal_m6p11_se	Brawley (Seismic Zone) alt 2	6.11	1.646E-02	
calicohidalgoshaw09m_m7p44_se	Calico-Hidalgo	7.44	6.197E-04	
deathvalleyblackmtns_m7p22_se	Death Valley (Black Mtns Frontal)	7.22	1.303E-03	
1602_m7p05_se	Dry Valley-Smoke Creek Ranch fault zone	7.05		
garlockgcgeshaw09mod_m7p5_se	Garlock: GC+GE	7.5	1.203E-03	2.218E-04
garlockgwgcshaw09mod_m7p67_se	Garlock: GW+GC	7.67	6.689E-04	5.081E-04
garlockgwgcgeshaw09m_m7p73_se	Garlock: GW+GC+GE	7.73	5.437E-04	1.002E-04
greatvalley11ellbgeo_m6p55_se	Great Valley 11	6.55	1.499E-03	
helendalesolockharts_m7p39_se	Helendale-So Lockhart	7.39	1.466E-04	
huntermountainsaline_m7p16_se	Hunter Mountain-Saline Valley	7.16	1.165E-03	
imperialshaw09modgeo_m7p04_se	Imperial	7.04	7.076E-03	
johnsonvalleyno2011r_m7p07_se	Johnson Valley (No)	7.07	5.204E-04	
lenwoodlockhartoldwo_m7p5_se	Lenwood-Lockhart-Old Woman Springs	7.5	2.546E-04	
newportinglewoodalt1_m7p15_se	Newport-Inglewood alt 1	7.15	3.160E-04	
oceansidealt1ellbgeo_m7p24_se	Oceanside alt1	7.24	1.566E-04	
rodgerscreekhealdsbu_m7p19_se	Rodgers Creek - Healdsburg	7.19	2.430E-03	
sangabrielellbgeol_m7p23_se	San Gabriel	7.23	2.776E-04	
santacruzislandshaw0_m7p12_se	Santa Cruz Island	7.12	4.649E-04	
santarosaislandshaw0_m6p89_se	Santa Rosa Island	6.89	1.486E-03	
santaynezrivershaw09_m7p14_se	Santa Ynez River	7.14	2.250E-04	
sierramadreellbgeol_m7p16_se	Sierra Madre	7.16	7.615E-04	
sisarellbgeol_m7p01_se	Sisar	7.01	4.971E-04	

sosierranevadashaw09_m7p49_se	So Sierra Nevada	7.49	1.742E-04	
venturapitaspointell_m7p12_se	Ventura-Pitas Point	7.12	2.579E-04	
westtahoeellbgeol_m7p15_se	West Tahoe	7.15	3.965E-04	
whitewolfellbgeol_m7p14_se	White Wolf	7.14	3.444E-04	
whittieralt2ellbgeol_m6p98_se	Whittier alt 2	6.98	1.010E-03	