

GROUND MOTION MAPS

How To Obtain the Basic Values



Instructional Materials Complementing *FEMA 451, Design Examples*

Ground Motion Maps 5b - 1

This series of slides would not normally be used as is but rather to develop a Group Exercise that shows how to use the USGS website to retrieve certain ground motion data from the USGS website (see Slide 9 in this set).

Seismic Ground Motions

- 1 **Determine basic values from maps for bedrock conditions**
- 2, 3 Classify soil conditions at site and determine site coefficients
- 4 Determine site-adjusted values
- 4 Take two-thirds for use in design
- 5 Construct design response spectrum
- 7 Site-specific studies permitted/required



Instructional Materials Complementing *FEMA 451, Design Examples*

Ground Motion Maps 5b - 2

This lesson focuses on the first step: getting the basic values from the maps. Subsequent lessons will cover the other steps.

Mapped Acceleration Parameters

- Two sets of maps; acceleration parameter is in units of gravity
- S_S for spectral response acceleration at 0.2 sec
- S_1 for spectral response acceleration at 1.0 sec
- Shortcut to Seismic Design Category A:
 - $S_S < 0.15$ and $S_1 < 0.04$



Ground Motion Parameters & Seismic Hazard

Mapped Contours of S_S

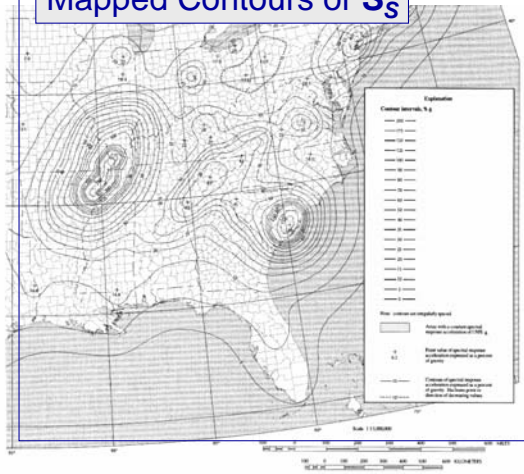


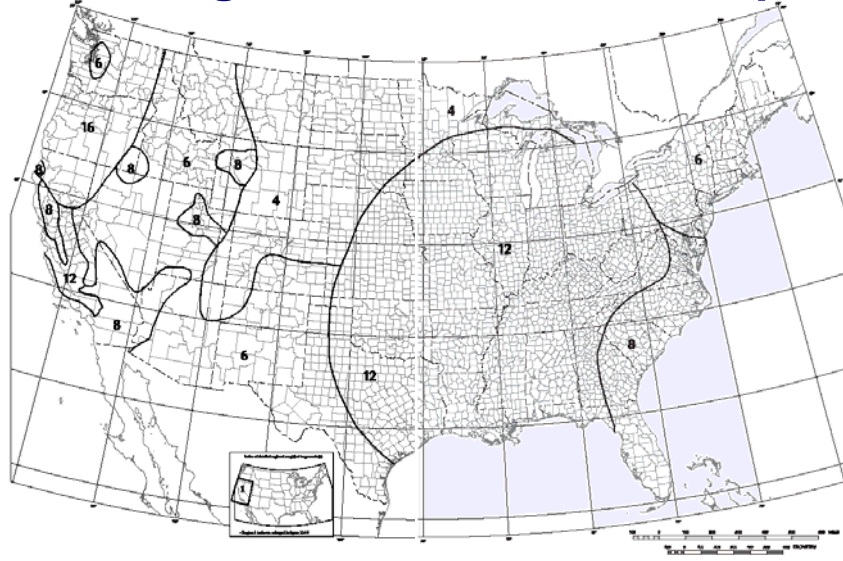
FIGURE 9.4.1.1(j) — continued
 MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION FOR
 CONTIGUOUS UNITED STATES, OF 0.2 g SPECTRAL RESPONSE
 ACCELERATION (5% OF CRITICAL DAMPING), SITE CLASS B

S_S and S_1 are the mapped 2% in 50 year spectral accelerations for firm rock

S_{DS} and S_{D1} are the design level spectral accelerations (modified for site and “expected good performance”)



Long-Period Transition Maps



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Ground Motion Maps 5b - 5

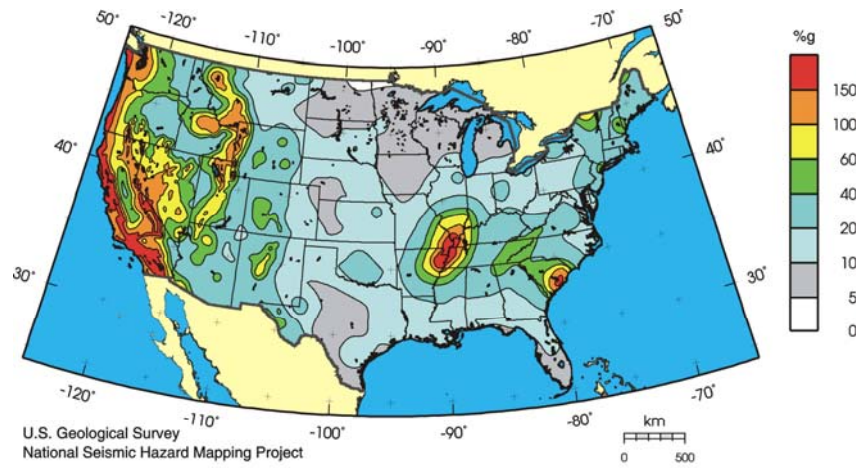
Location of Deterministic Areas



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Ground Motion Maps 5b - 6

Typical Probabilistic Map



S_s - 0.2 Spectral Response Acceleration



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Ground Motion Maps 5b - 7

The USGS probabilistic maps are generally rendered in color. But the MCE maps for use with codes are usually rendered in black and white.

CD vs Internet

- Internet
- CD
- Both sources give the same answers
- Both sources have a similar user interface
- The graphics are somewhat different



Internet Ground Motion Tool

<http://earthquake.usgs.gov/research/hazmaps/>



SEISMIC DESIGN VALUES FOR BUILDINGS

S_s and S_1 , Hazard Curves, Uniform Hazard Spectra, and Residential Design Category

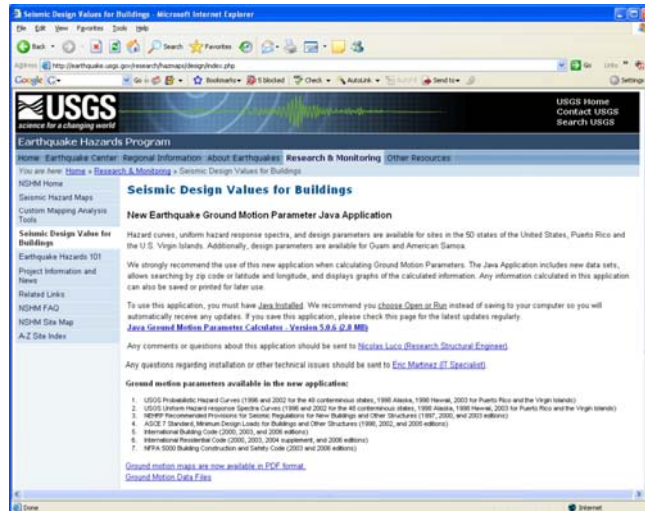


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Ground Motion Maps 5b - 9

Please note that the USGS is constantly changing its web-based tools, and the following slides may or may not reflect the current information on the web. Also, the web site shown above may not be current. Google “USGS Seismic Hazard Maps” to locate the latest information.

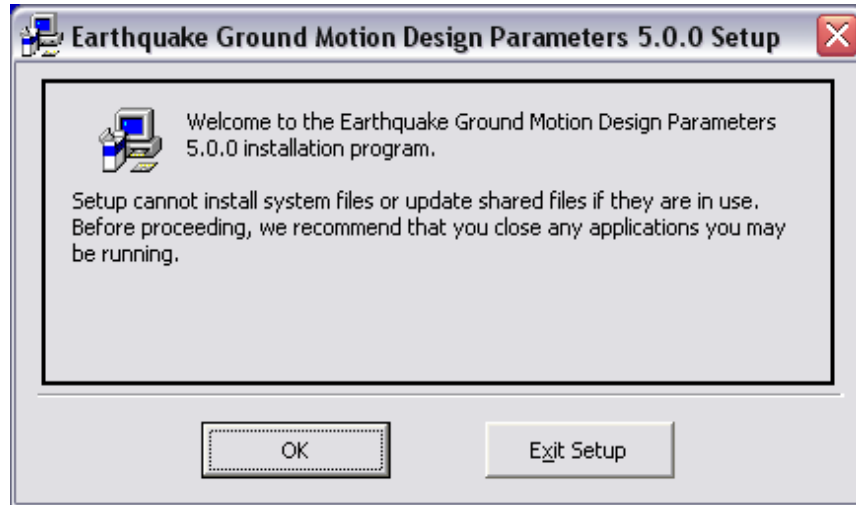
USGS Ground Motion Calculator



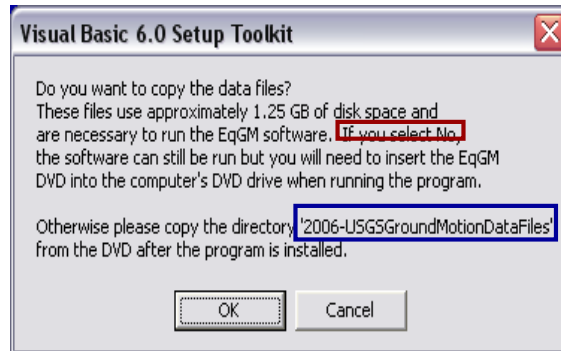
Instructional Materials Complementing *FEMA 451, Design Examples*

Ground Motion Maps 5b - 10

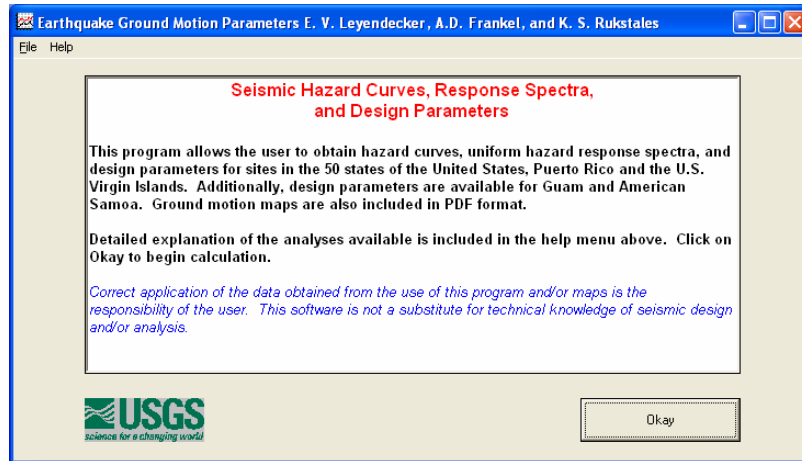
Installation



Installation Caution



Opening Screen



Analysis Options

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options | International Building Code

USGS Probabilistic Hazard Curves
USGS Uniform Hazard Response Spectra
NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures
International Building Code
International Residential Code
ASCE 7 Standard, Minimum Design Loads for Buildings and Other Structures
NFPA 5000 Building Construction and Safety Code

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

Latitude Longitude

(59.0 to 24.6) (-125.0 to -65.0)

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate Ss and S1 Calculate SM and SD Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Clear Output View Maps

Output for Calculations

Description



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 14

IBC Option

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code Description

Select Geographic Region

Conterminous 48 States

Select Edition

2006 International Building Code

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

Latitude Longitude

(50.0 to 24.6) (-125.0 to -65.0)

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate Ss and S1 Calculate SM and SD Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Clear Output View Maps



User Aids

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code Description

Select Geographic Region

Conterminous 48 States

Select Edition

2006 International Building Code

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

Latitude Longitude

(50.0 to 24.6) (-125.0 to -65.0)

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate Ss and S1 Calculate SM and SD Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Output for Calculations

Clear Output View Maps



Calculate S_s AND S_1

Earthquake Ground Motion Parameters

Project Name: Help

Analysis Options: International Building Code

Select Geographic Region
 Conterminous 48 States

Select Edition
 2006 International Building Code

Select Site Location - See Site Location Notes
 Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code: California 94111

Calculate Design Parameters
 Ground Motion Parameters: MCE Ground Motion

Calculate Ss and S1 **Calculate SM and SD Values**

Calculate Design Spectra
 Map Spectrum Site-Modified Spectrum
 Design Spectrum View Spectra

Output for Calculations

Conterminous 48 States
 2006 International Building Code
 Spectral Response Accelerations S_s and S_1
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 S_s and S_1 = Merged Spectral Acceleration Values
 Site Class B - $F_a = 1.00$, $F_v = 1.00$
 Data are based on a 0.01 deg grid spacing.

Period (sec)	Centroid S_a (g)	Maximum S_a (g)	Minimum S_a (g)
0.2	1.500 S_s , Site Class B	1.500 S_s , Site Class B	0.2
1.0	0.602 S_1 , Site Class B	0.614 S_1 , Site Class B	0.600 S_1 , Site Class B

Clear Output View Maps



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 17

Location By Zipcode

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code Description

Select Geographic Region
 Conterminous 48 States

Select Edition
 2006 International Building Code

Select Site Location - See Site Location Notes
 Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code California 94111

Calculate Design Parameters
 Ground Motion Parameters MCE Ground Motion

Calculate Ss and S1 Calculate SM and SD Values

Calculate Design Spectra
 Map Spectrum Site-Modified Spectrum
 Design Spectrum View Spectra

Output for Calculations

Conterminous 48 States
 2006 International Building Code
 Spectral Response Accelerations Ss and S1
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 Ss and S1 = Mapped Spectral Acceleration Values
 Site Class B - Fa = 1.00, Fv = 1.00
 Data are based on a 0.01 deg grid spacing.

Period (sec)	Centroid Sa (g)	Ss, Site Class B	S1, Site Class B
0.2	1.500	Ss, Site Class B	S1, Site Class B
1.0	0.602	Ss, Site Class B	S1, Site Class B

Period (sec)	Maximum Sa (g)	Ss, Site Class B	S1, Site Class B
0.2	1.500	Ss, Site Class B	S1, Site Class B
1.0	0.614	Ss, Site Class B	S1, Site Class B

Period (sec)	Minimum Sa (g)	Ss, Site Class B	S1, Site Class B
0.2	1.500	Ss, Site Class B	S1, Site Class B
1.0	0.600	Ss, Site Class B	S1, Site Class B

Clear Output View Maps



Calculate S_{MS} , S_{M1} , S_{DS} , S_{D1}

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code Description

Select Geographic Region

Conterminous 48 States

Select Edition

2006 International Building Code

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code California 94111

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate S_s and S_1 Calculate SM and SD Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Output for Calculations

Conterminous 48 States
 2006 International Building Code
 Spectral Response Accelerations S_s and S_1
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 S_s and S_1 = Mapped Spectral Acceleration Values
 Site Class B - $F_a = 1.00$, $F_v = 1.00$
 Data are based on a 0.01 deg grid spacing.

Period (sec)	Centroid S_a (g)		
0.2	1.500	S_s , Site Class B	
1.0	0.602	S_1 , Site Class B	

Period (sec)	Maximum S_a (g)		
0.2	1.500	S_s , Site Class B	
1.0	0.614	S_1 , Site Class B	

Period (sec)	Minimum S_a (g)		
0.2	1.500	S_s , Site Class B	
1.0	0.600	S_1 , Site Class B	

Clear Output View Maps



Calculate Site Coefficients

Site Coefficients
✕

Soil Factors as a Function of Site Class and Spectral Accelerations

Values of F_a as a Function of Site Class and 0.2 sec MCE Spectral Acceleration

Site Class	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	a	a	a	a	a

Values of F_v as a Function of Site Class and 1.0 sec MCE Spectral Acceleration

Site Class	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	a	a	a	a	a

Notes:

Use straight-line interpolation for intermediate values of S_a and S_1 .

Note a: Site-specific geotechnical investigation and dynamic site response analyses shall be performed.

Calculate Site Coefficient

Spectral Accelerations

S_s, g	S_1, g
1.500	0.602

Site Class

- Site Class A
- Site Class B
- Site Class C
- Site Class D
- Site Class E
- Site Class F

Discussion

Site Coefficients

Interpolated soil factors for the conditions shown. Values may also be entered manually.

Fa 1.00	Fv 1.50
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OK



S_{MS} , S_{M1} , S_{DS} , S_{D1} Values

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code

Select Geographic Region

Continous 48 States

Select Edition

2006 International Building Code

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code California 94111

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate S_s and S_1 Calculate S_M and S_D Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Output for Calculations

2006 International Building Code
Spectral Response Accelerations S_M s and S_{M1}
State - California
Zip Code - 94111
Zip Code Latitude = 37.798300
Zip Code Longitude = -122.400000
 S_M s = $F_a S_s$ and S_{M1} = $F_v S_1$
Site Class D - $F_a = 1.00$, $F_v = 1.50$
Data are based on a 0.01 deg grid spacing.

Period	S_s	S_M	Site Class
(sec)	(g)		
0.2	1.500	S_M s, Site Class D	
1.0	0.903	S_{M1} , Site Class D	

Continous 48 States
2006 International Building Code
Spectral Response Accelerations S_D s and S_{D1}
State - California
Zip Code - 94111
Zip Code Latitude = 37.798300
Zip Code Longitude = -122.400000
 S_D s = $2/3 \times S_M$ s and S_{D1} = $2/3 \times S_{M1}$
Site Class D - $F_a = 1.00$, $F_v = 1.50$
Data are based on a 0.01 deg grid spacing.

Period	S_s	S_D s	Site Class
(sec)	(g)		
0.2	1.000	S_D s, Site Class D	
1.0	0.602	S_{D1} , Site Class D	

Clear Output View Maps



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 21

Calculate MCE Spectrum

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code Description

Select Geographic Region

Conterminous 48 States

Select Edition

2006 International Building Code

Select Site Location -See Site Location Notes

Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code California 94111

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate Ss and S1 Calculate SM and SD Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Output for Calculations

Conterminous 48 States
 2006 International Building Code
 Map Response Spectra for Site Class B
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 Ss and S1 = Mapped Spectral Acceleration Values
 Site Class B - Fa = 1.00, Fv = 1.00
 Data are based on a 0.01 deg grid spacing.

Period	Sa	Sd
(sec)	(g)	in.
0.000	0.600	0.000
0.080	1.500	0.094
0.200	1.500	0.586
0.401	1.500	2.360
0.500	1.204	2.940
0.600	1.003	3.528
0.700	0.860	4.117
0.800	0.752	4.705
0.900	0.669	5.293
1.000	0.602	5.881
1.100	0.547	6.469
1.200	0.502	7.057
1.300	0.463	7.645
1.400	0.430	8.233
1.500	0.401	8.821
1.600	0.376	9.409
1.700	0.354	9.997
1.800	0.334	10.585

Clear Output View Maps



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 22

Calculate S_M Spectrum

Output for Calculations

Conterminous 48 States
 2006 International Building Code
 Site Modified Response Spectra for Site Class D
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 SMs = FaSs and SM1 = FvS1
 Site Class D - Fa = 1.00, Fv = 1.50
 Data are based on a 0.01 deg grid spacing.

Period (sec)	Sa (g)	Sd (in.)
0.000	0.800	0.000
0.120	1.500	0.212
0.200	1.500	0.586
0.602	1.500	5.310
0.700	1.290	6.175
0.800	1.129	7.057
0.900	1.003	7.939
1.000	0.903	8.821
1.100	0.821	9.703
1.200	0.752	10.585
1.300	0.695	11.468
1.400	0.645	12.350
1.500	0.602	13.232
1.600	0.564	14.114
1.700	0.531	14.996
1.800	0.502	15.878
1.900	0.475	16.760
2.000	0.451	17.642



Calculate S_D Spectrum

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options International Building Code

Select Geographic Region

Conterminous 48 States

Select Edition

2006 International Building Code

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code California 94111

Calculate Design Parameters

Ground Motion Parameters MCE Ground Motion

Calculate S_s and S_1 Calculate SM and SD Values

Calculate Design Spectra

Map Spectrum Site-Modified Spectrum

Design Spectrum View Spectra

Output for Calculations

Conterminous 48 States
 2006 International Building Code
 Design Response Spectra for Site Class D
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 $S_Ds = 2/3 \times S_Ms$ and $S_{D1} = 2/3 \times S_{M1}$
 Site Class D - $F_a = 1.00$, $F_v = 1.50$
 Data are based on a 0.01 deg grid spacing.

Period	S_s	S_d
(sec)	(g)	in.
0.000	0.400	0.000
0.120	1.000	0.142
0.200	1.000	0.391
0.602	1.000	3.540
0.700	0.860	4.117
0.800	0.752	4.705
0.900	0.689	5.293
1.000	0.602	5.881
1.100	0.547	6.469
1.200	0.502	7.057
1.300	0.463	7.645
1.400	0.430	8.233
1.500	0.401	8.821
1.600	0.376	9.409
1.700	0.354	9.997
1.800	0.334	10.585
1.900	0.317	11.174

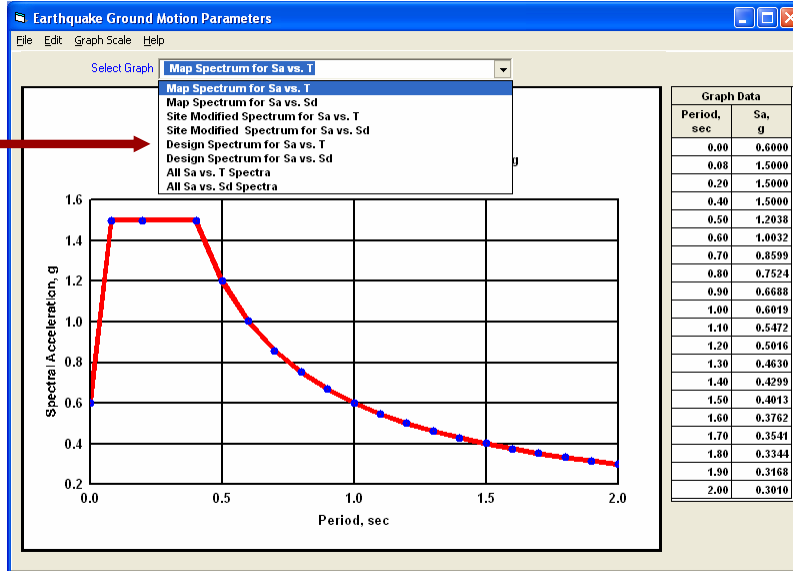
Clear Output View Maps



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 24

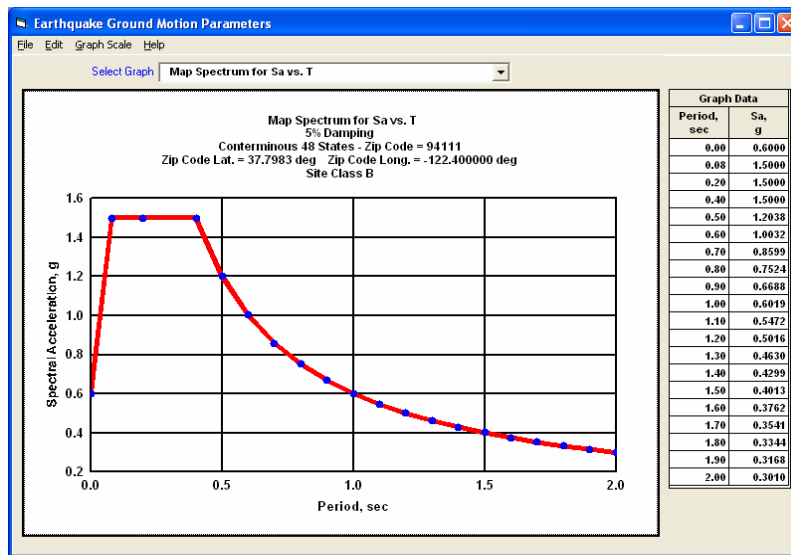
Graphic Options



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 25

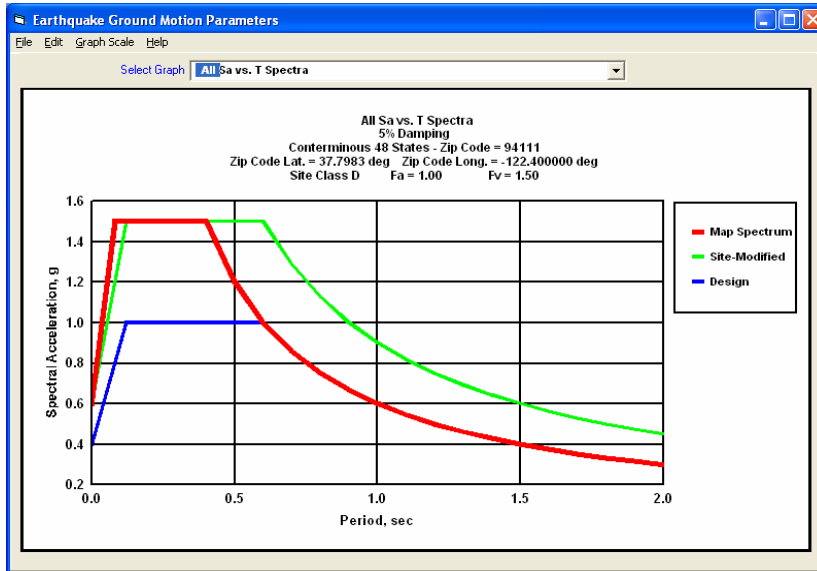
Map Spectrum: $S_a - T$



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 26

All Spectra: $S_a - T$



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 27

Calculate Hazard Curves

Earthquake Ground Motion Parameters

File Project Name Help

Analysis Options ▾ USGS Probabilistic Hazard Curves Description

Select Geographic Region

Conterminous 48 States

Select Edition

2002 Data

Select Site Location - See Site Location Notes

Latitude-Longitude : Recommended Zip Code

5-Digit Zip Code California 94111

Hazard Curve

Ground Motion Parameters Peak Ground Acceleration

Calculate View

Single Hazard Values

PE and Exp. Time Return Period

Prob. of Exceedance (%) 2 Exp. Time (Years) 30

Calculate

Output for Calculations

Peak Ground Acceleration
 State - California
 Zip Code - 94111
 Zip Code Latitude = 37.798300
 Zip Code Longitude = -122.400000
 B/C Boundary

Data are based on a 0.05 deg grid spacing.
 Frequency of Exceedance values less than 10E-4 should be used with caution.

Ground Motion (g)	Frequency of Exceedance (per year)
0.0050	4.644E-01
0.0070	4.151E-01
0.0098	3.557E-01
0.0137	2.898E-01
0.0192	2.234E-01
0.0269	1.637E-01
0.0376	1.157E-01
0.0527	7.956E-02
0.0738	5.427E-02
0.1030	3.681E-02
0.1450	2.408E-02
0.2030	1.496E-02
0.2840	8.207E-03
0.3970	3.587E-03
0.5560	1.117E-03
0.7780	2.292E-04
1.0900	2.862E-05

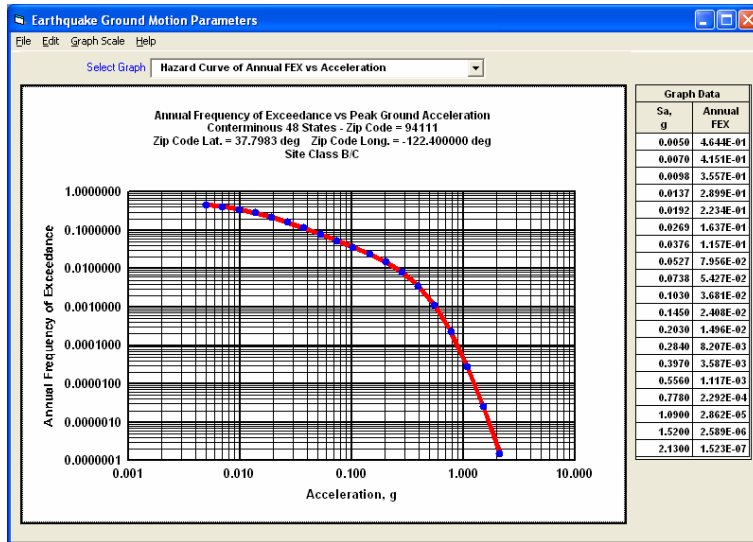
Clear Output View Maps



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 28

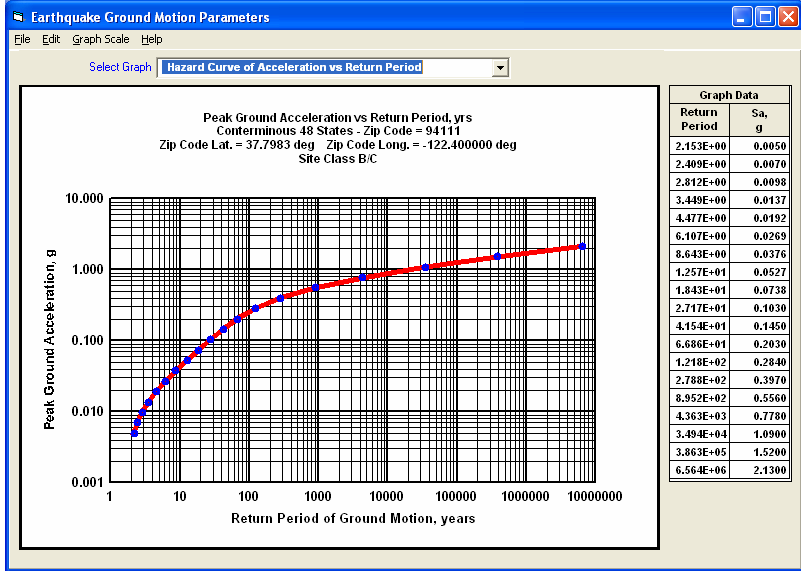
Annual Frequency of Exceedance



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 29

Return Period



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 30

Single Values

Earthquake Ground Motion Parameters

Analysis Options: USGS Probabilistic Hazard Curves

Select Geographic Region: Conterminous 48 States

Select Edition: 2002 Data

Select Site Location - See Site Location Notes

Latitude-Longitude: Recommended | Zip Code

5-Digit Zip Code: California | 94111

Hazard Curve: Peak Ground Acceleration

Calculate

Single Hazard Values

PE and Exp. Time | Return Period

Prob. of Exceedance (%): 10 | Exp. Time (Years): 30

Calculate

Output for Calculations

Ground Motion of Exceedance (g)	Frequency (per year)	Return Period (years)	Exp. Time (years)
0.0050	4.844E-01		
0.0070	4.151E-01		
0.0098	3.557E-01		
0.0137	2.899E-01		
0.0192	2.234E-01		
0.0269	1.637E-01		
0.0376	1.157E-01		
0.0527	7.956E-02		
0.0738	5.427E-02		
0.1030	3.681E-02		
0.1450	2.408E-02		
0.2030	1.496E-02		
0.2840	8.207E-03		
0.3970	3.587E-03		
0.5580	1.117E-03		
0.7780	2.292E-04		
1.0900	2.862E-05		
1.5200	2.589E-06		
2.1300	1.523E-07		

Ground Motion of Exceedance (g) | Frequency (per year) | Return Period (years) | Exp. Time (years)

0.4634 | 2.100E-03 | 0476 | 10.0 | 50

Clear Output | View Maps

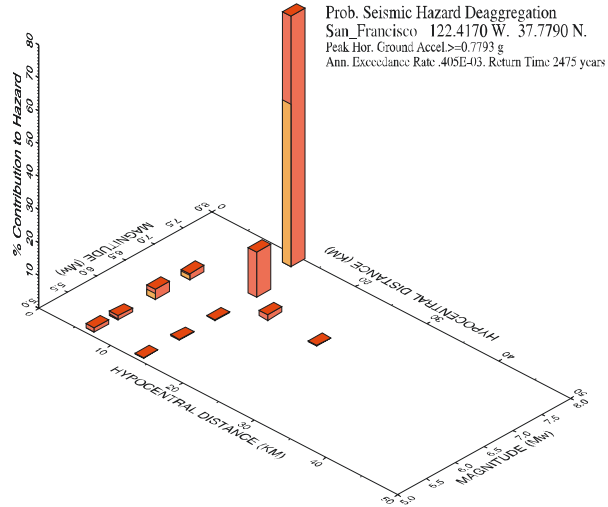


Deaggregation

- Breaking apart of the probabilistic hazard analysis
- Helps remove some of the “black box” effect
- Helps visualize the source of the hazard
- Many uses, e.g. liquefaction analysis, time history determination



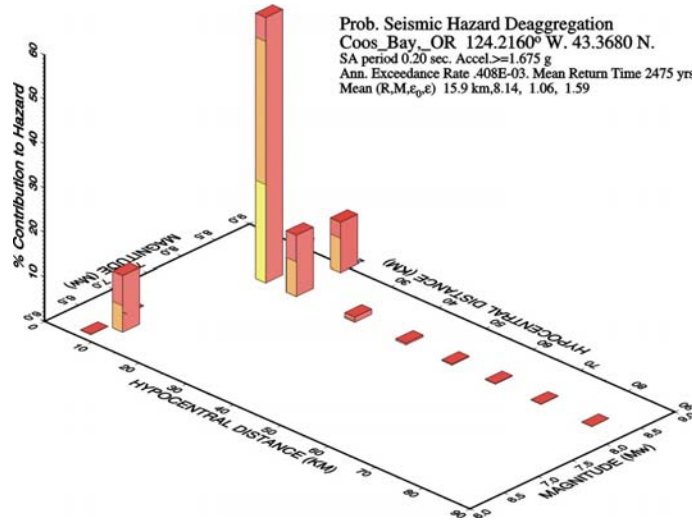
Deaggregation – San Francisco



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 33

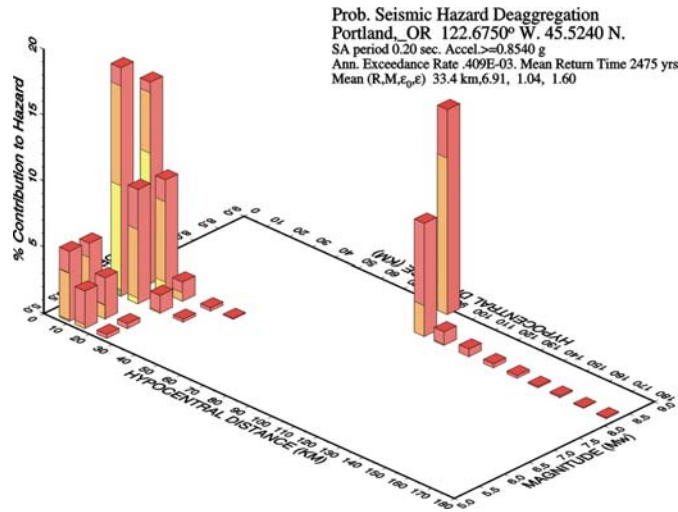
Deaggregation - Coos Bay, Oregon



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 34

Deaggregation - Portland, Oregon

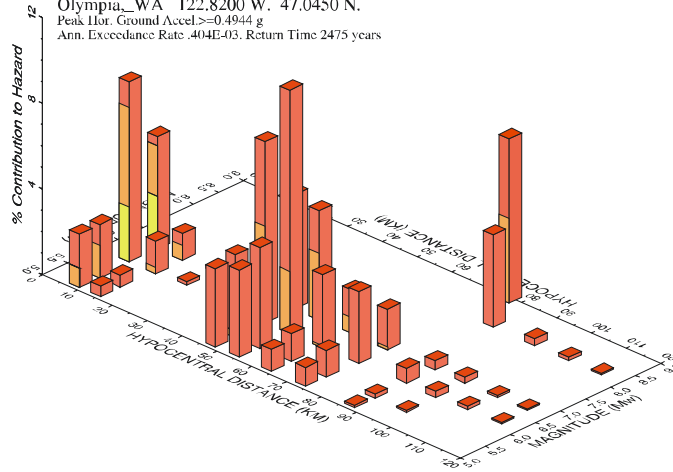


Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 35

Deaggregation – Olympia, Washington

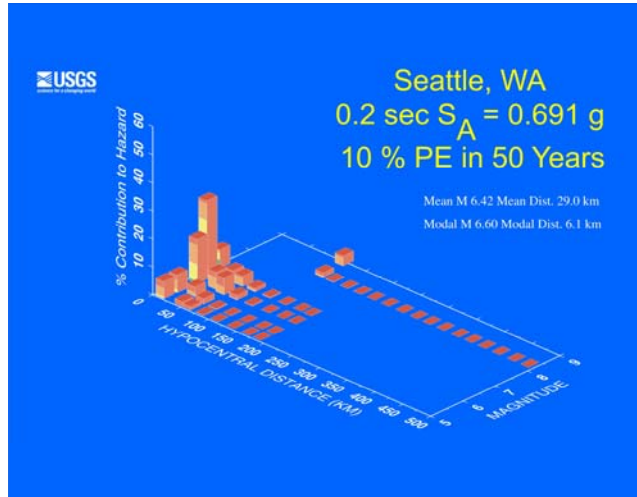
Prob. Seismic Hazard Deaggregation
 Olympia_WA 122.8200 W. 47.0450 N.
 Peak Hor. Ground Accel ≥ 0.4944 g
 Ann. Exceedance Rate .404E-03. Return Time 2475 years



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 36

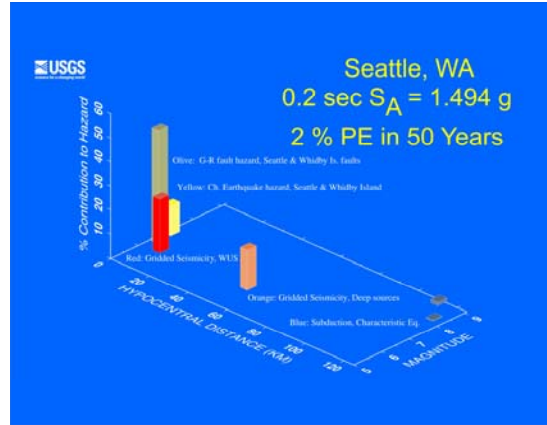
Seattle – 0.2 sec, Detailed



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 37

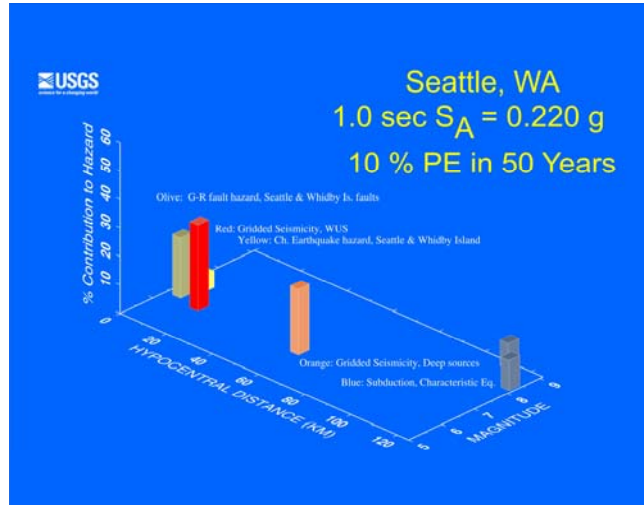
Seattle – 0.2 sec



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 38

Seattle – 1.0 sec



Instructional Materials Complementing FEMA 451, Design Examples

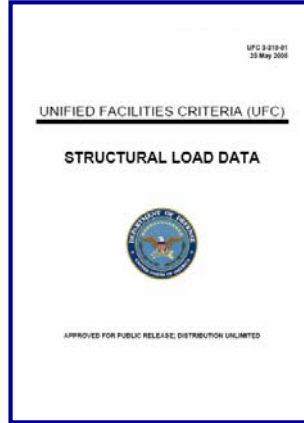
Ground Motion Maps 5b - 39

Design Values Outside the United States

- Based on GASHAP Data
- 10% PE in 50 years
- PGA only
- Estimate 2% from 10% PE by multiplying by 2.0
- $S_s = 2.5 \times \text{PGA}$
- $S_1 = \text{PGA}$
- Use site-specific studies where available
- USGS studies where available



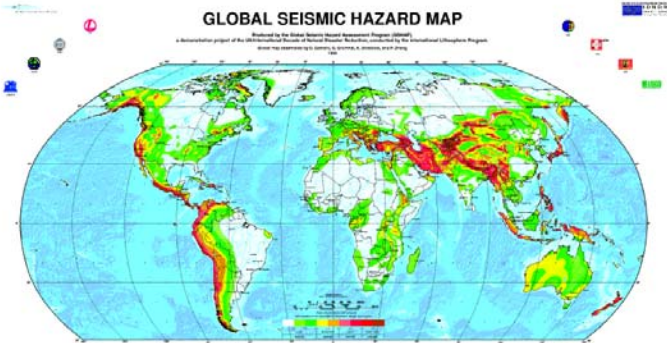
UFC 3-310-1



Instructional Materials Complementing *FEMA 451, Design Examples*

Ground Motion Maps 5b - 41

What is GSHAP?



Instructional Materials Complementing FEMA 451, Design Examples

Ground Motion Maps 5b - 42