ASCE STANDARD ASCE/SEI 7-05

Including Supplement No. 1

American Society of Civil Engineers

# Minimum Design Loads for Buildings and Other Structures

This document uses both the International System of Units (SI) and customary units.

ASCE

SEI
Structural Engineering Institute
of the American Society of Civil Engineers

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$\delta_{xe}$ = deflection of Level $x$ at the center of the mass at and above Level $x$ determined by an elastic analysis, Section 12.8-6

$\delta_{xm}$ = modal deflection of Level $x$ at the center of the mass at and above Level $x$ as determined by Section 19.3.2

$\tilde{\delta}_x, \tilde{\delta}_{x1}$ = deflection of Level $x$ at the center of the mass at and above Level $x$, Eqs. 19.2-13 and 19.3-3 (in. or mm)

$\theta$ = stability coefficient for $P$-delta effects as determined in Section 12.8.7

$\rho$ = a redundancy factor based on the extent of structural redundancy present in a building as defined in Section 12.3.4

$\rho_s$ = spiral reinforcement ratio for precast, prestressed piles in Sections 14.2.7.1.6 and 14.2.7.2.6

$\lambda$ = time effect factor

$\Omega_0$ = overstrength factor as defined in Tables 12.2-1, 5.4-1, and 15.3-1

## 11.4 SEISMIC GROUND MOTION VALUES

**11.4.1 Mapped Acceleration Parameters.** The parameters $S_S$ and $S_1$ shall be determined from the 0.2 and 1.0 s spectral response accelerations shown on Figs. 22-1 through 22-14, respectively. Where $S_1$, is less than or equal to 0.04 and $S_S$ is less than or equal to 0.15, the structure is permitted to be assigned to Seismic Design Category A and is only required to comply with Section 11.7.

**11.4.2 Site Class.** Based on the site soil properties, the site shall be classified as Site Class A, B, C, D, E, or F in accordance with Chapter 20. Where the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the authority having jurisdiction or geotechnical data determines Site Class E or F soils are present at the site.

**11.4.3 Site Coefficients and Adjusted Maximum Considered Earthquake (MCE) Spectral Response Acceleration Parameters.** The MCE spectral response acceleration for short periods ($S_{MS}$) and at 1 s ($S_{M1}$), adjusted for Site Class effects, shall be determined by Eqs. 11.4-1 and 11.4-2, respectively.

$$S_{MS} = F_a S_s \quad (11.4\text{-}1)$$

$$S_{M1} = F_v S_1 \quad (11.4\text{-}2)$$

where

$S_S$ = the mapped MCE spectral response acceleration at short periods as determined in accordance with Section 11.4.1, and

$S_1$ = the mapped MCE spectral response acceleration at a period of 1 s as determined in accordance with Section 11.4.1

where site coefficients $F_a$ and $F_v$ are defined in Tables 11.4-1 and 11.4-2, respectively. Where the simplified design procedure of Section 12.14 is used, the value of $F_a$ shall be determined in accordance with Section 12.14.8.1, and the values for $F_v$, $S_{MS}$, and $S_{M1}$ need not be determined.

**TABLE 11.4-1 SITE COEFFICIENT, $F_a$**

| Site Class | Mapped Maximum Considered Earthquake Spectral Response Acceleration Parameter at Short Period | | | | |
|---|---|---|---|---|---|
| | $S_S \le 0.25$ | $S_S = 0.5$ | $S_S = 0.75$ | $S_S = 1.0$ | $S_S \ge 1.25$ |
| 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 | See Section 11.4.7 | | | | |

NOTE: Use straight-line interpolation for intermediate values of $S_S$.

**TABLE 11.4-2 SITE COEFFICIENT, $F_v$**

| Site Class | Mapped Maximum Considered Earthquake Spectral Response Acceleration Parameter at 1-s Period | | | | |
|---|---|---|---|---|---|
| | $S_1 \le 0.1$ | $S_1 = 0.2$ | $S_1 = 0.3$ | $S_1 = 0.4$ | $S_1 \ge 0.5$ |
| 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 | See Section 11.4.7 | | | | |

NOTE: Use straight-line interpolation for intermediate values of $S_1$.

**11.4.4 Design Spectral Acceleration Parameters.** Design earthquake spectral response acceleration parameter at short period, $S_{DS}$, and at 1 s period, $S_{D1}$, shall be determined from Eqs. 11.4-3 and 11.4-4, respectively. Where the alternate simplified design procedure of Section 12.14 is used, the value of $S_{DS}$ shall be determined in accordance with Section 12.14.8.1, and the value for $S_{D1}$ need not be determined.

$$S_{DS} = \frac{2}{3} S_{MS} \quad (11.4\text{-}3)$$

$$S_{D1} = \frac{2}{3} S_{M1} \quad (11.4\text{-}4)$$

**11.4.5 Design Response Spectrum.** Where a design response spectrum is required by this standard and site-specific ground motion procedures are not used, the design response spectrum curve shall be developed as indicated in Fig. 11.4-1 and as follows:

1. For periods less than $T_0$, the design spectral response acceleration, $S_a$, shall be taken as given by Eq. 11.4-5:

$$S_a = S_{DS}\left(0.4 + 0.6\frac{T}{T_0}\right) \quad (11.4\text{-}5)$$

2. For periods greater than or equal to $T_0$ and less than or equal to $T_S$, the design spectral response acceleration, $S_a$, shall be taken equal to $S_{DS}$.

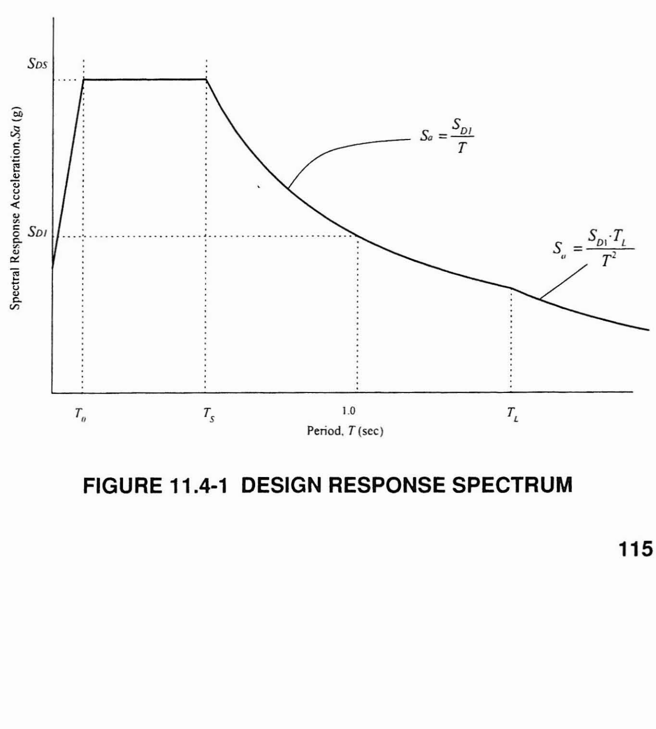



FIGURE 11.4-1 DESIGN RESPONSE SPECTRUM

3. For periods greater than $T_S$, and less than or equal to $T_L$, the design spectral response acceleration, $S_a$, shall be taken as given by Eq. 11.4-6:

$$S_a = \frac{S_{D1}}{T} \quad (11.4\text{-}6)$$

4. For periods greater than $T_L$, $S_a$ shall be taken as given by Eq. 11.4-7:

$$S_a = \frac{S_{D1} T_L}{T^2} \quad (11.4\text{-}7)$$

where

$S_{DS}$ = the design spectral response acceleration parameter at short periods

$S_{D1}$ = the design spectral response acceleration parameter at 1-s period

$T$ = the fundamental period of the structure, s

$T_0 = 0.2\frac{S_{D1}}{S_{DS}}$

$T_S = \frac{S_{D1}}{S_{DS}}$ and

$T_L$ = long-period transition period (s) shown in Fig. 22-15 (Conterminous United States), Fig. 22-16 (Region 1), Fig. 22-17 (Alaska), Fig. 22-18 (Hawaii), Fig. 22-19 (Puerto Rico, Culebra, Vieques, St. Thomas, St. John, and St. Croix), and Fig. 22-20 (Guam and Tutuila).

**11.4.6 MCE Response Spectrum.** Where a MCE response spectrum is required, it shall be determined by multiplying the design response spectrum by 1.5.

**11.4.7 Site-Specific Ground Motion Procedures.** The site-specific ground motion procedures set forth in Chapter 21 are permitted to be used to determine ground motions for any structure. A site response analysis shall be performed in accordance with Section 21.1 for structures on Site Class F sites, unless the exception to Section 20.3.1 is applicable. For seismically isolated structures and for structures with damping systems on sites with $S_1$ greater than or equal to 0.6, a ground motion hazard analysis shall be performed in accordance with Section 21.2.

## 11.5 IMPORTANCE FACTOR AND OCCUPANCY CATEGORY

**11.5.1 Importance Factor.** An importance factor, $I$, shall be assigned to each structure in accordance with Table 11.5-1 based on the Occupancy Category from Table 1-1.

**11.5.2 Protected Access for Occupancy Category IV.** Where operational access to an Occupancy Category IV structure is required through an adjacent structure, the adjacent structure shall conform to the requirements for Occupancy Category IV structures. Where operational access is less than 10 ft from an interior lot line or another structure on the same lot, protection from potential falling debris from adjacent structures shall be provided by the owner of the Occupancy Category IV structure.

**TABLE 11.5-1 IMPORTANCE FACTORS**

| Occupancy Category | $I$ |
|---|---|
| I or II | 1.0 |
| III | 1.25 |
| IV | 1.5 |

**TABLE 11.6-1 SEISMIC DESIGN CATEGORY BASED ON SHORT PERIOD RESPONSE ACCELERATION PARAMETER**

| Value of $S_{DS}$ | Occupancy Category | | |
|---|---|---|---|
| | I or II | III | IV |
| $S_{DS} < 0.167$ | A | A | A |
| $0.167 \le S_{DS} < 0.33$ | B | B | C |
| $0.33 \le S_{DS} < 0.50$ | C | C | D |
| $0.50 \le S_{DS}$ | D | D | D |

## 11.6 SEISMIC DESIGN CATEGORY

Structures shall be assigned a Seismic Design Category in accordance with Section 11.6.1.1.

Occupancy Category I, II, or III structures located where the mapped spectral response acceleration parameter at 1-s period, $S_1$, is greater than or equal to 0.75 shall be assigned to Seismic Design Category E. Occupancy Category IV structures located where the mapped spectral response acceleration parameter at 1-s period, $S_1$, is greater than or equal to 0.75 shall be assigned to Seismic Design Category F. All other structures shall be assigned to a Seismic Design Category based on their Occupancy Category and the design spectral response acceleration parameters, $S_{DS}$ and $S_{D1}$, determined in accordance with Section 11.4.4. Each building and structure shall be assigned to the more severe Seismic Design Category in accordance with Table 11.6-1 or 11.6-2, irrespective of the fundamental period of vibration of the structure, $T$.

Where $S_1$ is less than 0.75, the Seismic Design Category is permitted to be determined from Table 11.6-1 alone where all of the following apply:

1. In each of the two orthogonal directions, the approximate fundamental period of the structure, $T_a$, determined in accordance with Section 12.8.2.1 is less than $0.8T_s$, where $T_s$ is determined in accordance with Section 11.4.5.
2. In each of two orthogonal directions, the fundamental period of the structure used to calculate the story drift is less than $T_s$.
3. Eq. 12.8-2 is used to determine the seismic response coefficient $C_s$.
4. The diaphragms are rigid as defined in Section 12.3.1 or for diaphragms that are flexible, the distance between vertical elements of the seismic force-resisting system does not exceed 40 ft.

Where the alternate simplified design procedure of Section 12.14 is used, the Seismic Design Category is permitted to be determined from Table 11.6-1 alone, using the value of $S_{DS}$ determined in Section 12.14.8.1.

## 11.7 DESIGN REQUIREMENTS FOR SEISMIC DESIGN CATEGORY A

**11.7.1 Applicability of Seismic Requirements for Seismic Design Category A Structures.** Structures assigned to Seismic Design Category A need only comply with the requirements of

**TABLE 11.6-2 SEISMIC DESIGN CATEGORY BASED ON 1-S PERIOD RESPONSE ACCELERATION PARAMETER**

| Value of $S_{D1}$ | OCCUPANCY CATEGORY | | |
|---|---|---|---|
| | I or II | III | IV |
| $S_{D1} < 0.067$ | A | A | A |
| $0.067 \le S_{D1} < 0.133$ | B | B | C |
| $0.133 \le S_{D1} < 0.20$ | C | C | D |
| $0.20 \le S_{D1}$ | D | D | D |

# Chapter 20
# SITE CLASSIFICATION PROCEDURE FOR SEISMIC DESIGN

## 20.1 SITE CLASSIFICATION

The site soil shall be classified in accordance with Table 20.3-1 and Section 20.3 based on the upper 100 ft (30 m) of the site profile. Where site-specific data are not available to a depth of 100 ft, appropriate soil properties are permitted to be estimated by the registered design professional preparing the soil investigation report based on known geologic conditions. Where the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the authority having jurisdiction or geotechnical data determines Site Class E or F soils are present at the site. Site Classes A and B shall not be assigned to a site if there is more than 10 ft of soil between the rock surface and the bottom of the spread footing or mat foundation.

## 20.2 SITE RESPONSE ANALYSIS FOR SITE CLASS F SOIL

A site-response analysis in accordance with Section 21.1 shall be provided for Site Class F soils, unless the exception to Section 20.3.1 is applicable.

## 20.3 SITE CLASS DEFINITIONS

Site class types shall be assigned in accordance with the definitions provided in Table 20.3-1 and this section.

**20.3.1 Site Class F.** Where any of the following conditions is satisfied, the site shall be classified as Site Class F and a site response analysis in accordance with Section 21.1 shall be performed.

1. Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clays, and collapsible weakly cemented soils.

   **EXCEPTION:** For structures having fundamental periods of vibration equal to or less than 0.5 s, site-response analysis is not required to determine spectral accelerations for liquefiable soils. Rather, a site class is permitted to be determined in accordance with Section 20.3 and the corresponding values of $F_a$ and $F_v$ determined from Tables 11.4-1 and 11.4-2.

2. Peats and/or highly organic clays [$H > 10$ ft (3 m)] of peat and/or highly organic clay where $H$ = thickness of soil.
3. Very high plasticity clays [$H > 25$ ft (7.6 m) with $PI > 75$].
4. Very thick soft/medium stiff clays [$H > 120$ ft (37 m)] with $s_u < 1000$ psf (50 kPa).

**20.3.2 Soft Clay Site Class E.** Where a site does not qualify under the criteria for Site Class F, and there is a total thickness of soft clay greater than 10 ft (3 m) where a soft clay layer is defined by $s_u < 500$ psf (25 kPa), $w \geq 40$ percent, and $PI > 20$, it shall be classified as Site Class E.

**20.3.3 Site Classes C, D, and E.** The existence of Site Class C, D, and E soils shall be classified by using one of the following three methods with $\bar{v}_s$, $\bar{N}$, and $\bar{s}_u$ computed in all cases as specified in Section 20.4:

1. $\bar{v}_s$ for the top 100 ft (30 m) ($\bar{v}_s$ method).
2. $\bar{N}$ for the top 100 ft (30 m) ($\bar{N}$ method).
3. $\bar{N}_{ch}$ for cohesionless soil layers ($PI < 20$) in the top 100 ft (30 m) and $\bar{s}_u$ for cohesive soil layers ($PI > 20$) in the top 100 ft (30 m) ($\bar{s}_u$ method). Where the $\bar{N}_{ch}$ and $\bar{s}_u$ criteria differ, the site shall be assigned to the category with the softer soil.

**20.3.4 Shear Wave Velocity for Site Class B.** The shear wave velocity for rock, Site Class B, shall be either measured on site or estimated by a geotechnical engineer, engineering geologist, or seismologist for competent rock with moderate fracturing and weathering. Softer and more highly fractured and weathered rock shall either be measured on site for shear wave velocity or classified as Site Class C.

**20.3.5 Shear Wave Velocity for Site Class A.** The hard rock, Site Class A, category shall be supported by shear wave velocity measurement either on site or on profiles of the same rock type in the same formation with an equal or greater degree of weathering

**TABLE 20.3-1 SITE CLASSIFICATION**

| Site Class | $\bar{v}_s$ | $\bar{N}$ or $\bar{N}_{ch}$ | $\bar{s}_u$ |
|---|---|---|---|
| A. Hard rock | >5,000 ft/s | NA | NA |
| B. Rock | 2,500 to 5,000 ft/s | NA | NA |
| C. Very dense soil and soft rock | 1,200 to 2,500 ft/s | >50 | >2,000 psf |
| D. Stiff soil | 600 to 1,200 ft/s | 15 to 50 | 1,000 to 2,000 psf |
| E. Soft clay soil | <600 ft/s | <15 | <1,000 psf |
| | Any profile with more than 10 ft of soil having the following characteristics:<br>- Plasticity index PI > 20,<br>- Moisture content $w \geq 40\%$, and<br>- Undrained shear strength $\bar{s}_u < 500$ psf | | |
| F. Soils requiring site response analysis in accordance with Section 21.1 | See Section 20.3.1 | | |

For SI: 1 ft/s = 0.3048 m/s 1 lb/ft$^2$ = 0.0479 kN/m$^2$

and fracturing. Where hard rock conditions are known to be continuous to a depth of 100 ft (30 m), surficial shear wave velocity measurements are permitted to be extrapolated to assess $\bar{v}_s$.

## 20.4 DEFINITIONS OF SITE CLASS PARAMETERS

The definitions presented in this section shall apply to the upper 100 ft (30 m) of the site profile. Profiles containing distinct soil and rock layers shall be subdivided into those layers designated by a number that ranges from 1 to $n$ at the bottom where there are a total of $n$ distinct layers in the upper 100 ft (30 m). Where some of the $n$ layers are cohesive and others are not, $k$ is the number of cohesive layers and $m$ is the number of cohesionless layers. The symbol $i$ refers to any one of the layers between 1 and $n$.

**20.4.1 $\bar{v}_s$, Average Shear Wave Velocity.** $\bar{v}_s$ shall be determined in accordance with the following formula:

$$\bar{v}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}} \qquad (20.4\text{-}1)$$

$d_i$ is the thickness of any layer between 0 and 100 ft (30 m).

$v_{si}$ is the shear wave velocity in ft/s (m/s).

whereby $\sum_{i=1}^{n} d_i$ is equal to 100 ft (30 m).

**20.4.2 $\bar{N}$, Average Field Standard Penetration Resistance and $\bar{N}_{ch}$, Average Standard Penetration Resistance for Cohesionless Soil Layers.** $\bar{N}$ and $\bar{N}_{ch}$ shall be determined in accordance with the following formulas:

$$\bar{N} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{N_i}} \qquad (20.4\text{-}2)$$

where $N_i$ and $d_i$ in Eq. 20.4-2 are for cohesionless soil, cohesive soil, and rock layers.

$$\bar{N}_{ch} = \frac{d_s}{\sum_{i=1}^{m} \frac{d_i}{N_i}} \qquad (20.4\text{-}3)$$

where $N_i$ and $d_i$ in Eq. 20.4-3 are for cohesionless soil layers only and $\sum_{i=1}^{m} d_i = d_s$ where $d_s$ is the total thickness of cohesionless soil layers in the top 100 ft (30 m). $N_i$ is the standard penetration resistance (ASTM D1586) not to exceed 100 blows/ft (328 blows/m) as directly measured in the field without corrections. Where refusal is met for a rock layer, $N_i$ shall be taken as 100 blows/ft (328 blows/m).

**20.4.3 $\bar{s}_u$, Average Undrained Shear Strength.** $\bar{s}_u$ shall be determined in accordance with the following formula:

$$\bar{s}_u = \frac{d_c}{\sum_{i=1}^{k} \frac{d_i}{s_{ui}}} \qquad (20.4\text{-}4)$$

where

$\sum_{i=1}^{k} d_i = d_c$ and

$d_c$ = the total thickness of cohesive soil layers in the top 100 ft (30 m)

$PI$ = the plasticity index as determined in accordance with ASTM D4318

$w$ = the moisture content in percent as determined in accordance with ASTM D2216

$s_{ui}$ = the undrained shear strength in psf (kPa), not to exceed 5,000 psf (240 kPa) as determined in accordance with ASTM D2166 or ASTM D2850

# Chapter 21
# SITE-SPECIFIC GROUND MOTION PROCEDURES FOR SEISMIC DESIGN

## 21.1 SITE RESPONSE ANALYSIS

The requirements of Section 21.1 shall be satisfied where site response analysis is performed or required by Section 11.4.7. The analysis shall be documented in a report.

**21.1.1 Base Ground Motions.** A maximum considered earthquake (MCE) response spectrum shall be developed for bedrock, using the procedure of Sections 11.4.6 or 21.2. Unless a site-specific ground motion hazard analysis described in Section 21.2 is carried out, the MCE rock response spectrum shall be developed using the procedure of Section 11.4.6 assuming Site Class B. If bedrock consists of Site Class A, the spectrum shall be adjusted using the site coefficients in Section 11.4.3 unless other site coefficients can be justified. At least five recorded or simulated horizontal ground motion acceleration time histories shall be selected from events having magnitudes and fault distances that are consistent with those that control the MCE. Each selected time history shall be scaled so that its response spectrum is, on average, approximately at the level of the MCE rock response spectrum over the period range of significance to structural response.

**21.1.2 Site Condition Modeling.** A site response model based on low-strain shear wave velocities, nonlinear or equivalent linear shear stress-strain relationships, and unit weights shall be developed. Low-strain shear wave velocities shall be determined from field measurements at the site or from measurements from similar soils in the site vicinity. Nonlinear or equivalent linear shear stress-strain relationships and unit weights shall be selected on the basis of laboratory tests or published relationships for similar soils. The uncertainties in soil properties shall be estimated. Where very deep soil profiles make the development of a soil model to bedrock impractical, the model is permitted to be terminated where the soil stiffness is at least as great as the values used to define Site Class D in Chapter 20. In such cases, the MCE response spectrum and acceleration time histories of the base motion developed in Section 21.1.1 shall be adjusted upward using site coefficients in Section 11.4.3 consistent with the classification of the soils at the profile base.

**21.1.3 Site Response Analysis and Computed Results.** Base ground motion time histories shall be input to the soil profile as outcropping motions. Using appropriate computational techniques that treat nonlinear soil properties in a nonlinear or equivalent-linear manner, the response of the soil profile shall be determined and surface ground motion time histories shall be calculated. Ratios of 5 percent damped response spectra of surface ground motions to input base ground motions shall be calculated. The recommended surface MCE ground motion response spectrum shall not be lower than the MCE response spectrum of the base motion multiplied by the average surface-to-base response spectral ratios (calculated period by period) obtained from the site response analyses. The recommended surface ground motions that result from the analysis shall reflect consideration of sensitivity of response to uncertainty in soil properties, depth of soil model, and input motions.

## 21.2 GROUND MOTION HAZARD ANALYSIS

The requirements of Section 21.2 shall be satisfied where a ground motion hazard analysis is performed or required by Section 11.4.7. The ground motion hazard analysis shall account for the regional tectonic setting, geology, and seismicity, the expected recurrence rates and maximum magnitudes of earthquakes on known faults and source zones, the characteristics of ground motion attenuation, near source effects, if any, on ground motions, and the effects of subsurface site conditions on ground motions. The characteristics of subsurface site conditions shall be considered either using attenuation relations that represent regional and local geology or in accordance with Section 21.1. The analysis shall incorporate current seismic interpretations, including uncertainties for models and parameter values for seismic sources and ground motions. The analysis shall be documented in a report.

**21.2.1 Probabilistic MCE.** The probabilistic MCE spectral response accelerations shall be taken as the spectral response accelerations represented by a 5 percent damped acceleration response spectrum having a 2 percent probability of exceedance within a 50-yr. period.

**21.2.2 Deterministic MCE.** The deterministic MCE response acceleration at each period shall be calculated as 150 percent of the largest median 5 percent damped spectral response acceleration computed at that period for characteristic earthquakes on all known active faults within the region. For the purposes of this standard, the ordinates of the deterministic MCE ground motion response spectrum shall not be taken lower than the corresponding ordinates of the response spectrum determined in accordance with Fig. 21.2-1, where $F_a$ and $F_v$ are determined using Tables 11.4-1 and 11.4-2, respectively, with the value of $S_S$ taken as 1.5 and the value of $S_1$ taken as 0.6.

**21.2.3 Site-Specific MCE.** The site-specific MCE spectral response acceleration at any period, $S_{aM}$, shall be taken as the

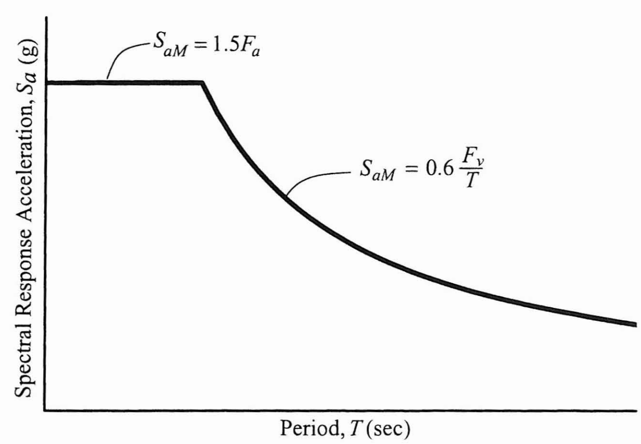



**FIGURE 21.2-1 DETERMINISTIC LOWER LIMIT ON MCE RESPONSE SPECTRUM**

lesser of the spectral response accelerations from the probabilistic MCE of Section 21.2.1 and the deterministic MCE of Section 21.2.2.

## 21.3 DESIGN RESPONSE SPECTRUM

The design spectral response acceleration at any period shall be determined from Eq. 21.3-1:

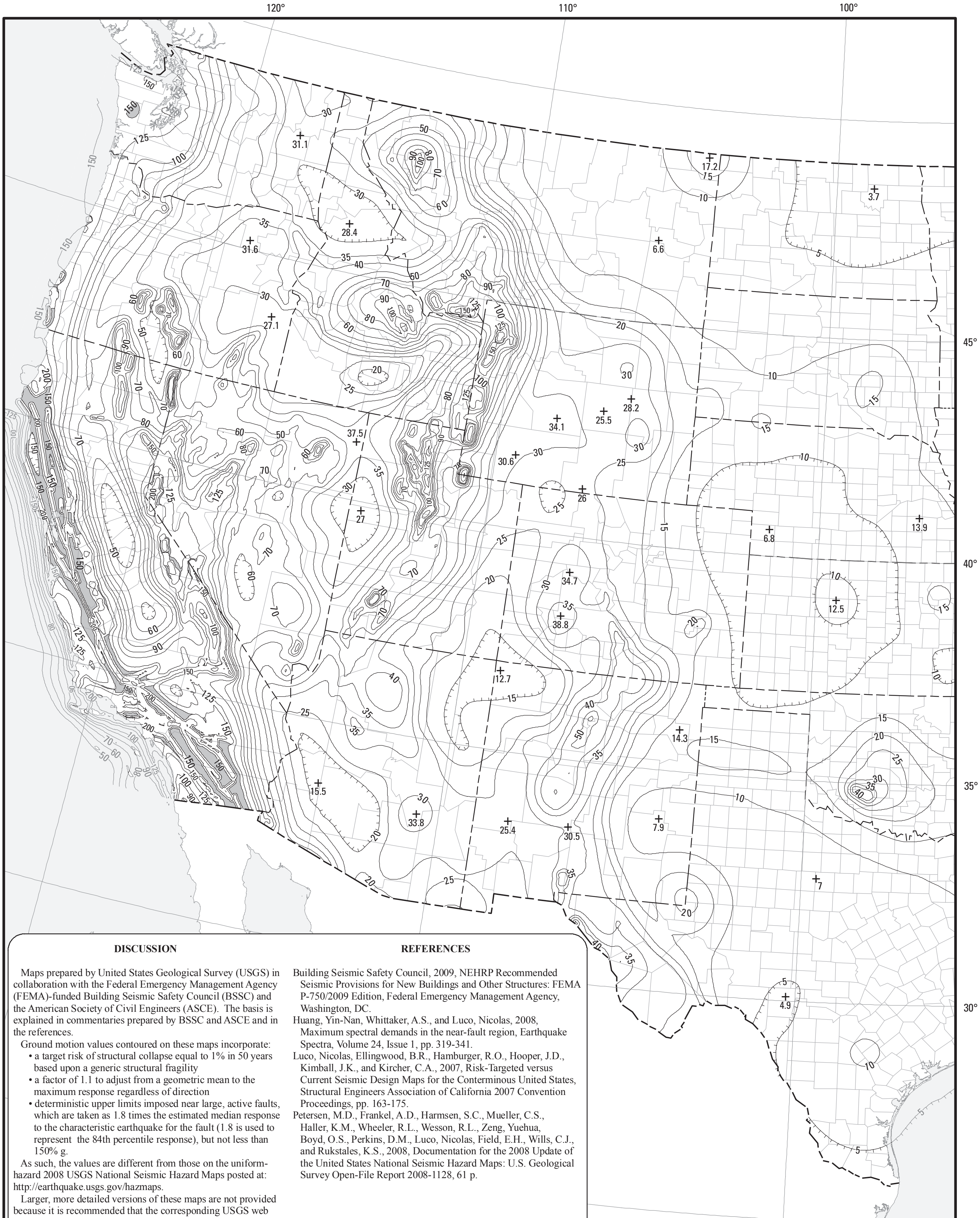
$$S_a = \frac{2}{3} S_{aM} \qquad (21.3\text{-}1)$$

where $S_{aM}$ is the MCE spectral response acceleration obtained from Section 21.1 or 21.2. The design spectral response acceleration at any period shall not be taken less than 80 percent of $S_a$ determined in accordance with Section 11.4.5. For sites classified as Site Class F requiring site response analysis in accordance with Section 11.4.7, the design spectral response acceleration at any period shall not be taken less than 80 percent of $S_a$ determined for Site Class E in accordance with Section 11.4.5.

## 21.4 DESIGN ACCELERATION PARAMETERS

Where the site-specific procedure is used to determine the design ground motion in accordance with Section 21.3, the parameter $S_{DS}$ shall be taken as the spectral acceleration, $S_a$, obtained from the site-specific spectra at a period of 0.2 s, except that it shall not be taken less than 90 percent of the peak spectral acceleration, $S_a$, at any period larger than 0.2 s. The parameter $S_{D1}$ shall be taken as the greater of the spectral acceleration, $S_a$, at a period of 1 s or two times the spectral acceleration, $S_a$, at a period of 2 sec. The parameters $S_{MS}$ and $S_{M1}$ shall be taken as 1.5 times $S_{DS}$ and $S_{D1}$, respectively. The values so obtained shall not be less than 80 percent of the values determined in accordance with Section 11.4.3 for $S_{MS}$ and $S_{M1}$ and Section 11.4.4 for $S_{DS}$ and $S_{D1}$.

The following figures are from ASCE 7 (2010) publication




**DISCUSSION**

Maps prepared by United States Geological Survey (USGS) in collaboration with the Federal Emergency Management Agency (FEMA)-funded Building Seismic Safety Council (BSSC) and the American Society of Civil Engineers (ASCE). The basis is explained in commentaries prepared by BSSC and ASCE and in the references.

Ground motion values contoured on these maps incorporate:

- a target risk of structural collapse equal to 1% in 50 years based upon a generic structural fragility
- a factor of 1.1 to adjust from a geometric mean to the maximum response regardless of direction
- deterministic upper limits imposed near large, active faults, which are taken as 1.8 times the estimated median response to the characteristic earthquake for the fault (1.8 is used to represent the 84th percentile response), but not less than 150% g.

As such, the values are different from those on the uniform-hazard 2008 USGS National Seismic Hazard Maps posted at: http://earthquake.usgs.gov/hazmaps.

Larger, more detailed versions of these maps are not provided because it is recommended that the corresponding USGS web tool (http://earthquake.usgs.gov/designmaps or http://content.seinstitute.org) be used to determine the mapped value for a specified location.

**REFERENCES**

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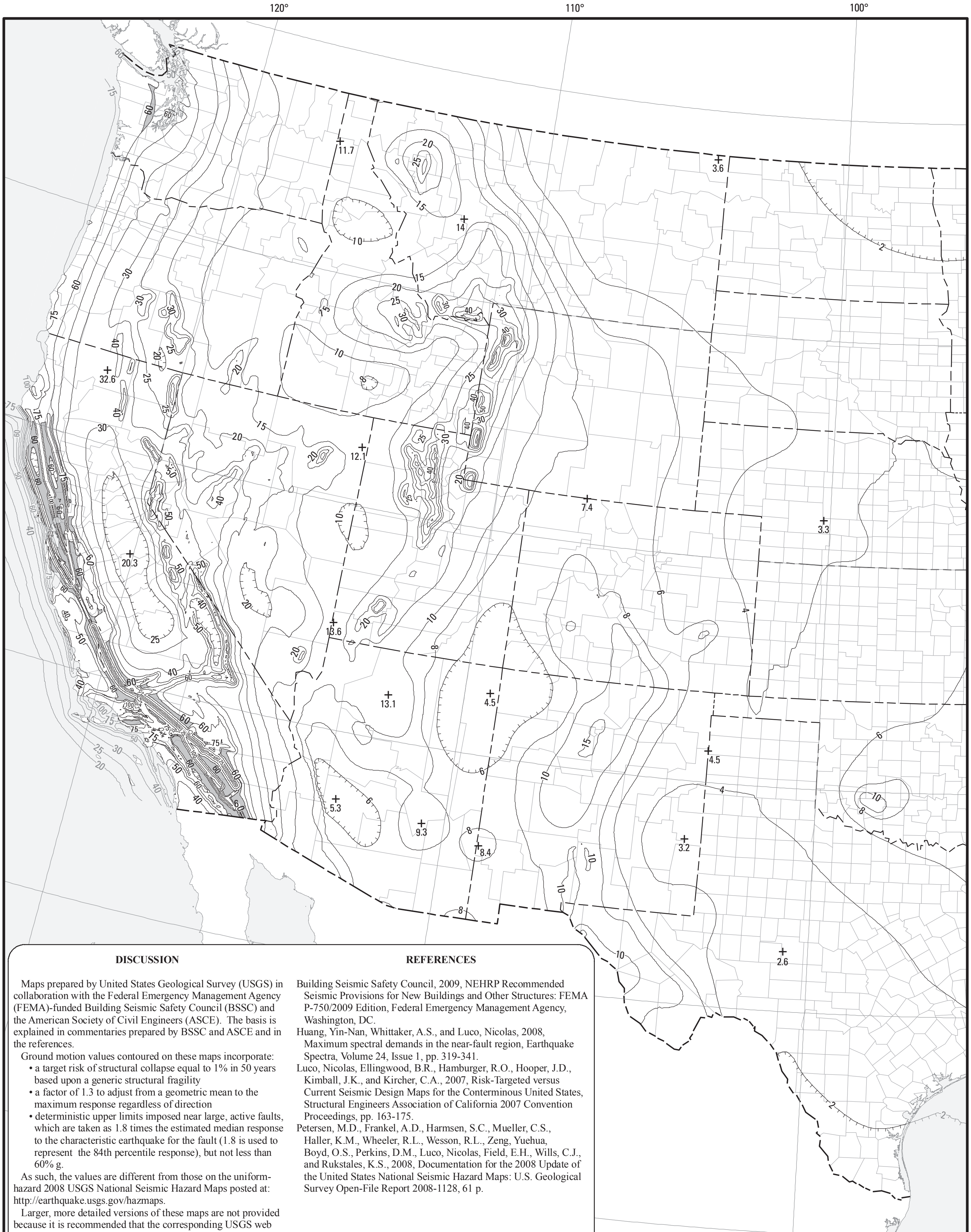
**Figure 22-1 $S_s$ Risk-Targeted Maximum Considered Earthquake ($MCE_R$) Ground Motion Parameter for the Conterminous United States for 0.2 s Spectral Response Acceleration (5% of Critical Damping), Site Class B.**


**Figure 22-1** ***(continued)*** **$S_s$ Risk-Targeted Maximum Considered Earthquake ($MCE_R$) Ground Motion Parameter for the Conterminous United States for 0.2 s Spectral Response Acceleration (5% of Critical Damping), Site Class B.**




**DISCUSSION**

Maps prepared by United States Geological Survey (USGS) in collaboration with the Federal Emergency Management Agency (FEMA)-funded Building Seismic Safety Council (BSSC) and the American Society of Civil Engineers (ASCE). The basis is explained in commentaries prepared by BSSC and ASCE and in the references.

Ground motion values contoured on these maps incorporate:

- a target risk of structural collapse equal to 1% in 50 years based upon a generic structural fragility
- a factor of 1.3 to adjust from a geometric mean to the maximum response regardless of direction
- deterministic upper limits imposed near large, active faults, which are taken as 1.8 times the estimated median response to the characteristic earthquake for the fault (1.8 is used to represent the 84th percentile response), but not less than 60% g.

As such, the values are different from those on the uniform-hazard 2008 USGS National Seismic Hazard Maps posted at: http://earthquake.usgs.gov/hazmaps.

Larger, more detailed versions of these maps are not provided because it is recommended that the corresponding USGS web tool (http://earthquake.usgs.gov/designmaps or http://content.seinstitute.org) be used to determine the mapped value for a specified location.

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**Figure 22-2 $S_1$ Risk-Targeted Maximum Considered Earthquake ($MCE_R$) Ground Motion Parameter for the Conterminous United States for 1.0 s Spectral Response Acceleration (5% of Critical Damping), Site Class B.**


**Figure 22-2 (*Continued*) $S_1$ Risk-Targeted Maximum Considered Earthquake ($MCE_R$) Ground Motion Parameter for the Conterminous United States for 1.0 s Spectral Response Acceleration (5% of Critical Damping), Site Class B.**

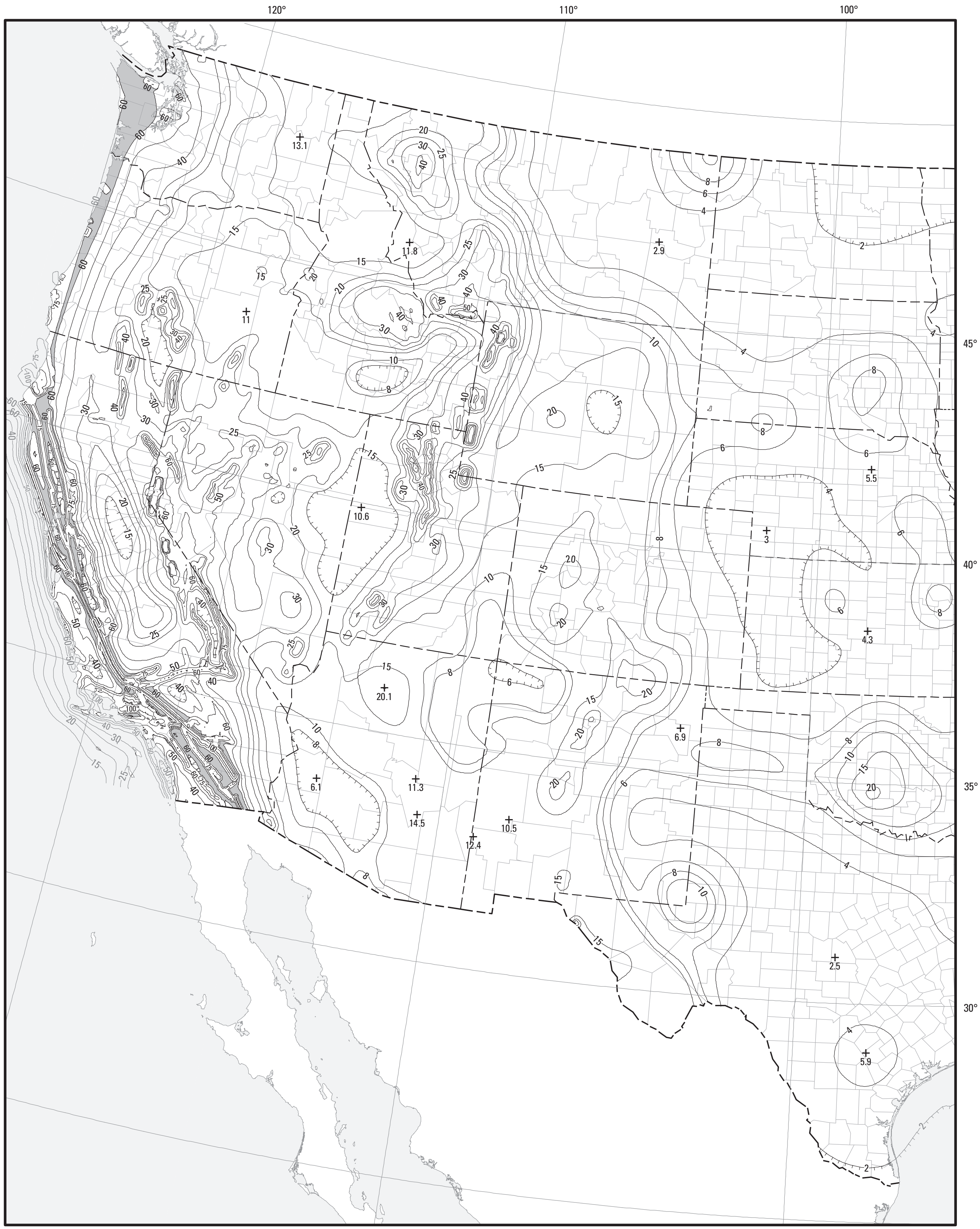


**Figure 22-7 Maximum Considered Earthquake Geometric Mean ($MCE_G$) PGA, %g, Site Class B for the Conterminous United States.**


**Figure 22-7 (*continued*) Maximum Considered Earthquake Geometric Mean ($MCE_G$) PGA, %g, Site Class B for the Conterminous United States.**

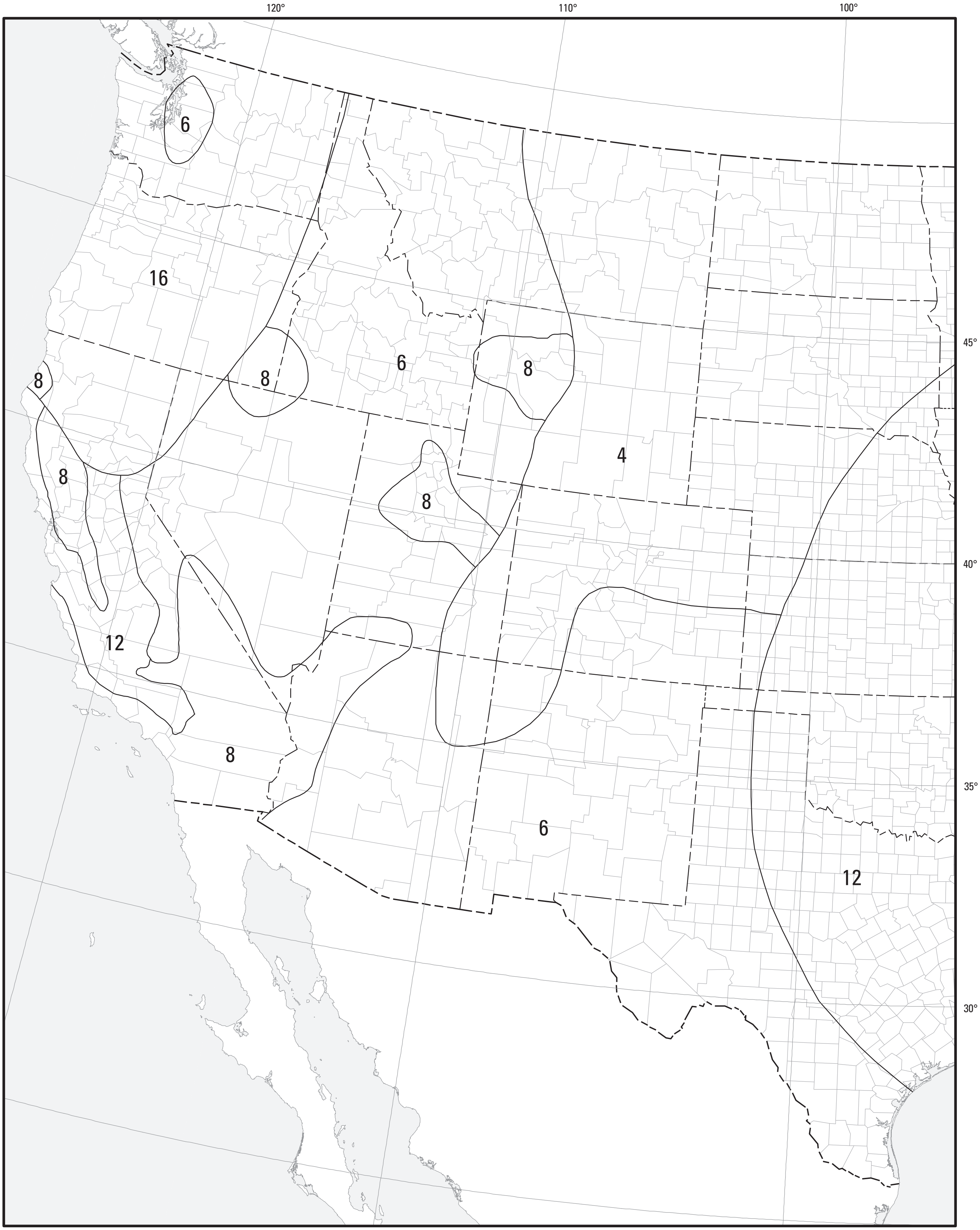


**Figure 22-12 Mapped Long-Period Transition Period, $T_L$ (s), for the Conterminous United States.**


**Figure 22-12 (*continued*) Mapped Long-Period Transition Period, $T_L$ (s), for the Conterminous United States.**