



1 **A Procedure to Select Earthquake Time Histories for Deterministic Seismic Hazard Analysis:**
2 **Case Studies of Major Cities in Taiwan**

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11 **Abstract:** In performance-based seismic design, ground-motion time histories are needed for analyzing
12 dynamic responses of nonlinear structural systems. However, the number of strong-motion data at
13 design level is often limited. In order to analyze seismic performance of structures, ground-motion time
14 histories need to be either selected from recorded strong-motion database, or numerically simulated
15 using stochastic approaches. In this paper, a detailed procedure to select proper acceleration time
16 histories from the Next Generation Attenuation (NGA) database for several cities in Taiwan is presented.
17 Target response spectra are initially determined based on a local ground motion prediction equation
18 under representative deterministic seismic hazard analyses. Then several suites of ground motions are
19 selected for these cities using the Design Ground Motion Library (DGML), a recently proposed
20 interactive ground-motion selection tool. The selected time histories are representatives of the regional
21 seismic hazard, and should be beneficial to earthquake studies when comprehensive seismic hazard
22 assessments and site investigations are yet available. Note that this method is also applicable to site-
23 specific motion selections with the target spectra near the ground surface considering the site effect.

24

25 **Keywords:** Ground motion selection, Seismic hazard analysis, NGA database, DGML tool



26 **1 Introduction**

27 In performance-based earthquake engineering, ground-motion time histories are usually needed for
28 analyzing the distribution of dynamic responses of nonlinear systems, such as site response or structural
29 analysis. In such an analysis, it is one of the key aspects to use appropriate acceleration time histories,
30 which should realistically reflect regional seismology and site conditions.

31 Understandably, the selected time histories should reasonably respond to seismic hazards at a given
32 site. For example, a recent technical guideline implemented by the U.S. Nuclear Regulatory
33 Commission (USNRC, 2007) prescribed the probabilistic seismic hazard analysis (PSHA) as the
34 underlying approach to generate time histories for future earthquake-resistant designs. Many studies
35 have highlighted the importance of matching a target response spectrum in the ground-motion selection
36 and modification process (e.g., Bommer and Acevedo, 2004). The target spectrum can be obtained by
37 deterministic seismic hazard analysis (DSHA), probabilistic seismic hazard analysis (PSHA) or seismic
38 design codes. A classic example is SIMQKE, which generates synthetic time histories to match a target
39 response spectrum with an iterative process using Gaussian random process and a time-varying
40 modulating function (Gasparini and Vanmarcke, 1976).

41 Recently, some scholars studied that a well-selected ground motion suite should match not only the
42 target mean, but also the variation of the target spectrum (Jayaram et al., 2011; Wang, 2011). In other
43 words, a suite of ground motions should be selected in performance-based earthquake engineering; the
44 resulting ground motion suite should properly capture the statistical distribution of ground motions
45 under the given earthquake scenario, which is commonly specified by means, standard deviations, and
46 inherent correlations (e.g., Baker and Jayaram, 2008; Wang and Du, 2012) of a target spectrum. There
47 are several ground motion selection algorithms available in the literature (Baker, 2010; Jayaram et al.,
48 2011; Wang, 2011). One of the recently proposed interactive tools is the Design Ground Motion Library
49 (DGML), which allows for selecting a suite of modified ground motions (multiple by scale factors) on
50 the basis of response spectral shape, as well as the characteristics of the recordings such as magnitude,
51 distances, faulting types and site conditions (Wang et al., 2015).

52 This paper aims at presenting a detailed procedure in selecting ground-motion time histories for
53 major cities of Taiwan using the DGML interactive tool. With deterministic seismic hazard analysis for



54 these cities, several suites of time histories are selected from the Pacific Earthquake Engineering
55 Research Center's Next Generation Attenuation (NGA) strong-motion database (Chiou et al., 2008).
56 Those selected motion suites are appropriate for general seismic designs, e.g., dynamic analysis of
57 structures in these cities.

58 **2 Deterministic Seismic Hazard Analyses (DSHA) for Major Cities in Taiwan**

59 **2.1 Overview of DSHA**

60 Seismic hazard analysis is an approach to describe the potential shaking intensity for future earthquakes,
61 which can be estimated by deterministic or probabilistic approaches. The deterministic approach
62 estimates the intensity measure amplitude (e.g., peak ground acceleration PGA as 0.2 g) under an
63 assigned earthquake scenario, while the probabilistic approach estimates the annual rate of exceeding
64 specific level of earthquake shaking at a site (e.g., PGA=0.2 g corresponding to 10% probability of
65 exceedance in 50 years).

66 Compared to the complicated probabilistic approach, DSHA is a logically simple and transparent
67 method. The purpose of DSHA is to use the maximum magnitude and shortest source-to-site distance to
68 evaluate the ground motion intensities under such a worse-case scenario. The basic steps are listed as
69 follows: (1) Identify all possible fault sources of earthquakes around a given site; (2) Define the
70 maximum magnitude and closest distance for each fault; (3) Compute the ground motion intensities
71 based on attenuation relationships; (4) Take the maximum intensity amplitudes as the final DSHA
72 estimate. Figure 1 shows a schematic diagram illustrating the framework and the algorithm for DSHA.
73 Seismic source models, the maximum earthquake of each source, and ground motion prediction
74 equations (GMPEs) are key inputs for DSHA. The detailed source models and GMPEs used in this
75 study would be introduced in this following subsection.

76 **2.2 Seismic source model and ground-motion model**

77 Figures 2 and 3 show the up-to-date seismic source models for Taiwan (Cheng et al., 2007), which have
78 also been used in a few seismic hazard studies by several authors (Cheng et al., 2007; Wang and Huang,
79 2014). It includes 20 area sources, in addition to 49 line sources associated with each active fault on



80 this island. Table 1 summarizes the best-estimated maximum magnitude for each source from the
81 literature (Cheng et al., 2007). With those best estimates, the response spectra for major cities in Taiwan
82 are also presented in this section with DSHA calculations.

83 Ground motion prediction equations (GMPEs) are commonly used to predict ground motion
84 intensities (e.g., PGA) as a function of earthquake magnitude, source-to-site distance, site parameters,
85 etc. A few regional GMPEs models have been developed based on local strong-motion data in Taiwan
86 (Cheng et al., 2007; Lin et al., 2011). Specifically, the recent GMPE developed by Lin et al. (2011) is
87 capable of predicting PGA and response spectra for periods ranging from 0.01 s to 5 s, and therefore it
88 is adopted in this study, to develop the target response spectra for selecting earthquake time histories.

89 The function form of the adopted model (Lin et al. 2011) is expressed as follows:

90
$$\ln Y = c_1 + c_2 M_w + c_3 \ln(R + c_4 e^{c_5 M_w}) \quad \sigma_{\ln Y} = \sigma^* \quad (1)$$

91 where Y denotes PGA or spectral accelerations in unit of g ; M_w refers to moment magnitude; R is the
92 rupture distance (closest distance from the rupture surface to site) in km ; c_1 to c_5 are regressed
93 coefficients. The model's coefficients are summarized in Table 2, and $\sigma_{\ln Y}$ denotes the model's standard
94 deviation. It is noted that this model was developed using around 5,000 earthquake records, 98% of
95 which are taken from Taiwan. Therefore, the attenuation model should provide more realistic ground
96 motion estimates in Taiwan (Lin et al., 2011), making it appropriate to construct the target response
97 spectra.

98 It is also worth noting that we only employ the local ground motion model in this study. It is
99 understood that logic-tree analyses can be used to quantify the so-called epistemic uncertainty in PSHA.
100 But as studied by some scholars (e.g., Krinitzsky, 2003), the weights in logic-tree analyses cannot be
101 scientifically verified. Therefore, this study used one local model available as the best estimate. When
102 new local models are developed, the update of seismic hazards or sensitivity analyses will be worth
103 conducting in future.

104

105

106 **2.3 DSHA-based response spectra for major cities in Taiwan**



107 The aforementioned DSHA procedures can be performed for major cities in Taiwan, with the adopted
108 seismic source models (Figures 2 and 3) and attenuation relationship introduced in previous subsections.
109 Six major cities are chosen for such calculations, and coordinates of the study cities (i.e., the city's
110 geographical centers) are summarized in Table 3. For each site or city, the worse-case scenario was
111 firstly identified, and then the corresponding response spectrum was determined by using the adopted
112 local GMPE.

113 Figure 4 shows the resulting response spectra from DSHA calculations for the six considered cities
114 in Taiwan. Table 3 also summarizes the controlling seismic source for each site. For example, the
115 DSHA seismic hazard at the center of Taipei is governed by Area Source C. In other words, the Area
116 Source C, rather than the other line sources or active faults, contributes to the deterministic seismic
117 hazard for the center of Taipei. The same situation is occurring to other cities with an area source being
118 the controlling source. This is expected, since the DSHA seismic hazard from an area source could be
119 commonly higher than a line source due to the relatively closer source-to-site distance.

120 It should be noted that the adopted local GMPE has been thoroughly compared with the globally
121 NGA GMPEs (Abrahamson and Silva, 2008; Boore and Atkinson, 2008; Campbell and Bozorgnia,
122 2008; Chiou and Youngs, 2008). In general, the PGA amplitudes predicted by the adopted model is
123 generally comparable to those of the NGA models, except that for scenarios with distances greater than
124 20 km the estimated PGAs of the local model attenuate faster. The steeper slope of the local attenuation
125 curves could be due to the fact that the local crust is relatively weak, given that Taiwan is a very young
126 orogeny (Lin et al., 2011). This implies that a design or target spectrum derived from local GMPEs is
127 particularly necessary for selecting suitable ground-motion time histories for local engineering practice.

128 **3 Selection of Ground-Motion Time Histories**

129 **3.1 The NGA database and Design Ground Motion Library (DGML)**

130 The source for ground-motion selection in this study is the PEER-NGA strong motion database, which
131 contains 3,551 three-component recordings from 173 earthquakes (Chiou et al., 2008). Various subsets
132 of the database have been used to develop GMPE models for various ground motion intensities in
133 earthquake engineering (e.g., Du and Wang, 2013; Foulser-Piggott and Stafford, 2012). Figure 5 shows



134 the moment magnitude-rupture distance distribution of the ground motions in the NGA database. The
135 aforementioned interactive tool, DGML, is used to search ground-motion time histories in the NGA
136 database on the basis of similarity of a record's response spectrum to the target response spectrum over
137 a use-defined range of period (Wang et al., 2015). The DGML has the broad capability of searching for
138 ground-motion time histories in the library database on the basis of response spectral shape,
139 characteristics of the recordings in terms of earthquake magnitude and type of faulting distance, site
140 characteristics, duration, and presence of velocity pulses in near-fault time histories.

141 To select appropriate ground motions by DGML, it is requested to specify the seismological
142 parameter bounds (e.g., range of considered M_w and distance R) as inputs, which can implicitly
143 constrain the ground motion characteristics in addition to the explicit target spectrum. Given the fact
144 that the target spectra from DSHA are a result of the maximum earthquake and the closest source-to-site
145 distance, a relatively large magnitude bound ($5.5 < M_w < 8$) and a narrow distance range ($0 \text{ km} < R_{\text{rup}} < 30$
146 km) have been employed as the searching criteria, as shown in Fig. 6. Since all the six cities are located
147 at soil sites, a V_{s30} (time-averaged shear-wave velocity down to 30 m) bound in the range of 0-450 m/s
148 is also applied. Other causal parameters, such as the category of fault types or the range of duration
149 parameters, are not particularly specified.

150 Scaling factor is another key input for selecting ground motions. In engineering practice, recorded
151 ground motions usually need to be up-scaled to the level of the target or design spectrum. It has been
152 studied that time histories scaled by an appropriate factor could lead to an acceptable response results
153 (Watson-Lamprey and Abrahamson, 2006). Yet, if an excessive range of scale factors is applied, the
154 selected ground motion suite might result in drastically biased distribution of the other ground motion
155 characteristics (e.g., duration parameters) that cannot be represented by the target response spectrum.
156 Therefore, a relative narrow range of scale factors (0.4-2.5) is applied in this selection procedure.

157 Figure 6 shows the interface of DGML while searching for properly matched time histories with
158 target spectrum and magnitude and distance thresholds. The ranking of earthquake motions is tabulated
159 after spectral matching process. The motions of interest can be downloaded from the list, as well as their
160 descriptions such as fault types, earthquake magnitudes, rupture distances, durations, scaling factors,
161 and V_{s30} values (V_{s30} is commonly employed site condition indicator). Note that DGML is also capable



162 of performing weight-matching when a specific range of the motion's frequencies is of more interest in
163 follow-up applications.

164 **3.2 Time history recommendations for major cities of Taiwan**

165 With the target spectra from DSHA calculations, the selection procedures in DGML are performed to
166 select a suite of time histories from the NGA database for each city. Figure 7 shows the selected
167 response spectra for the six study cities. The median and median \pm one standard deviation of the
168 selected SA ordinates are also compared to the target spectrum in each plot. It can be seen that the
169 selected ground motion suites can properly match the target spectra over a wide period range. Table 4
170 summarizes the time histories selected from the database. Figures 8-14 show the selected time histories
171 for the six cities in Taiwan with seismic hazards calculated with DSHA calculations. Note that two sets
172 of selections were given for Taipei, with and without the consideration of basin effect. It should also be
173 noted that for each site the best-matching motions were selected regardless of local earthquakes or not,
174 in addition to one or two best-matching local motion (i.e., the Chi-Chi earthquake). The multiple time
175 histories in each suite are considered as a measure to account for the variability or natural randomness
176 of ground motion characteristics under a considered scenario, which, for example, is considered as
177 mandatory for probabilistic site response analyses prescribed in a technical reference (USNRC, 2007).

178 **4 Discussions**

179 **4.1 DSHA versus PSHA**

180 PSHA and DSHA are the two representative approaches in assessing earthquake hazards. Over the past
181 decades, numerous seismic hazard studies have been conducted with the two methods (e.g., Joshi et al.,
182 2007; Kolathayar and Sitharam, 2012; Moratto et al., 2007; Sitharam and Vipin, 2011; Stirling et al.,
183 2011). The two methods have also been prescribed in various technical references. As mentioned
184 previously, a technical reference (USNRC, 2007) prescribes PSHA as the underlying approach, in
185 contrast to another guideline implemented by Department of California Transportation prescribing
186 DSHA for bridge designs under earthquake loadings (Mualchin, 2011).



187 It is worth noting that extensive discussions over the pros and cons of the two methods have been
188 reported in the literature (e.g., Bommer, 2003; Castanos and Lomnitz, 2002; Krinitzsky, 2003; Klugel,
189 2008). In general, DSHA is a simple approach that earthquake scenarios are considered logically
190 understandably, but the uncertainties in DSHA may not be well quantified. On the other hand, PSHA is
191 capable of quantifying the uncertainties associated with earthquake scenarios via a probabilistic
192 approach; however, some scholars (e.g., Krinitzsky, 2003) pointed out the shortcomings in PSHA, such
193 as the uniform assumption in the occurrences of earthquakes. It is not this paper's purpose to argue
194 which seismic hazard method is superior. But with all that in mind, it should come to a logical
195 understanding that both the deterministic and probabilistic analyses are needed and useful in
196 engineering applications. The use of the DSHA approach in this paper is mainly due to its analytical
197 simplicity and transparency. Since it has been reported that DSHA rather than PSHA is more
198 appropriate for design of critical structures (Bommer et al., 2000), the selected ground motion suites,
199 with a representative seismic hazard analysis and a reputable earthquake database, are then
200 recommended for such applications.

201 **4.2 Site-specific time histories**

202 This paper presents an option to select earthquake time histories from the reputable NGA database. But
203 strictly speaking, those time history recommendations are not site-specific, because the site condition is
204 not carefully taken into account with a comprehensive site investigations and site response analyses. In
205 other words, the site-specific motions are those from seismic hazard analyses, to site response studies
206 (e.g., Du and Pan, 2016).

207 As a result, this study refers to those time-history recommendations as “tentative site-specific,”
208 because the site effect is not comprehensively characterized with a more detailed site response analysis,
209 but with a soil-site ground motion prediction model. Therefore, the selected ground motion time-
210 histories could be recommended for general earthquake analytical cases, where specific site
211 investigations are not performed. Since the recommended time-histories can reasonably reflect the local
212 seismic hazards at these cities, they should be used as basic results and then be serviceable for common
213 engineering practice.



214 **4.3 Basin effect**

215 Basin effect is another important issue to estimate the seismic hazards for sites within Taipei. From
216 analyzing the recorded time histories around Taipei (Sokolov et al., 2009; 2010), some suggestions were
217 made to up-scale low-frequency spectral accelerations to incorporate the basin effect in Taipei.
218 Following this suggestion, Figure 15 shows the response spectra with/without considering basin effects
219 for Taipei by DSHA calculations. Likewise, the time histories matching the up-scaled spectra (with
220 basin effects) as the target are selected from the database, as summarized in Table 4.

221 **4.4 Why Chi-Chi earthquake's motions are not selected?**

222 It somewhat comes to as a surprise that the motions of the Chi-Chi earthquake were “out-performed” by
223 non-local motions in matching the response spectra with local ground motion models. This is might be
224 due to two reasons. First, the adopted local GMPE was developed with 42 earthquakes, 85% of which
225 are not associated with the Chi-Chi earthquake, its foreshocks and aftershocks (Lin et al., 2011).
226 Therefore, the influence of the Chi-Chi earthquake (or others) should not play a dominating role on the
227 model performance, given such a pool of data employed. Except the Chi-Chi earthquake, most events
228 used for developing the local GMPE are not included in the NGA database.

229 The second reason is that the employed searching process does not specify more weights or
230 preferences to local earthquakes. As discussed previously, the search criterion are only associated with
231 the spectral shape, as well as seismological parameters such as magnitude, distance, site condition, *etc.*
232 With this in mind, as long as the size of the database is sufficient, it is not surprising that a non-local
233 ground motion can be found better matching the target spectra. This could also be the reason that the
234 NGA database features the functionality to perform limited searching among selected earthquakes,
235 when local earthquakes are judged to be more suitable for an application.

236 **5 Conclusions**

237 The paper presented the procedures to select earthquake time histories with target response spectra from
238 deterministic seismic hazard analysis (DSHA), using the recently proposed DGML selection tool. The
239 worst-case earthquake scenarios were first defined for six major cities in Taiwan, and the response



240 target spectra were computed by employing a regional attenuation model under these defined scenarios.
241 Finally, a suite of time histories are selected for each city by matching the calculated target spectra. The
242 selected suites of time histories can properly represent the regional seismic hazards, which are then
243 recommended and used for seismic analyses in these cities. The similar ground motion selection
244 approaches can also be applicable to selecting appropriate time histories at bedrock layers, as input
245 motions for a more comprehensive site investigations and site response analysis.

246 Given the limited understandings of the earthquake process and the randomness in nature, some
247 scholars have pointed out the importance of analytical simplicity to earthquake studies. Among several
248 approaches to define the target spectra, the ones from DSHA calculations are logically transparent and
249 simple, and therefore they are adopted in this study for selecting hazard-consistent time histories.

250 **Acknowledgments**

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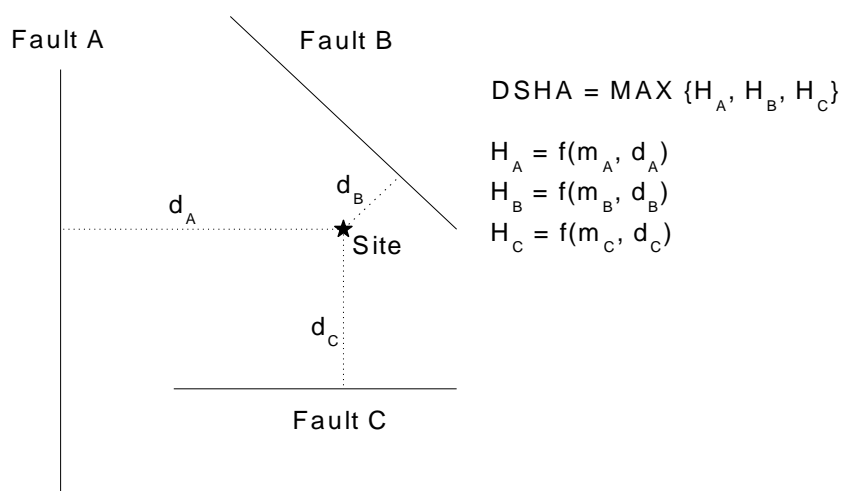


Figure 1. Schematic diagram illustrating the analytical framework of DSHA, where H denotes the seismic hazard induced by each source, m and d are the maximum earthquake magnitude and shortest source-to-site distance, and f is the function of a ground motion model

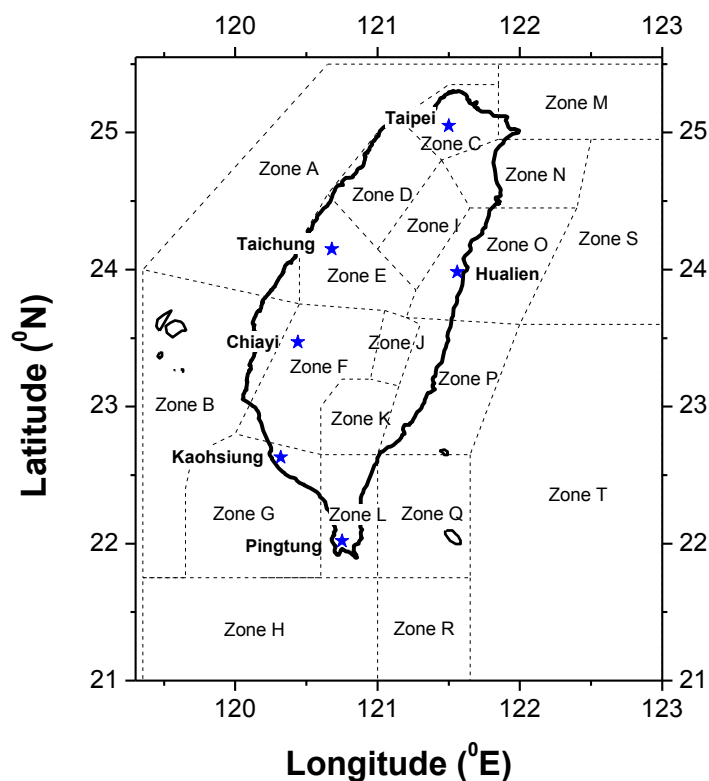


Figure 2. The area seismic source model for Taiwan (after Cheng et al., 2007)

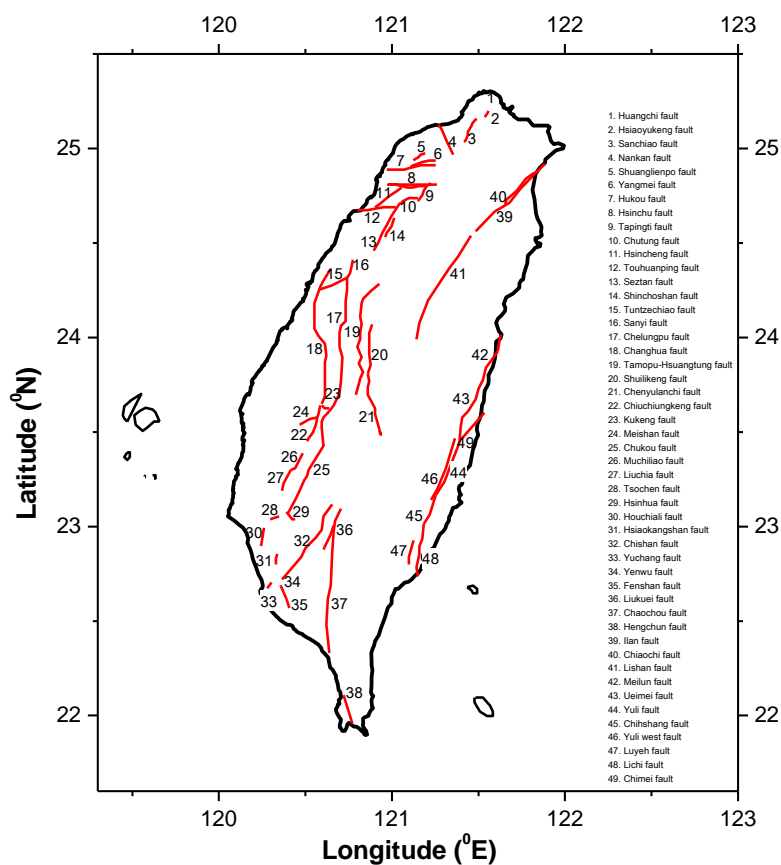


Figure 3. The line source model or the active faults in Taiwan (after Cheng et al., 2007)

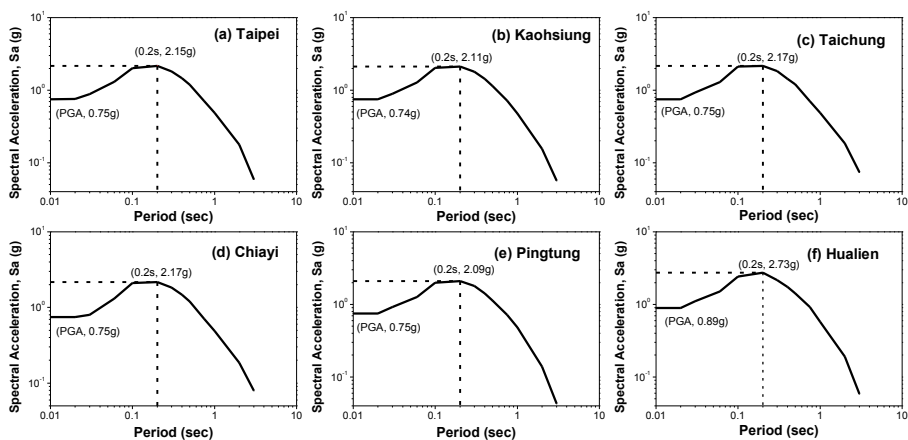


Figure 4. The response spectra for major cities in Taiwan with DSHA calculations

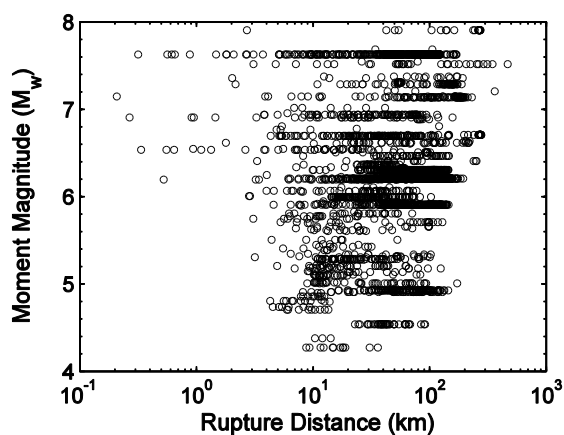


Figure 5. Moment magnitude and rupture distance distribution for PEER NGA records used in this study

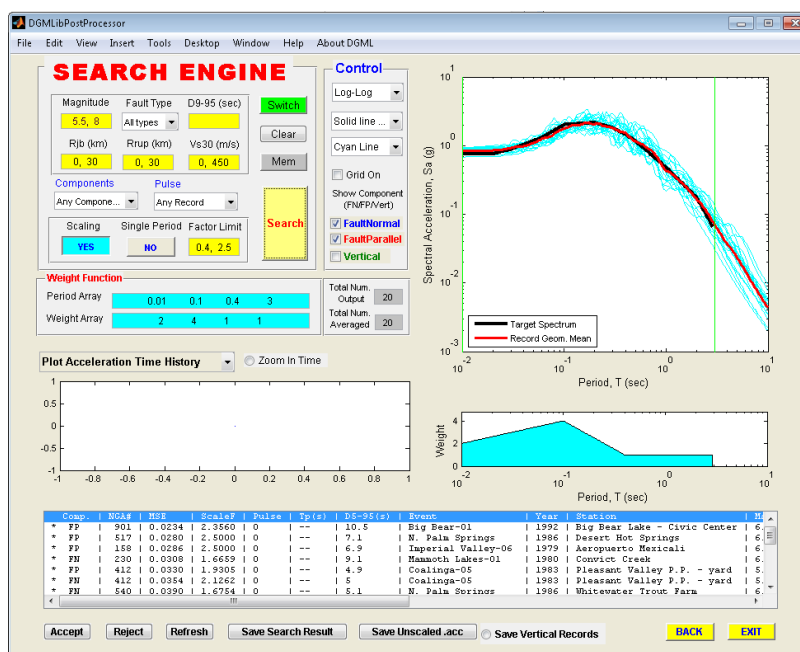


Figure 6. The screenshot of the database’s interface; with searching criteria as shown in the left, the properly matching motions are tabulated (not shown), and their response spectra are plotted in a graph along with the target spectra, shown in the right

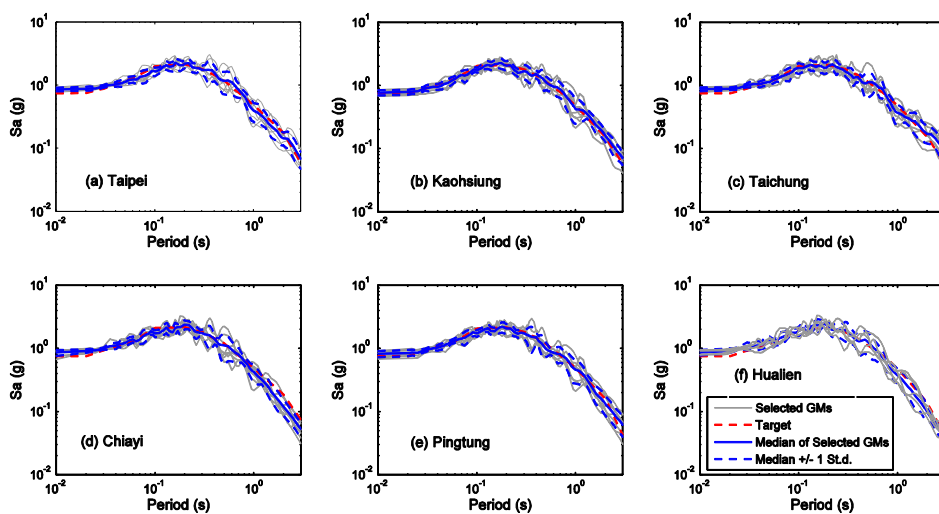


Figure 7. The target spectrum, individual and average response spectrum of selected records for six major cities in Taiwan

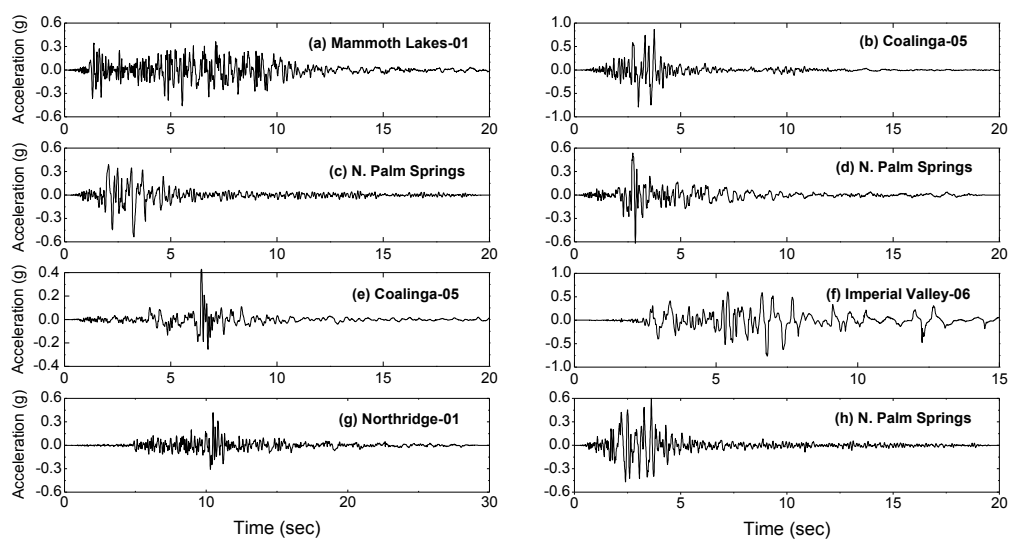


Figure 8. Eight time history recommendations for Taipei with DSHA calculations and the NGA strong-motion database

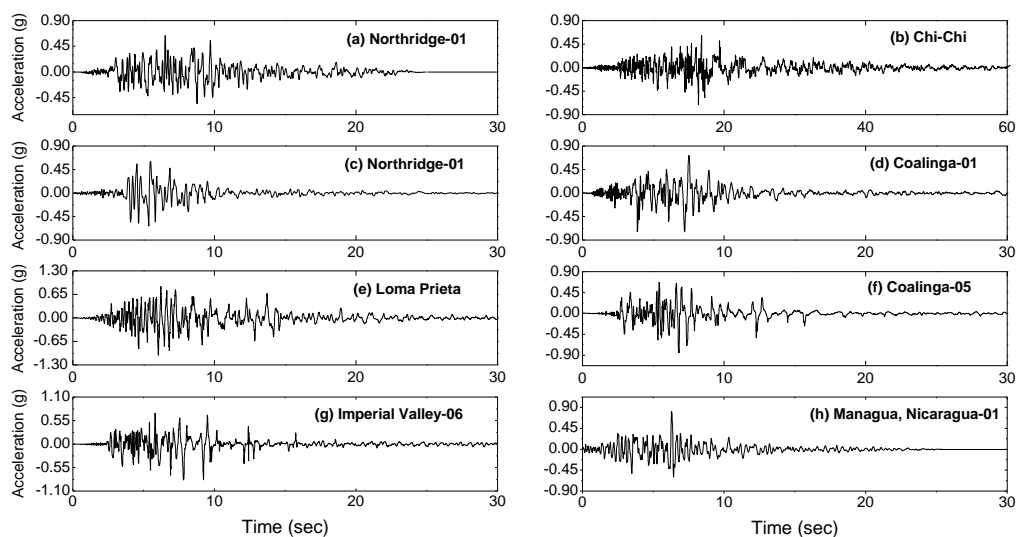


Figure 9. Another set of time history recommendations for Taipei with the basin effect taken into account

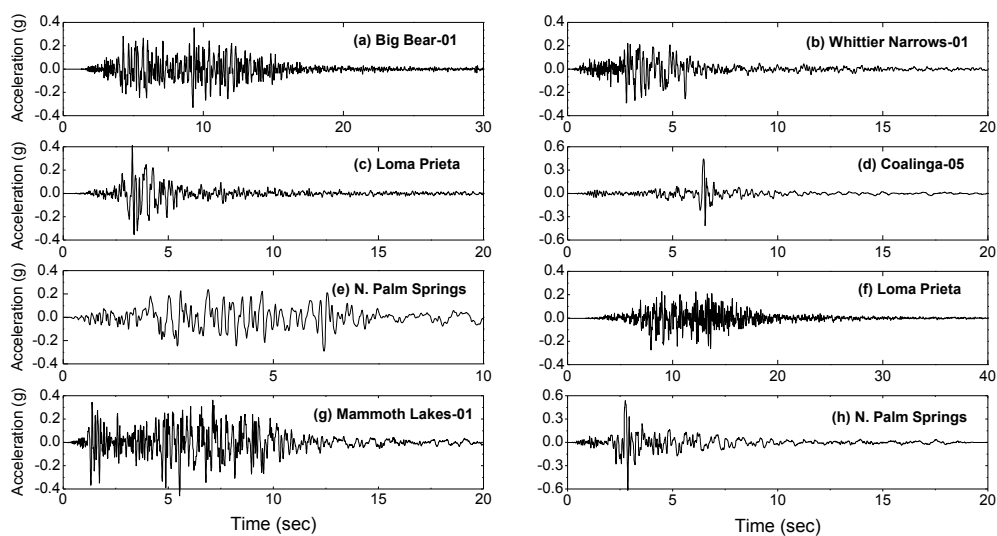


Figure 10. Eight time history recommendations for Kaohsiung with DSHA calculations and the NGA strong-motion database

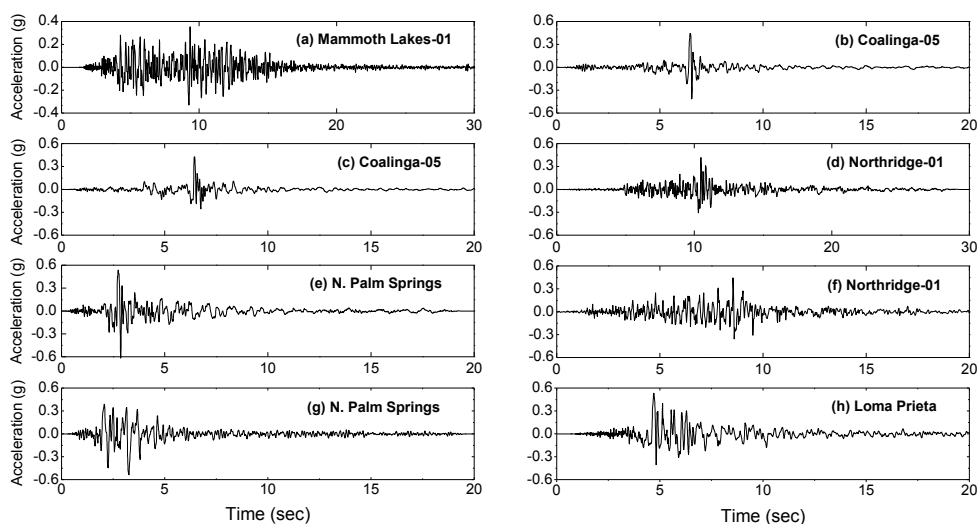


Figure 11. Eight time history recommendations for Taichung with DSHA calculations and the NGA strong-motion database

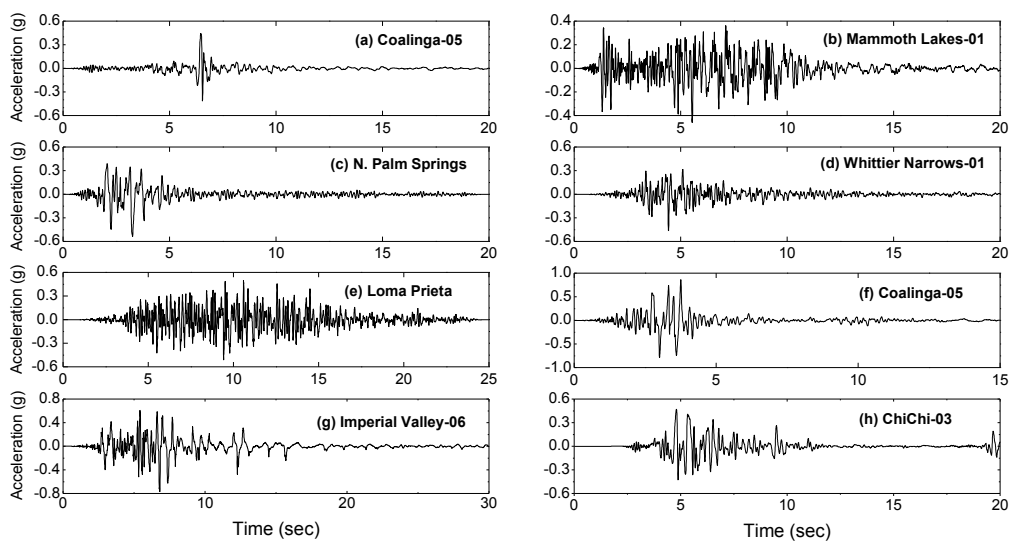


Figure 12. Eight time history recommendations for Chaiyi with DSHA calculations and the NGA strong-motion database

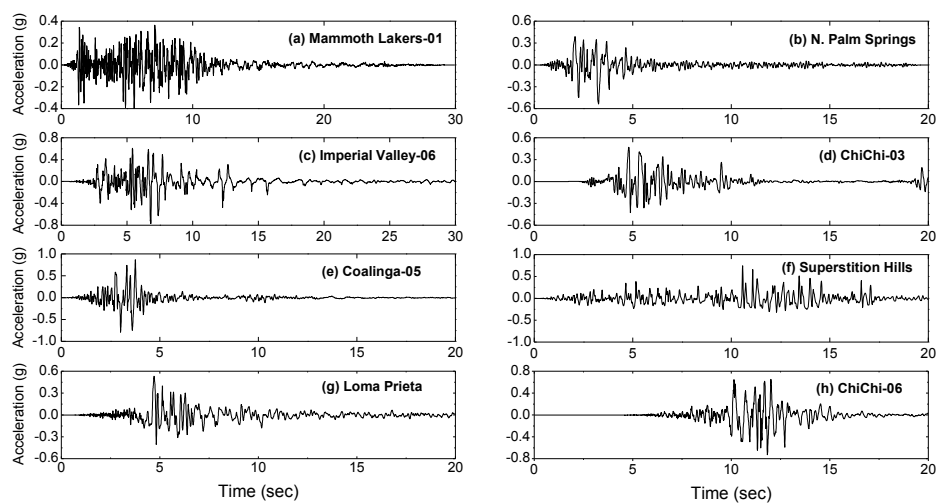


Figure 13. Eight time history recommendations for Hualien with DSHA calculations and the NGA strong-motion database

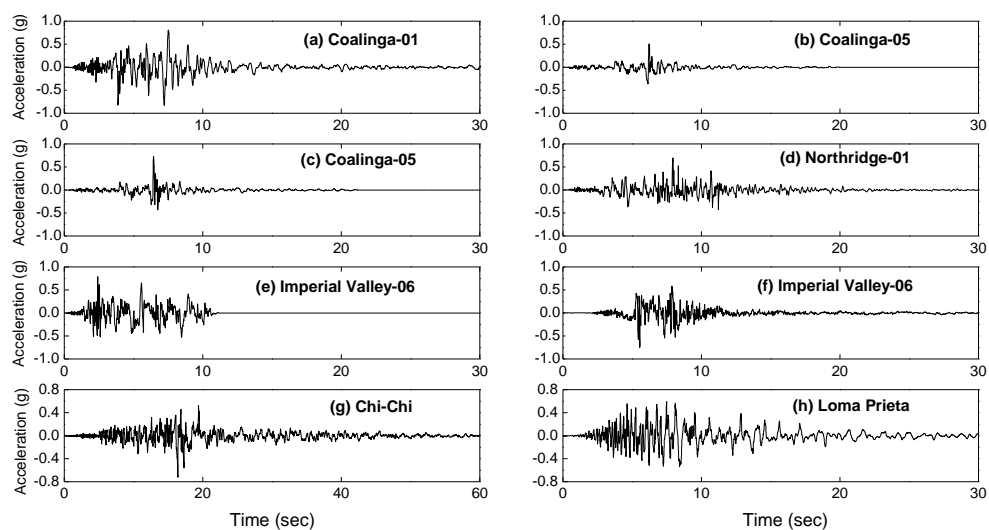


Figure 14. Eight time history recommendations for Pingtung with DSHA calculations and the NGA strong-motion database

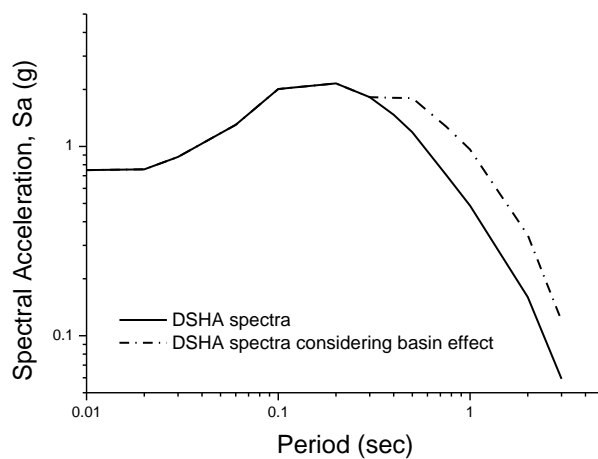


Figure 15. The basin effect in Taipei on response spectra; the spectra scaling follows the suggestions of Solokov et al. (2009, 2010)



Table 1. Summary of Maximum Earthquake Magnitudes (in M_w) of Each Seismic Source around Taiwan

Area source	Max. magnitude	Line source (active fault)	Max. magnitude	Line source (active fault)	Max. magnitude	Line source (active fault)	Max. magnitude
Zone A	6.5	Huangchi	7.0	Chenyulanchi	7.0	Lishan	6.9
Zone B	6.5	Hsiaoyukeng	7.0	Chiuchiungkeng	7.0	Meilun	7.3
Zone C	7.1	Sanchiao	7.0	Kukeng	6.3	Ueimei	7.5
Zone D	7.3	Nankan	6.5	Meishan	6.5	Yuli	7.5
Zone E	7.3	Shuanglienpo	6.2	Chukou	7.5	Chihshang	7.3
Zone F	7.3	Yangmei	6.6	Muchiliao	7.1	Yuli west	7.3
Zone G	6.5	Hukou	6.9	Liuchia	7.1	Luyeh	6.9
Zone H	7.3	Hsinchu	6.8	Tsochen	6.4	Lichi	7.1
Zone I	6.5	Tapingti	6.5	Hsinhua	6.4	Chimei	7.2
Zone J	6.5	Chutung	6.5	Houchiali	6.4		
Zone K	6.5	Hsincheng	6.7	Hsiaokangshan	6.5		
Zone L	7.3	Touhuanping	6.7	Chishan	7.3		
Zone M	6.5	Seztan	6.8	Yuchang	6.4		
Zone N	8.0	Shinchoshan	6.5	Yenwu	6.7		
Zone O	8.3	Tuntzechiao	6.5	Fenshan	6.7		
Zone P	7.8	Sanyi	6.9	Liukuei	6.7		
Zone Q	7.8	Cheitungpu	7.7	Chaochou	7.3		
Zone R	7.8	Changhua	7.6	Hengchun	7.2		
Zone S	8.0	T-H*	7.4	Ilan	6.9		
Zone T	7.8	Shuilikeng	7.0	Chiaochi	6.8		

* T-H: the Tamopu-Hsuangtung Fault



Table 2. Summary of the Coefficients of the Local Ground Motion Models used in This Study (Lin et al. 2011)

Periods (sec)	c_1	c_2	c_3	c_4	c_5	σ_{lnY}
PGA	-3.248	0.943	-1.471	0.1	0.648	0.628
0.01	-3.008	0.905	-1.451	0.11	0.638	0.623
0.06	-1.994	0.809	-1.5	0.251	0.518	0.686
0.09	-1.408	0.765	-1.551	0.28	0.51	0.709
0.1	-1.508	0.785	-1.551	0.28	0.5	0.713
0.2	-3.226	0.87	-1.211	0.045	0.708	0.687
0.3	-4.05	0.999	-1.205	0.03	0.788	0.657
0.4	-5.293	1.165	-1.167	0.011	0.958	0.655
0.5	-6.307	1.291	-1.134	0.0042	1.118	0.653
0.6	-7.209	1.395	-1.099	0.0016	1.258	0.642
0.75	-8.309	1.509	-1.044	0.0006	1.408	0.651
1	-9.868	1.691	-1.004	0.0004	1.485	0.677
2	-12.806	2.005	-0.975	0.0005	1.528	0.759
3	-13.886	2.099	-1.077	0.0004	1.548	0.787



Table 3. Summary of the Site's Coordinates, along with Respective Controlling Seismic Sources for Each Site in DSHA Computations

City	Latitude (° N)	Longitude (° E)	Controlling source	Maximum magnitude
Taipei	25.05	121.50	Zone C	7.1
Kaohsiung	22.63	120.32	Zone G	6.5
Taichung	24.15	120.68	Zone E	7.3
Chiayi	23.47	120.44	Zone F	7.3
Hualien	23.98	121.56	Zone O	8.3
Pingtung	22.02	120.75	Zone L	7.3



Table 4. Summary of the Earthquake Time History Recommendations from the NGA Database with DSHA Calculations

City	Earthquake motion	Year	Magnitude	Rupture Distance (km)	Station	Fault Mechanism	D_{s-95} (s)	V_{s30} (m/s)	Scale Factor
Taipei	Mammoth Lakes-01	1980	6.06	4.0	Convict Creek	N-O***	9.1	338	1.67
	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.-FP	Reverse	5.0	257	1.93
	N. Palm Springs	1986	6.06	6.0	Whitewater Trout Farm	R-O**	5.1	345	1.67
	N. Palm Springs	1986	6.06	11.2	North Palm Springs	R-O**	5.6	345	1.48
	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.-FN	Reverse	5.0	257	2.00
	Imperial Valley-06	1979	6.53	2.7	Bonds Corner	Reverse	9.7	223	1.05
	Northridge-01	1994	6.69	28.3	LA – Centinela St.	Reverse	13.0	235	0.98
	N. Palm Springs	1986	6.06	6.0	Whitewater Trout Farm	R-O**	5.1	345	1.52
Taipei (with basin effect)	Northridge-01	1994	6.69	14.7	Canoga Park	Reverse	11.1	268	0.50
	Chi-Chi	1999	7.62	10.0	CHY101	R-O**	29.0	259	1.16
	Northridge-01	1994	6.69	28.3	LA – Centinela St.	Reverse	13.0	235	0.98
	Coalinga-01	1983	6.36	8.4	Pleasant Valley P.P.	Reverse	8.0	257	1.32
	Loma Prieta	1989	6.93	15.2	Capitola	R-O**	14.7	289	1.50
	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.	Reverse	5.0	257	1.22
	Imperial Valley-06	1979	6.53	2.7	Bonds Corner	Strike-Slip	9.7	223	1.35
	M. - N.* -01	1972	6.24	4.1	Managua- ESSO	Strike-Slip	9.0	289	2.00
Kaohsiung	Big Bear-01	1992	6.46	9.4	Big Bear Lake	Strike-Slip	10.5	338	2.32
	Whittier Narrows-01	1987	5.99	14.5	Garvey Res	R-O**	5.9	468	2.49
	Loma Prieta	1989	6.93	10	Gilroy-Gavilan Coll	R-O**	4.7	729	2.04
	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.	Reverse	4.9	257	1.90
	N. Palm Springs	1986	6.06	6.8	Desert Hot Springs	R-O**	7.1	345	2.50
	Loma Prieta	1989	6.93	14.7	Santa Teresa Hills	R-O**	10	271	2.50
	Mammoth Lakes-01	1980	6.06	4	Convict Creek	N-O***	9.1	338	1.60
	N. Palm Springs	1986	6.06	11.2	North Palm Springs	R-O**	5.6	345	1.46



Table 4. Summary of the Earthquake Time History Recommendations from the NGA Database with DSHA Calculations (Continued-I)

City	Earthquake motion	Year	Magnitude	Rupture Distance (km)	Station	Fault Mechanism	D_{5-95} (s)	V_{s30} (m/s)	Scale Factor
Taichung	Mammoth Lakes-01	1980	6.06	6.6	Convict Creek	N-O**	9.1	338	1.69
	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.-FP	Reverse	4.9	257	1.96
	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.-FN	Reverse	5.0	257	1.99
	Northridge-01	1994	6.69	28.3	LA – Centinela St.	Reverse	11.9	235	1.99
	N. Palm Springs	1986	6.06	16.1	North Palm Springs	R-O**	5.6	345	1.51
	Northridge-01	1994	6.69	22.5	LA-UCLA	Reverse	9.4	398	2.00
	N. Palm Springs	1986	6.06	6.0	Whitewater Trout Farm	R-O**	25.8	345	1.70
	Loma Prieta***	1989	6.93	12.8	Gikroy Array #3	R-O**	7.7	349	1.63
Chiayi	Coalinga-05	1983	5.77	2.7	Pleasant Valley P.P	Reverse	4.9	257	1.92
	Mammoth Lakes-01	1980	6.06	6.6	Convict Creek	N-O**	9.1	338	1.66
	N. Palm Springs	1986	6.06	6.0	Whitewater Trout Farm	R-O**	5.1	345	1.67
	Whittier Narrows-01	1994	6.69	28.3	LA – Obregon Park	R-O**	7.8	349	2.00
	Loma Prieta	1989	6.93	17.5	WAHO	R-O**	11.1	376	1.30
	Coalinga-05***	1983	5.77	8.5	Oil City	Reverse	2.8	376	1.03
	Imperial Valley-06	1979	6.53	2.7	Bonds Corner	Reverse	9.7	223	1.04
	Chi-Chi-03	1989	6.2	7.6	TCU078	Reverse	6.7	443	1.66
Hualien	Mammoth Lakes-01	1980	6.06	6.6	Convict Creek	N-O**	9.1	338	2.01
	N. Palm Springs	1986	6.06	6.0	Whitewater Trout Farm	R-O**	5.1	345	2.00
	Imperial Valley-06	1979	6.53	2.7	Bonds Corner	Reverse	9.7	223	1.26
	Chi-Chi-03	1989	6.2	7.6	TCU078	Reverse	6.7	443	2.00
	Coalinga-05***	1983	5.77	8.5	Oil City	Reverse	2.8	376	1.24
	Superstition Hills-02	1987	6.54	5.6	Superstition Camera	Strike-Slip	12.1	362	1.53
	Loma Prieta***	1989	6.93	12.8	Gikroy Array #3	R-O**	7.7	349	1.92
	Chi-Chi-06	1989	6.3	10.1	TCU079	Reverse	4.0	443	1.28



Table 4. Summary of the Earthquake Time History Recommendations from the NGA Database with DSHA Calculations (Continued-II)

City	Earthquake motion	Year	Magnitude	Rupture Distance (km)	Station	Fault Mechanism	D ₅₋₉₅ (s)	V ₅₃₀ (m/s)	Scale Factor
	Imperial Valley-06	1979	6.53	0.3	Aeropuerto Mexicali	Strike-Slip	7.1	274	2.02
	Imperial Valley-06	1979	6.53	3.9	EL Centro Array #8	Strike-Slip	5.8	206	1.38
	Coalinga-01	1983	6.36	8.4	Pleasant Valley P.P.	Reverse	8.0	257	1.30
Pingtung	Coalinga-05	1983	5.77	16.1	Pleasant Valley P.P.	Reverse	5.0	257	1.50
	Coalinga-05	1983	5.77	23.5	Bonds Corner	Reverse	5.0	257	1.26
	Northridge-01	1994	6.69	15.6	Tarzana-Cedar Hill A	Reverse	10.3	257	2.00
	Chi-Chi	1999	7.62	10.0	CHY101	R-O**	29.0	258	1.59
	Loma Prieta	1989	6.93	15.2	Capitola	R-O**	14.7	288	1.43

1. * M. - N. = Managua – Nicaragua
2. R-O** = Reverse – oblique
3. N-O** = Normal – oblique
4. *** refers to pulse-like record