The 2002 Update Interactive Deaggregation Web Page

Introduction

This web page, http://eqint.cr.usgs.gov/eq/html/deaggint2002.html , is intended to assist the user who wants to determine the principal sources that contribute to seismic hazard at a specified site, according to the 2002 USGS national probabilistic seismic hazard model documented in Frankel *et al.* (2002). The previous -or 1996 -USGS seismic hazard model may be deaggregated at another web address, http://eqint.cr.usgs.gov/eq/html/deaggint.html .

What Is New in the Layout and Design?

We have kept a nearly identical layout of the Web page and a similar appearance of output files as those of the 1996 interactive deaggregation Web page. As before, two types of deaggregation may be performed. The first is in distance, R, magnitude, M, and ground-motion uncertainty, ε. The second displays information on the geographic location of sources, and uses color to represent average magnitude of sources in a given bin. The height of the hazard column for both of these types indicates the relative contribution of the source or sources in the (R,M) or (R,θ) bin, respectively. θ is a site-to-source azimuth for binned probabilistic sources.

The results of the (R,M, ε) deaggregation are output as a graph and a text file. In 2002 the magnitude bin width is 0.2 Mw units, but was 0.5 in 1996. The distance bin width is either 10 km or 25 km. It is 10 km where seismic activity is relatively high, such as in parts of the western U.S., the New Madrid Seismic Zone, and the Charleston, S.C. seismic zone; and is 25 km elsewhere. The hazard-column color scheme has changed. As at the previous Web site, colors on the hazard columns convey information about ε, the third component of probabilistic seismic hazard that is deaggregated, the first two being source-to-site distance and magnitude. At the 2002 deaggregation web site, color coding of the hazard columns at each (R,M) bin location indicates the average ε_0 for sources in that bin. ε_0 is the number of standard deviations (σ) that a given probabilistic ground motion is from the median motion for a given source. Typically, binned data include contributions from several sources and several attenuation models and a reported ε_0 is an average of all of the individual ε_0 contributions in the bin. A negative ε_0 implies that the probabilistic motion is less than the median motion that might be expected from a source. Binned contributions with a negative ε_0 are assigned warm colors, pink, red, brown. Binned contributions with a positive ε_0 are assigned cool colors, green, light blue and dark blue. Orange and yellow, respectively, are used to indicate bins whose ground motion is just below or just above the median, or, more exactly, whose logged ground motion is less than 1/2 σ from μ. μ is the logrithmic mean ground motion, and σ is the aleatory uncertainty of a ground-motion prediction equation, for a given (R,M).

The front face of each hazard column on a (R,M, ε) graph provides further information on contributions from ground-motion uncertainty, just as it did at the 1996 Web site. The front face of a hazard column is no longer shown with a set of colors. Instead, gray regions separated by horizontal lines show the relative contributions due to ground-motion uncertainty, i.e., the deaggregation of ε. These horizontal lines occur at 1σ intervals, ε=2, 1, 0, -1, -2. The topmost part of the front face of each column, which has the original column color, represents the contribution from potential ground motions that exceed $\mu + 2\sigma$ for a given (R,M). The first gray rectangle down from the colored top is the 1-to-2 σ above μ contribution, below which is the 0-to-1σ contribution, and so on. Thus, all of the information available in the 1996 deaggregation graphs has been retained in 2002, but a new emphasis has been placed on ε_0 in the updated version of the (R,M, ε) graphs.

Geographic Deaggregation of Seismic Hazard

Geographic deaggregations are optionally output at this web site. As in 1996, seismic hazard associated with known faults is plotted at the location on the fault or fault segment having the nearest distance to the site, consistent with distance metrics used to calculate hazard. The gridded seismicity contributions are now azimuthally binned into either 5^o or 45^o sections. The region around the site may be divided into coarse concentric cylinders with outer radii at R=25 km, 50 km, 100 km, 200 km, or fine concentric circles, dR=25 for all R. This option is invoked if you specify "coarse distance on the menu. Alternately, the region around the site may be divided into relatively fine concentric circles, with dR=10 km out to 500 km, then a catch-all annulus for R>500 km. Each of these annuli is divided into several equal-area subregions and the gridded contribution in each of these subregions is averaged and plotted at the middle azimuth.For instance, the 0-to-45^o gridded contribution is plotted at azimuth 22.5^o. One reason for presenting the geographic hazard contributions with coarse gridding is to show how gridded hazard compares with specific fault hazard. At many sites in the U.S., there is comparable hazard from sources on known faults as from gridded sources when the latter are binned relatively coarsely in distance and azimuth. However, if an overly fine spatial binning of gridded seismicity is used, the relative contribution from random or gridded seismicity sources tends to be difficult to compare to hazard from fault sources. Also, the coarse option of spatial binning allows the user to determine which if any azimuths exhibit higher gridded-source hazard than the others. Light blue circles and rays outline the boundaries of the new gridded-source hazard bins in the geographic hazard maps. The user chooses fine or coarse binning to get the 5^o or 45^o azimuthal bins, respectively, with the geographic deaggregation option. Similarly, the user chooses fine or coarse distance binning.

Fault traces corresponding to faults that are used in hazard calculations appear as *red* lines on the geographic hazard maps. The fault trace locations that appear on the geographic hazard plots of the 2002 PSHA can differ from those of 1996. The 2002 model includes several newly recognized faults and omits some faults that are no longer considered a seismic hazard. Some improvements in fault locations are also included in the 2002 PSHA update.

On geographic hazard maps that are made for sites near the New Madrid Seismic Zone (NMSZ), the margin of the Mississippi Embayment is plotted as a *brown* line. This brown line is a reminder that this sediment-filled embayment covers much of the region around the NMSZ. For many engineering applications, a soil site response that accounts for sediment properties, such as thickness, at many sites within the embayment is an appropriate modification to the USGS national-map PSHA, which makes a blanket assumption of firm rock site conditions (NEHRP BC boundary).

Rivers appear as *blue* lines on the geographically deaggregated hazard maps.

Historical earthquakes with **M**≥5 in the CEUS and **M**≥6 in the WUS are plotted as red diamonds. The earthquake catalog was updated to include sources through December, 2001. More detail on recorded earthquakes may be found in Frankel *et al.* (2002).

What's New about the Cascadia Subduction Hazard Model?

The contribution to seismic hazard from Cascadia subduction sources is now based on four models of the easternmost location of seismogenic rupture, used to model the epistemic uncertainty in that location. Three are from Flueck and one from Frankel. Some of the debate about this location focuses on the maximum depth at which brittle-rock or seismogenic slip can occur during a large subduction event. In the geographic deaggregation map option, for sites that are relatively near Cascadia sources, the locations of these down-dip edges of Cascadia sources are plotted as *orange* lines. In the course of a deaggregation analysis of seismic hazard, the location of the nearest point on each of these rupture surfaces to the site is determined in order to calculate the distance and azimuth associated with that hazard. For example, for a California site that is east of Cape Mendocino, several hazard columns associated with Gorda/Cascadia plate subduction sources will plot due west of the site. Four columns, each of which is associated with megathrust (**M**9) subduction, may appear on the geographic deaggregation plots, one for each of the subducting plate's seismogenic down-dip locations. Perhaps other hazard columns, associated with **M**8.3 ruptures, will appear at more distant locations on the subducting slab. Another new feature in the 2002 PSHA is that the Juan de Fuca plate bottom boundary bends in a northwesterly direction at a latitude of about 48.0^{o} N. This results in Cascadia source distances being greater for most sites in northern Washington and southern British Columbia, Canada than they were in the 1996 PSHA calculations. Recall, in the 1996 PSHA maps, the eastern or down dip limit of Cascadia source hazard was fixed at 123.8^{o} N at all latitudes. A final difference between the 2002 and the 1996 Cascadia seismic hazard models is that the **M**9 sources are given more epistemic weight than the **M**8.3 sources in the 2002 PSHA, 50%, versus 33% in the 1996 PSHA. A feature that has remained the same as that of 1996 is the use of the Youngs *et al.* and the Sadigh *et al.* (1997) attenuation models at relatively near-source distances, although a new 70-km limit is imposed for using the Sadigh *et al.* model with subduction sources.

We have not yet found a way to effectively show variations in source depth on geographic deaggregation maps along with the other three-dimensional information already present in these maps. Depth is accounted for by plotting gridded sources at a radial distance equal to the hypocentral distance (more exactly, distance to source cell) in the hazard calculation. For example, deep intraplate sources in the Puget Sound region, assumed to have focal depth of 50 km, will plot in the 50 to 100 km annulus, even if they are almost directly under the site. Subduction sources also have a significant depth - for Cascadia it is often 20 km- which is converted into part of the radial distance that is plotted. For these cases a better way to represent source depth in the geographic seismic hazard maps would be desirable.

Text Files

The text files that are published at the web sites shown above contain deaggregated seismic hazard information for a number of spectral periods, for the chosen probability of exceedance. One of the text files contains information for PGA, for 0.2-s and 1.0-s SA. The other text file contains information for four other periods; 0.1-s, 0.3-s, 0.5-s, and 2.0-s SA, respectively. Data for the period that the user chooses for analysis will be included in the text file that is output. The text files are quite similar to those that were published for the 1996 PSHA deaggregations.

A few additional items of possible interest are now included in the text files. One new item is the probability that the specified probabilistic PGA or SA will be less than the median motion of an earthquake source that might be recorded at the given site in a random 50-year period. This conditional probability is different for each attenuation model. The reported value is an average. A probability $< 5 \cdot 10^{-6}$ is reported as zero. Other new lines at the bottom of each SA period's report summarize the source types that principally contribute to the hazard. We consider 24 source types although further differentiation is possible. Deaggregation by these source types helps to show the new features in the 2002 PSHA model as well as features that were in the earlier PSHA. For example, you can see the contributions associated with the narrow Charleston S.C. source zone (new) and the broad Charleston S.C. source zone (like that of the 1996 maps) by looking at the bottom of the analysis, for sites that are in or relatively near South Carolina. New categories (compared to 1996) include extensional gridded sources and extensional faults, among others.

Following the source-type lines there may be lines that document the hazard from specific faults, fault zones, or fault segments. Such information is included if the specific fault scenario contributes at least 1% to the seismic hazard at the specified probability of exceedance (PE). Most faults in the USGS Quaternary fault data base are modeled to have both characteristic and truncated Gutenberg-Richter (GR) distributions of source magnitudes. Hazard contributions from characteristic earthquakes and GR earthquakes on a given fault are reported on separate lines that summarize faulting scenario contributions. Also, a specific fault segment may appear on more than one line for multi-segment source models. California fault/fault segment descriptions are often in abbreviated form in the deaggregation output. Appendix Table A1 below associates these abbreviations - used at the 1996 web page and at the 2002 web page - with more common names. For sites in northern and central California, the 2002 PSHA model's fault descriptions and segmentation models are taken from WG99. Some of these are in a terse code that can be hard to decipher. Appendix Table A2 below relates these fault codes to more recognizable fault names.

The probabilistic PGA and SA values that are published at this web site are the same as those from the 2002 PSHA maps at grid locations where they were calculated, for the 2% in 50 year and the 10% in 50 year PE. The calculations of Frankel *et al.* (2002) were performed at a grid of sites covering the conterminous U.S., at latitude and longitude increments of 0.05^o. For other site locations, and for lower and higher probabilities, this web site's analysis actually solves for the ground motion associated with the specified PE. For non-grid-point sites, the solution is iterative and may take a few minutes, so please be patient. At the 1996 deaggregated seismic hazard web site, probabilistic motions at all sites and for all PEs were potentially iterated. Thus, the 2002 analysis is modestly different from the 1996 analysis. There is now complete agreement between the "official" motions and the deaggregation motions at the grid points. The slight discrepencies between these SA values at the 1996 Web site does not affect the relative contributions or appearance of the 1996-model deaggregation plots, however.

Synthetic Seismograms from Deaggregation (M,R)

The generation of synthetic seismograms in 2002 for a point source having either the modal magnitude and distance or the mean magnitude and distance is an option at this Web site. Details on the method are given in the "stochastic seismogram" link at the 1996 Web site shown above. As in 1996, only one input file is used for a given site and PE to generate the seismograms. Epistemic uncertainty in ground-motion attenuation is sampled by choosing either a one-corner source model or a two-corner source model. Also, we do not consider different (M,R) pairs at this stage of the analysis, although for distributions of probabilistic sources that have two or more prominent hazard peaks, introducing such variability into the stochastic seismograms may be valuable for some engineering applications.

The output consists of two files. One is an ascii file showing the input-file information followed by six accelerograms sampled at a fixed delta-*t*. The second is a plot of the six seismograms and associated information.

Some changes from 1996 were introduced in the 2002 synthetic seismogram option. First, the six accelerograms that are published are no longer scaled to the probabilistic motion. They are selected, however, based on a nearness criterion of their SA values over a range of periods to those of the approximate uniform hazard spectrum, defined in Leyendecker *et al.* (2000). The fitting criterion is nearly the same as that used at the 1996 Web site, the details of which are reported at the "stochastic seismogram" link there. A new feature is that reduction of SA misfit at the period input by the user is given three times the weight as that at other periods in the selection process. As before, the selection is made from a pool of 60 seismograms. Because we no longer scale the records to match the probabilistic motion, it is important to realize that the published records' SA can be significantly different, sometimes a factor of two or more, from the probabilistic SA, both at the input oscillator period and at other periods. A plot of the six best-fitting seismograms is output. On this plot, the "achieved" SA at the period of interest is printed with each seismogram. This information may assist the user to determine whether the seismogram requires scaling to be suitable for his/her application. At the 1996 deagg. Web site, each of the seismograms was automatically scaled to the probabilistic motion at the PE and spectral period of interest.

Second, a new input file is used when the source is in the Basin and Range of the western U.S. This file, BASRANGE.DAT, has a western U.S. geometric spreading of r**(-1) for 0<r<40 km and r**(-0.5) for r>40 km, like that of Atkinson and Silva (2000), based on an investigation by Raoof *et al* (1999). Its Q_s is the Basin and Range Q_{Lg} of Benz *et al* (1997). This Q is $235f^{0.56}$ for 1<f < 5 Hz, and a constant Q of 192 for f < 1 Hz. The file has the WUS rock site amp of WR032496, a Brune (single-corner) source spectrum, and the 70-bar stress parameter of that file. The 2002 USGS PSHA model has a number of region-specific features associated with the Basin and Range seismotectonic province. A region-specific input file for generating synthetic seismograms for sources in that province is therefore an appropriate addition.

Third, generation of synthetic accelerograms uses version 2.20 of David Boore's smsim_td, compared to version 2.10 used for the 1996 seismograms. Version 2.20 allows for a magnitude-dependent geometric spreading coefficient and has some other minor changes from version 2.10. These changes are more fully documented at http://quake.wr.usgs.gov/~boore/software_online.htm .

Other Remarks:

Many of the introductory remarks that are available in links at the 1996 interactive seismic hazard deaggregation web site remain valid at the 2002 web site. For those who are unfamiliar with those remarks, it might be helpful to read them.

We expect to soon have hard-rock site-condition option as well as the BC-rock site-condition option at the 2002 Interactive Seismic Hazard Deaggregation Web site.

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References:

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Appendix:

Fault abbreviations for California faults are associated with fault names in Table A1.

Some important northern California fault scenarios may appear with their WG99 abbreviations in the 2002 deaggregation reports for California sites. These abbreviations and the corresponding recognizable names are shown in Table A2. Gray lines correspond to single-segment scenarios.White lines correspond to multiple-segment scenarios of the preceding gray-line segmentation models.

Table A1.

NAME	NAME2	DIP
mp.sa-southern	San Andreas fault, southern section	V
mp.sa-sanbern	San Andreas fault, San Bernardino section	V
mp.sa-1857	San Andreas fault, 1857 section	V
mp.sa-mojave	San Andreas fault, Mojave section	V
mp.sa-cholame	San Andreas fault, Cholame section	V
mp.sa-parkf	San Andreas fault, Parkfield section	V
jl0.sa-1906	San Andreas fault, 1906 section	V
jl0.sa-sntacruz	San Andreas fault, Santa Cruz Mountains section	V
jl0.sa-peninsla	San Andreas fault, Peninsula section	V
mp.imperial	Imperial fault	V
sj14	Superstition Hills fault	V
sj13	Superstition Mountains fault	V
sj12	San Jacinto fault, Borrego section	V
sj11	San Jacinto fault, Coyote Creek section	V
sj10	San Jacinto fault, Anza section	V
sj9	San Jacinto fault, San Jacinto Valley section	V
sj8	San Jacinto fault, San Bernardino section	V
bb.lagunasalada	Laguna Salada fault	V
el19	Elsinore fault, Coyote Mountain section	V
el18	Elsinore fault, Julian section	V
el17	Elsinore fault, Temecula section	V
el16	Elsinore fault, Glen Ivy section	V
el15	Elsinore fault, Whittier section	V
jl0.hayward-all	Hayward fault, total length	V
jl0.hayward-s	Hayward fault, southern section	V
jl0.hayward-n	Hayward fault, northern section	V
jl0.rodgerscrk	Rodgers Creek fault	V
bb.chinocentral	Chino - Central Ave. fault	SW
mp.sierramad-sf	Sierra Madre fault, San Fernando	N
mp.sierramad-cn	Sierra Madre fault	N
bb.malibucoast	Malibu Coast fault	N
mp.arroyo-more	Mission Ridge-Arroyo Parida-Santa Ana fault	N
mp.oakr-on	Oak Ridge (onshore)	S
bb.simi	Simi-Santa Rosa fault	N
bb.sanjose	San Jose fault	NW
bb.clamshell	Clamshell-Sawpit fault	NW
mp.anacapa-d	Anacapa Dume fault	N
bb.lionshead	Lions Head fault	NE
bb.sanluisrng	San Luis Range fault, south margin	N
jl0.battlecrk	Battle Creek fault	S
bb.birchck	Birch Creek fault	E
bb.deepspr	Deep Springs fault	NW
bb.fishslu	Fish Slough fault	W
pm.ltsalmon-on	Little Salmon fault (onshore)	NE
pm.ltsalmon-off	Little Salmon fault (offshore)	NE
pm.tablebluff	Table Bluff fault	NE
pm.trinidad	Trinidad fault	NE
pm.ficklehill	Fickle Hill fault	NE
pm.madriver	Mad River fault	NE
pm.mckinleyvl	McKinleyville fault	NE
pm.biglagoon	Big Lagoon-Bald Mountain fault zone	NE
bb.htcmaymcarth	Hat Creek-McArthur-Mayfield fault	W
bb.gooselk	Goose Lake fault	W
jl0.grtvly13	Great Valley 13 fault	W
bnoridge	Northridge fault	S
mp.oakr-off	Oak Ridge fault (offshore)	S
bnchanslp	North Channel Slope fault	N
mp.brawley	Brawley seismic zone	V
mp.elmoreran	Elmore Ranch fault	V
bb.earthqkvlly	Earthquake Valley fault	V
jl0.hayward-see	Hayward fault, southeast extension	V
jl0.calav-n	Calaveras fault north	V
bb.garlockw	Garlock fault west	V
bb.garlocke	Garlock fault east	V
bb.owllk	Owl Lake fault	V
bb.rosecny-osz	Rose Canyon fault	V
bb.nwprting-osz	Newport-Inglewood fault (offshore)	V
bb.palsv-crndbk	Coronado Bank fault	V
bb.newporting	Newport-Inglewood fault	V
bb.bigpine	Big Pine fault	V
bb.cucamonga	Cucamonga fault	N
bb.sangab	San Gabriel fault	V
bb.holser	Holser fault	S
mp.santamonica	Santa Monica fault	N
bb.hollywood	Hollywood fault	N
bb.raymond	Raymond fault	N
mp.verdugo	Verdugo fault	NE

Table A2.

NAME	Mch	Recognizable name	dip
scz -- 1-1	7.0	SAN ANDREAS FAULT - SANTA CRUZ SEGMENT	90
pn --1-2	7.1	SAN ANDREAS FAULT - PENINSULA SEGMENT	90
ncs --san -1-3	7.4	SAN ANDREAS FAULT - NORTH COAST SOUTH SEGMENT	90
ncn -- sao - 1-4	7.3	SAN ANDREAS FAULT - NORTH COAST NORTH SEGMENT	90
scz+pn--sas+sap -1-5	7.4		90
ncs+ncn --san+sao -1-7	7.7		90
scz+pn+ncs -- sas+sap+san 1-8	7.7		90
pn+ncs+ncn--sap+san+sao-1-9	7.8		90
scz+pn+ncs+ncn --sas+sap+san+sao 1-10	7.9		90
sh -- hs 2-1	6.7	SOUTHERN HAYWARD	90
nh -- hn 2-2	6.4	NORTHERN HAYWARD	90
sh+nh -- hs+hn 2-5	6.9		90
rc 2-7	7.0	RODGERS CREEK	90
nh+rc-- hn+rc 2-9	7.1		90
sh+nh+rc-- hs+hn+rc 2-10	7.2		90
sc -- cs -- average used-3-1	5.8	SOUTHERN CALAVERAS	90
cc -- average used-3-2	6.2	CENTRAL CALAVERAS	90
sc+cc -- cs+cc -- average used-3-5	6.4		90
nc -- cn--3-7	6.8	NORTHERN CALAVERAS	90
cc+nc -- cc+cn-3-9	6.9		90
sc+cc+nc--cs+cc+cn-3-10	7.0		90
con -- average -4-1	6.2	CONCORD	90
sgv --gvs -- average - 4-2	6.2	SOUTHERN GREEN VALLEY	90
con+sgv--con+gvs--4-5	6.5		90
ngv --gvn--average-4-7	6.2	NORTHERN GREEN VALLEY	90
sgv+ngv --gvs+gvn-4-9	6.5		90
con+sgv+ngv--con+gvs+gvn-4-10	6.7		90

sgs--5-1	7.0	SAN GREGORIO SOUTH	90
sgn -- 5-9	7.2	SAN GREGORIO NORTH	90
sgs+sgn --5-10	7.5		90
sg --gs --6-1	6.6	SOUTHERN GREENVILLE	90
ng -- gn -- 6-9	6.6	NORTHERN GREENVILLE	90
sg+ng --gs+gn -- 6-10	6.9		90
mtd-- 7-10	6.6	MT. DIABLO THRUST	38
mtd-- 7-10	6.9		38