Appendix J

Digital Seismic Hazard Products

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This appendix contains the digital data associated with the seismic hazard results presented in Chapter 10 for use in subsequent development of soil hazard curves for various facilities. These results include mean and fractile baserock hazard curves, mean and fractile baserock uniform hazard response spectra (UHRS), magnitude and distance deaggregation of the mean rock hazard, and deaggregation earthquake (DE) response spectra. In addition, the appendix contains the digital data for the randomized dynamic properties for the Saddle Mountains basalts/interbeds sequence described in Section 9.6. The digital data for each site are contained in the folder labeled Appendix J Supplemental Material. This folder contains supplements labeled labeled Appendix_J_Site*X*, where *X* is A, B, C, D, or E for the five hazard sites. The various data files are described in the following sections.

J.1 Mean and Fractile Baserock Total Hazard Curves

The mean and fractile total hazard curves are contained folder Hazard.*X*, where *X* refers again to the site. The folder contains 20 files corresponding to the 20 spectral periods at which the hazard was computed. The file names are T*xxx*.MFH, where *xxx* indicates the spectral period as indicated in Table J.1. Each file contains two header records indicating the site, the spectral period, and the column headings. The remaining records contain seven columns of data. Column 1 contains the ground motion level (either peak ground acceleration [PGA] or 5% damped pseudo spectral acceleration in gs); column 2 contains the mean annual frequency of exceedance (AFE); and columns 3 through 7 contain the fractile values of AFE for the 5th, 16th, 50th, 84th, and 95th fractiles.

Table J.1. Spectral Period Designations for Hazard Results Files

File Indicator *xxx*	Spectral Period (s)	File Indicator *xxx*	Spectral Period (s)
001	PGA (0.01 s)	040	0.4
002	0.02	050	0.5
003	0.03	075	0.75
004	0.04	100	1.0
005	0.05	150	1.5
007	0.075	200	2.0
010	0.1	300	3.0
015	0.15	500	5.0
020	0.2	750	7.5
030	0.3	ten	10.0

J.2 Mean and Fractile Baserock UHRS

The mean and fractile hazard curves were interpolated (linearly in log pSA-log-AFE) to develop UHRS for 27 return periods between 10^2 and 10^7. The UHRS are contained in folder UHRS.*X*. Summary files Site*X*-Mean.out, Site X-05th.out, Site X-16th.out, Site X-50th.out, Site X-84th.out, and Site X-

95th.out contain tables of the UHRS based on the mean, 5^{th}, 16^{th}, 50^{th}, 84^{th}, and 95^{th} fractile hazard, respectively. Each file contains four header records and a record for each of the 20 spectral periods from 0.01 to 10 s. The remaining columns contain the corresponding ground motion levels for the 27 return periods. In addition to the summary files, the folder contains individual files for each return period and set of hazard curves. The files are designated SiteX-*yy*-*afe*.txt, where *yy* indicates the hazard basis (e.g., mean for mean hazard and 05 for 5^{th} percentile hazard), and *afe* indicated the return period. The files contain a column labeled "Amp" indicating the value of pSA divided by PGA. The individual UHRS files based on mean hazard also list the mean magnitude, mean distance, and mean epsilon for the contributions to hazard for each spectral period. Table J.2 lists the 27 return periods, the corresponding AFE values, and the *afe* file designations.

Table J.2. Return Period Designations for Individual UHRS Files

Return Period (years)	AFE	*afe* File Designation	Return Period (years)	AFE	*afe* File Designation
100	1.000E-02	1e2	33,333	3.000E-05	3e5
133	7.519E-03	7e3	50,000	2.000E-05	2e5
200	5.000E-03	5e3	100,000	1.000E-05	1e5
333	3.003E-03	3e3	133,333	7.500E-06	7e6
500	2.000E-03	2e3	200,000	5.000E-06	5e6
1,000	1.000E-03	1e3	333,333	3.000E-06	3e6
1,333	7.502E-04	7e4	500,000	2.000E-06	2e6
2,000	5.000E-04	5e4	1,000,000	1.000E-06	1e6
2,500	4.000E-04	4e4	1,333,333	7.500E-07	7e7
3,333	3.000E-04	3e4	2,000,000	5.000E-07	5e7
5,000	2.000E-04	2e4	3,333,333	3.000E-07	3e7
10,000	1.000E-04	1e4	5,000,000	2.000E-07	2e7
13,333	7.500E-05	7e5	10,000,000	1.000E-07	1e7
20,000	5.000E-05	5e5			

J.3 Magnitude and Distance Deaggregation of Mean Baserock Hazard

Folder DEAGG.*X* contains the results of deaggregation of the mean hazard at the 27 return periods listed in Table J.2. The folder contains 20 files with the designation TOT*xxx*.MRH, with *xxx* indicating the spectral period as indicated in Table J.1. The structure of each file is as follows: The first record is the site name. The second record contains the number of return periods (27), the number of individual magnitude bins (45 spaced at 0.1 magnitude units), the number of distance bins (15), and the rupture distance at the upper end of each distance bin (e.g., the value for the first bin is 5, indicating the contribution from distances in the range $0 \leq R_{RUP} < 5$ km). The remaining records consist of 27 blocks of data for each return period.

The first record of each block lists the ground motion level for the return period, the AFE for the return period, the modal magnitude increment, and the modal distance bin. This record is followed by 45 records corresponding to the 45 magnitude bins. With the exception of the first bin, each magnitude bin represents the contribution from earthquakes of magnitude in the range of $m_i \pm \Delta m/2$, where Δm is the magnitude increment of 0.1 units. The first bin contains the contributions from magnitudes from m_0 to $m_0 + \Delta m/2$. The first value of each record lists the magnitude m_i and the second value the AFE values for m_i from all distances. The next 15 values list the values of AFE for magnitude m_i and for each of the 15 magnitude bins. These 15 values sum to the second value on the record. The last value on each line lists the hazard contribution weighted mean distance for earthquakes of magnitude m_i.

J.4 Deaggregation Earthquake Response Spectra

The deaggregation results given in folder DEAGG.*X* were used to construct DE response spectra for use in developing site amplification functions. The DE spectra are contained in folder DESPEC.*X*.

The concept of DE spectra was developed in McGuire et al. (2001) and consists of representing all of the earthquakes contributing to the hazard by a limited number of representative scenarios. McGuire et al. (2001) typically used three DE scenarios. However, because of the wide range in magnitudes and source types contributing to the hazard, four DE scenarios are developed, representing the contributions of earthquakes in the range of **M** 5.0 to 5.9, 6.0 to 6.9, 7.0 to 7.9, and 8 or greater. The highest magnitude DE scenario also represents the contribution from the Cascadia interface source. DE scenarios were developed for each of the 27 return periods and for each of the 20 spectral accelerations.

Two types of DE spectra are provided. The first are conditional mean spectra (CMS) following the concept developed by Baker and Cornell (2006). The CMS is constructed by calculation the value of epsilon for the scenario earthquake that produces a ground motion level that matched the corresponding UHRS at a designated period T*. The expected value of epsilon at all other periods is computed using the correlation model developed by Baker and Jayaram (2008). For this study, the modifications to the Baker and Jayaram (2008) correlation model developed by Carlton and Abrahamson (2014) to account for high frequency content were implemented. The CMS were constructed from a weighed combination of backbone ground motion prediction equations (GMPEs) following Approach 2.5 described in Carlton and Abrahamson (2014) to account for differences in spectral shape among the alternative GMPEs. The Carlton and Abrahamson (2014) Approach 2.5 developed deaggregation weights (w^d_k) based on the contribution of each GMPE to the site hazard. As this approach is not practical for the 1,000+ crustal backbone GMPEs and the 500+ subduction backbone GMPEs, the deaggregation weight concept was applies to alternative GMPE contributions that represented differences in spectral shape. For the crustal backbone GMPEs, deaggregation weights were developed for the seven alternative V_S-kappa adjustments and logic tree weights were used to develop median spectra and corresponding sigma values over the other branches of the crustal backbonde logic trees developed in Chapter 9. For the subduction backbone GMPEs, deaggregation weights were developed for the alternative values of anelastic attenuation (Θ_6), alternative values of ΔC_1, and the major differences in V_S adjustment (weighted combination of adjustments 1 and 2 versus weight combination of adjustments 3 and 4). Figure J.1 shows an example of DE CMS developed for an AFE of 10^{-4} and T* of 1.0s.

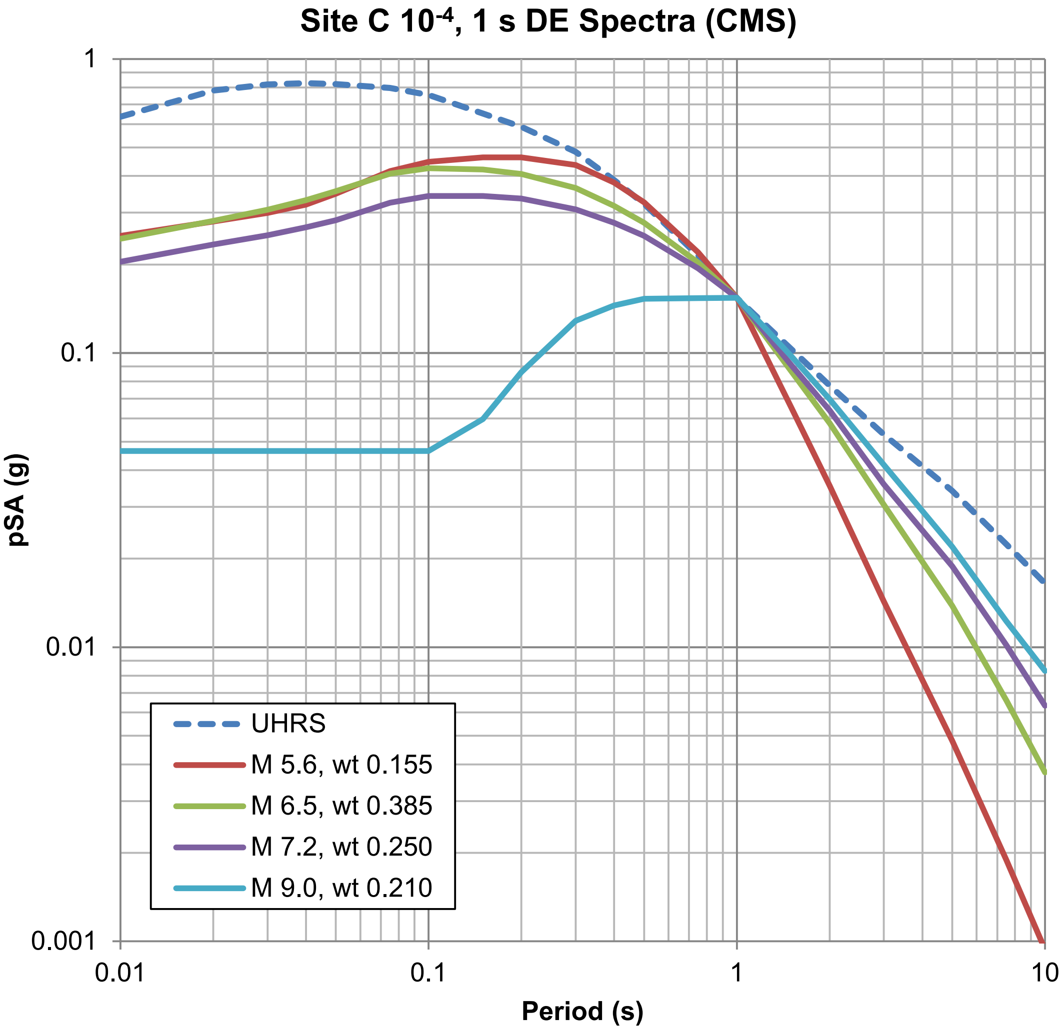

Figure J.1 Example DE CMS.

Other applications of the DE concept have used median spectral shapes for the scenario earthquakes scaled to match the UHRS at a designated period or range of periods. These scaled median spectra (SMS) are then used to develop inputs for site-response analyses. SMS spectra were also developed for the DE scenarios for each of the 27 return periods and the 20 spectral periods by scaling the weighted median spectral developed for each CMS to match the UHRS at *T**. Figure J.2 show an example of the SMS developed for the same scenarios as the CMS shown in Figure J.1.

In some cases, particularly at large values of AFE, the value of epsilon at *T** may be negative. For these cases, the concept of a CMS may produce unrealistic spectral shapes. Following the recommendation of Dr. N. Abrahamson (personnel communication 2014), CMS are not created when whenever the epsilon value at *T** is negative, and SMS spectra are used instead for these cases.

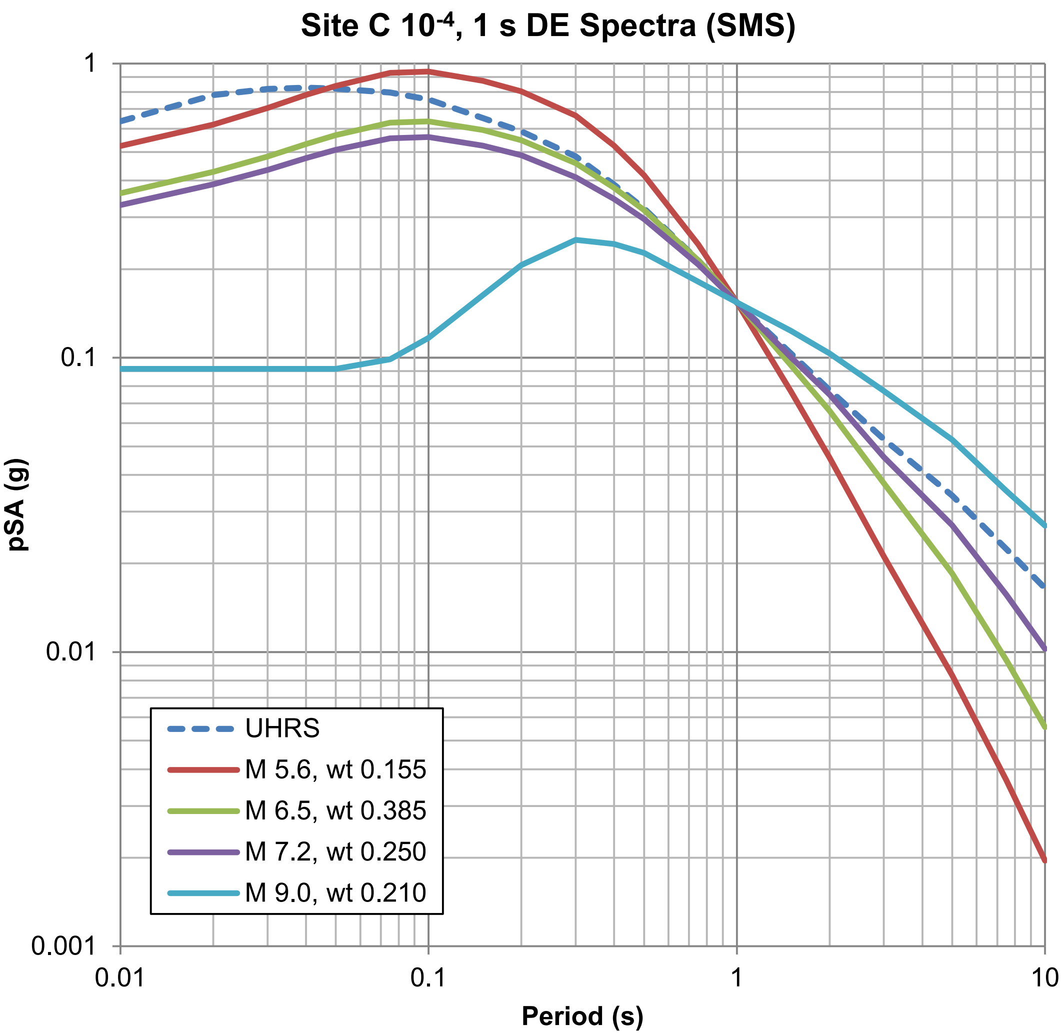

Figure J.2. Example DE SMS

Folder DESPEC.*X* contains individual sets of CMS and SMS for the 540 cases (27 return periods times values of *T**). The files are designated by T*xxx_afe*.*ext*, where *xxx* is the value of *T** as indicated in Table J.1, *afe* is the return period as indicated in Table J.2, and *ext* is either CMS or SMS indicating the type of DE spectra. Each file has a header record indicating the site, the AFE, the spectral period, and a table of data. The first line of the table indicates the DE scenario magnitude, the second line indicates the corresponding scenario rupture distance (in km), and the third line indicates the weight applied to the scenario, representing the contribution of earthquakes in the scenario magnitude range to the total mean hazard. Note that in many cases, the weight for some scenarios is zero. The remaining records list the pSA (5% damping) for each of the spectral periods listed in the first column.

It should be noted that the above set of spectra represent a somewhat maximum level of characterization of DE spectra to represent the hazard. The user may want to use fewer DE spectra, perhaps broadening them to cover the UHRS, as discussed in Carlton and Abrahamson (2014).

J.5 Randomized Dynamic Properties for Saddle Mountains Basalt Stack

Folder SM_Profiles.*X* contains the synthetic dynamic properties profiles for the Saddle Mountain Basalts (SMB). These files were generated by the Ground Motion Characterization Technical Integration Team to represent possible realizations of the SMB dynamical properties for the five sites considered. Details on the development of these profiles are contained in Section 9.6.4. These profiles, together with the dynamical models for the supra-basalt sediments (to be developed by others after site investigations are completed) and for the baserock, can be used in site-specific site-response studies to propagate ground motions from baserock to the surface.

J.5.1 File Structure and Naming Convention

The files are all written in comma-separated values (csv), and can be read and manipulated using Excel or opened as ASCII files. The file names take the form *Si*_Synth_Prof_*nn*.csv, using the following conventions:

- *S* represents the site (A through E)
- *i* represents the profile number (1 or 2; see Section 7.2.6 for details)
- *nn* represents the synthetic profile number (01 through 60). All 60 profiles are equally likely.

J.5.2 Detailed Description of File Contents

The organization of data within each file are similar (but not identical) to the "Options" 2 and 3 data in the SHAKE91 program (Idriss and Sun 1992). Each section of the file is separated from the previous section by one or more header lines containing textual descriptions. These portions are described below.

1. File header (1 line). Example: Site E - Profile 2 synthetic profile no. 27
2. Thickness of supra-basalt sediments. This section contains one line, in which the second column contains the randomized supra-basalt thickness (given in meters). This random value is based on the data contained in Table 9.21. This is the only information about the supra-basalt sediments provided in these files.
3. Stratigraphy and velocity of SMB column. Each row following the header row contains five columns the following information for one SMB layer:
    a. layer thickness(m)
    b. shear-wave velocity Vs (m/s)
    c. material density (gr/cc; not randomized)
    d. degradation curve number (see description below)
    e. layer description.
4. Degradation properties for all layers. This section contains one set of randomized degradation curves for each degradation curve number (column d) identified previously. These values are contained in three columns, as follows:

a. Percent strain. For linear materials, 2 values of strain are tabulated; for nonlinear materials, 21 values of strain are tabulated.

b. G/Gmax. This is the ratio of reduced-shear modulus to low-strain shear modulus.

c. Damping ratio. This is given as fraction of critical damping, not as a percentage. The maximum value allowed is 0.15.

J.6 References

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Baker J and N Jayaram. 2008. Correlation of spectral acceleration values from NGA ground motion models, *Earthquake Spectra*, v. 24, p. 299 – 317.

Carlton B and N Abrahamson. 2014. Issues and approaches for implementing conditional mean spectra in practice. *Bulletin of the Seismological Society of America*, v. 104, p. 503-512.

Idriss IM and JI Sun. 1992. *SHAKE91: A computer program for conducting equivalent linear seismic response analyses of horizontally layered soil deposits*. Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, California.

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