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Evolution of Seismic Design Value Maps Over Time

May 19, 2022

Ronald O. Hamburger
Project 17 Director

nehrp FEMA Building Seismic Safety Council

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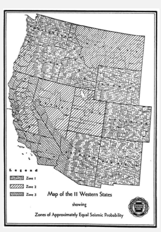
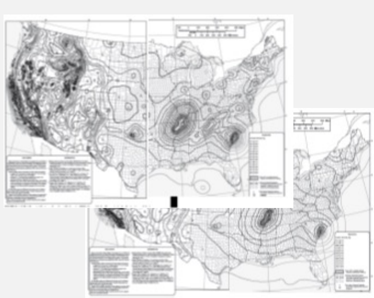
1935 UBC Seismic Zone Map





2014 BSSC Seismic Design Value Maps

- Since the earliest building codes containing seismic criteria, required seismic forces have been based on seismic risk maps
- The maps are based on science
- Design of buildings is not science, but rather, an application of engineering judgment, informed by science
- Since 2000, seismic design maps have resulted from collaboration of:
  - USGS – Science
  - BSSC - Engineering

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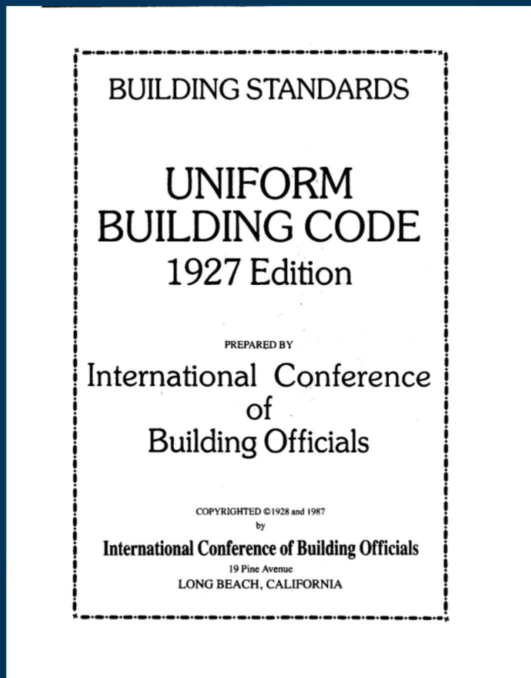
BUILDING STANDARDS

UNIFORM BUILDING CODE
1927 Edition

PREPARED BY
International Conference of Building Officials

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by
International Conference of Building Officials
19 Pine Avenue
LONG BEACH, CALIFORNIA

The Beginning

- No seismic map provided
- If you wanted to design for earthquake, you designed for it!
    - Soils with allowable bearing load of 2 tons/sq ft or greater - 0.075W
    - All other soils – 0.10W

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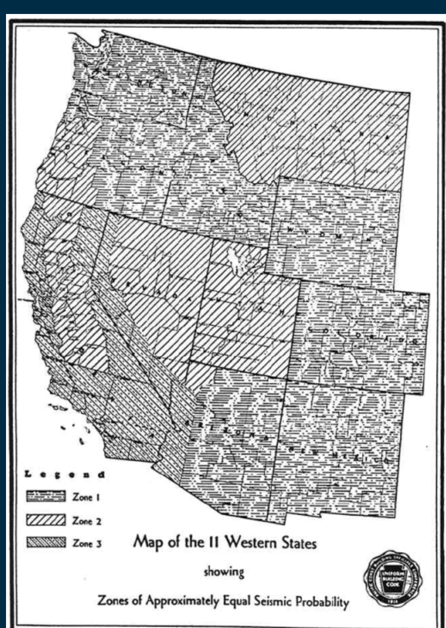

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The first seismic risk map 1935 UBC

- Provided qualitative rating of seismic risk, based on observed seismicity in the Western U.S.
- Design values not directly tied to anticipated ground acceleration

$$F = CW$$

Zone	Firm soil Q> 2ksf	Soft soil Q<2ksf
1	0.02	0.04
2	0.04	0.08
3	0.08	0.16

Zone 1 – regions not subject to frequent seismic disturbances
Zone 2 – twice the forces shown
Zone 3 – four times the forces shown

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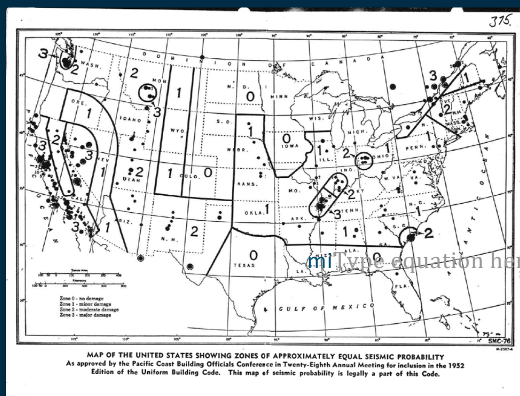

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The Map Goes National - 1949 UBC

- For reference purposes, maps shows "intensity dots" representing historic earthquakes – suggesting tie between design values and MMI
- Zones of approximately equal seismic probability
  - Zone 0 – no damage
  - Zone 1 – minor damage
  - Zone 2 – moderate damage
  - Zone 3 – major damage
- Base shear tied loosely to spectral response

$$C = \frac{.15}{N + 4.5}$$

(13% for single story buildings in zone 3)

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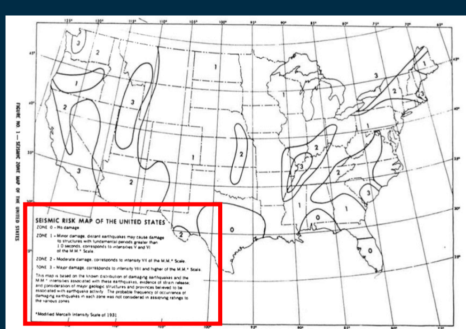

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1960s-1973

- Clear tie to MMI
  - Zone 1 – minor damage – corresponds to intensity V or VI MMI
  - Zone 2 – moderate damage – MMI VII
  - Zone 3 – MMI VIII or higher
- Links to spectral acceleration strengthened and improved

$$F = ZKCW$$

$$C = \frac{.05}{\sqrt[3]{T}} \leq 0.1$$

Zone	Z
0	0
1	¼
2	½
3	1

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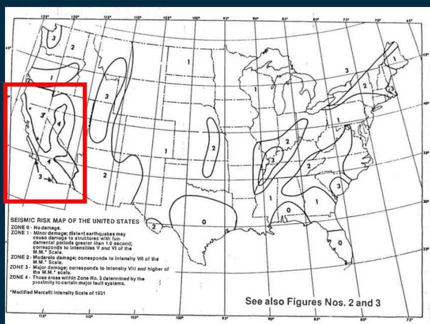

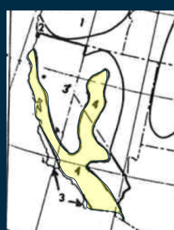

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1976 UBC

- Introduced zone 4 – "those sites within zone 3 determined by their proximity to major active faults"

$$F = ZIKCSW$$

$$C = \frac{1}{15\sqrt{T}} \leq 0.12$$

$$CS < 0.14$$

- Occupancy Importance "I" and Soil Factor "S" added
- Soil Factor function of Site Period T_s

Zone	Z
1	3/16
2	3/8
3	3/4
4	1

Base Shear = 0.186g (worst case)

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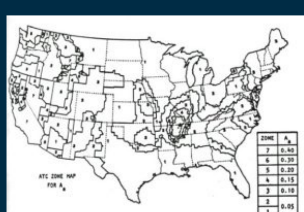
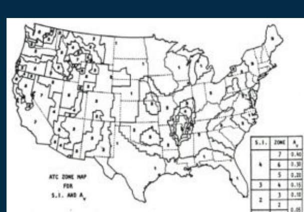


A_a



A_v

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ATC-03 1978

- Introduced separate zonation maps based on:
  - A_a – effective peak acceleration
  - A_v – effective peak velocity
  - (Similar to present day S_{DS} and S_{D1} but without site class consideration)
- Maintained concept of "zones" with uniform force criteria throughout zone
- Declared that the Aa and Av values represented 475-year (10%-50 year exceedance motions)
- Base shear equations directly tied to design ground motion spectral response accelerations

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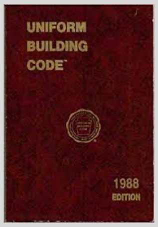

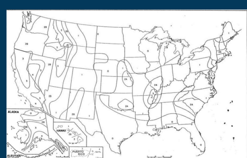

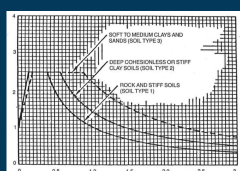

1988 UBC

- Mostly adopted ATC 3-06 criteria
  - Retained seismic zone map
  - Z became (but was not called) the effective peak ground acceleration

TABLE NO. 23-I
SEISMIC ZONE FACTOR Z

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

  - Base shear equation re-formulated

$$V = \frac{ZIC}{R_w} W$$

$$C = \frac{1.25}{ST^{2/3}} < 2.75$$

  - Base Shear =0.183W (worst case)

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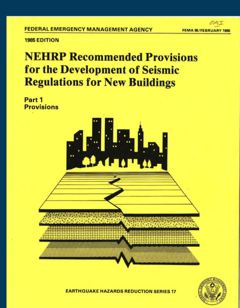

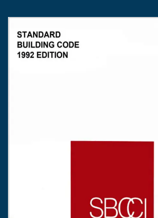

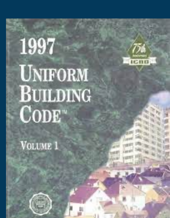

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NEHRP Provisions

- 1988 edition transcribed into:
  - 1992 Southern Standard Building Code
  - 1993 National (BOCA) Building Code
- Retained 500-year A_a and A_v maps
- Retained “strength level” base shear forces (essentially 1.4 UBC / ASD levels)
- 1997 UBC ultimately adopted:
  - Strength level forces
  - C_a and C_v concepts (similar to A_a and A_v)

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The International Building Code

- By the mid-1990s, BOCA, ICBO and SBCCI were talking about collaborating to produce a single code
- Reconciliation of the three codes (and two seismic design procedures) became an important focus of BSSC
- In 1994, BSSC and USGS formed the Seismic Design Values Working Group to develop a unified approach to seismic hazard characterization in the building codes
  - In the eastern U.S. – 500-year ground motion did not capture historic events (1811-12 New Madrid, 1886 Charleston)
  - In the western U.S. – longer return period ground motion resulted in unreasonably high design values

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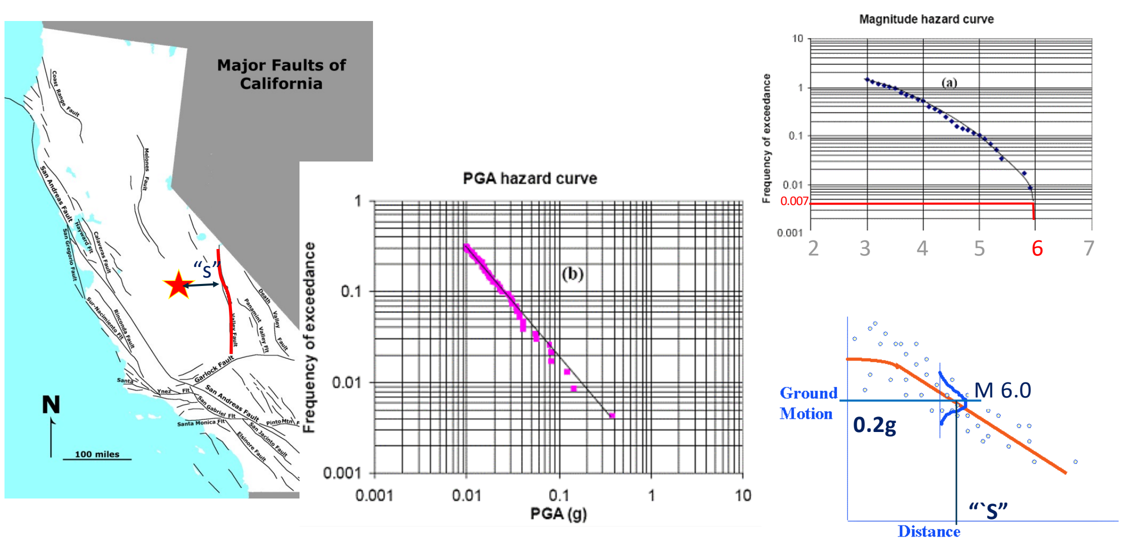
Probabilistic Seismic Hazard Analysis



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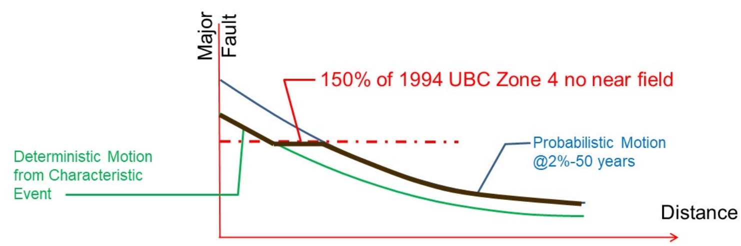
Project ’97
“the Goldilocks solution”

- Define MCE as 2%-50 year exceedance motion, unless this exceeded 150% of 1994 UBC Zone 4 motion
  - Site located close to major active fault
  - Use 150% of median motion from a “characteristic” event on the proximate fault (or faults), but not less than 150% of 1994 UBC motion
- Design motion taken as 2/3 MCE motion



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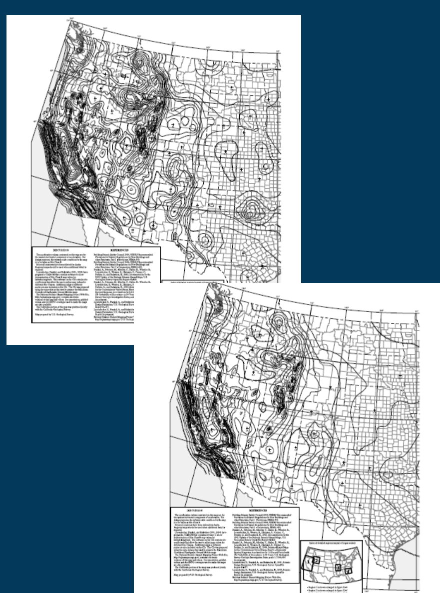
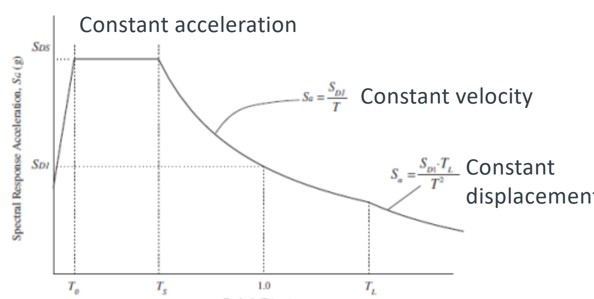


1997 NEHRP Provisions ASCE 7-98, 7-02, IBC 2000

- S_S and S_1 maps
- 5 Site Classes (A, B, C, D, E and F)
- Base shear equations tied to classic Newmark & Hall Spectrum



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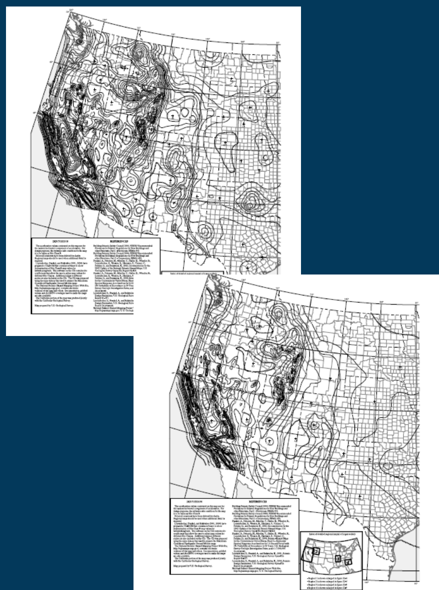

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1997 NEHRP Provisions
ASCE 7-98, 7-02, IBC 2000

- Significant variation in ground motion intensity and design base shear from location to location
- New maps impossible to read in areas of high seismicity
  - USGS Digital tool
- As scientific opinion on:
  - Sources
  - Recurrence
  - GMPEs

  Changed, to did the values

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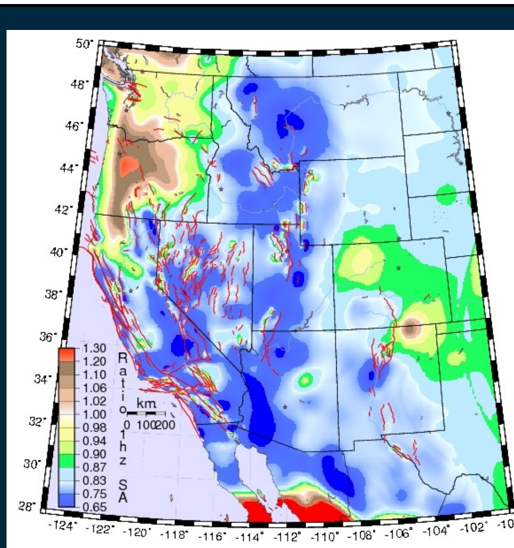

2%-50 years $\frac{S_{1-2008}}{S_{1-2002}}$

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Project '07

- Joint BSSC – USGS project to determine how new scientific knowledge should be used for the next generation (ASCE 7-10) maps
  - New GMPEs
  - Account for directionality of motion
  - "Deal" with:
    - unhappiness in eastern U.S. that they were now having to design for "California" ground motions
    - Unhappiness in California that they would now design for lower motions than had historically been used.

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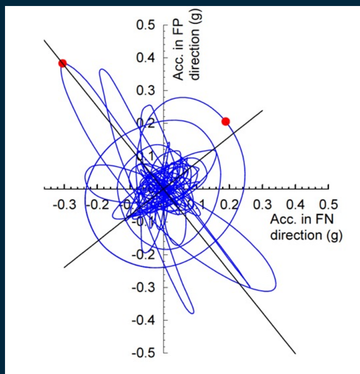

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Ground Motion Directionality

- Typical ground motion recording includes
  - X component
  - Y component
  - oriented at 90º
- Ground Motion Prediction Models use "geomean"
- For this motion:
- X=0.28g, Y=0.5g, GM=0.37g
- Structural engineers on the committee felt GM had no particular relevance and felt more comfortable designing for the maximum component (factor of 1.1 for short period, 1.3 for long period)

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Uniform Hazard v. Uniform Risk

- Under ASCE 7.05, design values in Memphis, TN, San Francisco, CA and Los Angeles, CA are similar
- Yet in past 200 years
  - S.F. has experienced at least 5 significant earthquakes (1836, 1868, 1906, 1957, 1989)
  - LA has experienced at least 8 significant earthquakes (1857, 1933, 1952, 1971, 1979, 1987, 1993, 1994)
  - Memphis has experienced only one series of events (all in 1811-1812)
- Engineers in the Memphis region complained that it did not make sense given this experience that the design requirements were the same
- This is because we were designing for uniform risk of ground motion exceedance, not uniform risk of collapse

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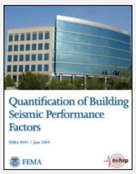
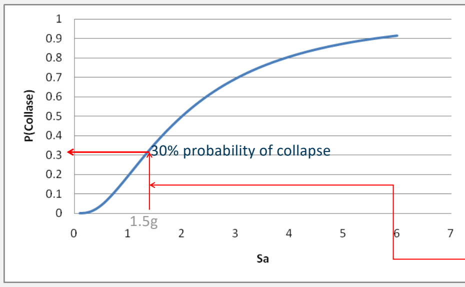
Risk of Collapse

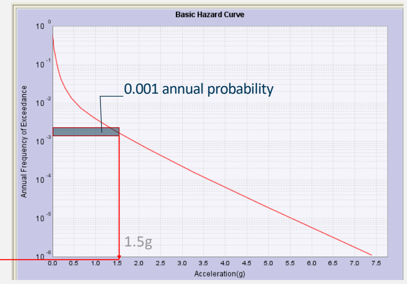
$$P(collapse) = \#\text{ of collapses per yr} = \int_{Sa(T)=0}^{Sa(T)=\infty} P(collapse|Sa(T))P(S_a(T)d\lambda)$$

Fragility

Hazard







$$Annual\ Collapses\ at\ 1.5g = \frac{.001}{year} * 0.3 prob\ given\ 1.5g$$
$$= 0.0003/year$$

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Risk Coefficient Maps

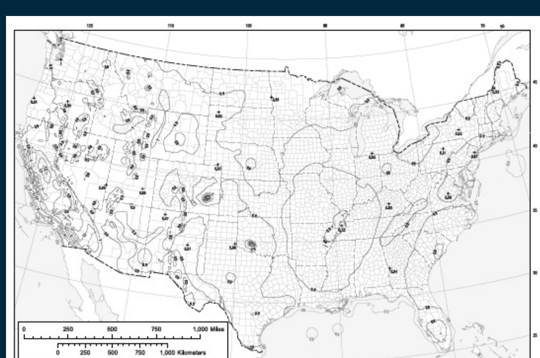

FIGURE 22-17 Mapped Risk Coefficient at 0.2 s Spectral Response Period, C_{RS}.

- 2%-50 year ground motion adjusted by risk coefficients
  - ~0.7 in eastern U.S.
  - ~1.1in western U.S.
- Resulting ground motion maps referenced by:
  - 2009 NEHRP Provisions
  - ASCE 7-10, ASCE 7-16
  - IBC 2012, 2015, 2018, 2021
- As the 2014 NEHRP Provisions cycle concluded, two issues surfaced:
  - Realization that the “classic” Newmark-Hall spectrum didn’t always work very well
  - General unhappiness with the “pogo stick”

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Project '17

- Joint BSSC – USGS project to determine how new scientific knowledge should be used for the next generation (ASCE 7-22) maps
- Primary Issues:
  - Very large magnitude earthquakes (Cascadia subduction zone)
  - Inclusion of basin effects
  - Spectral shape
  - Precision v Uncertainty
  - Acceptable Risk
  - Use of deterministic caps
  - "Pogo stick"

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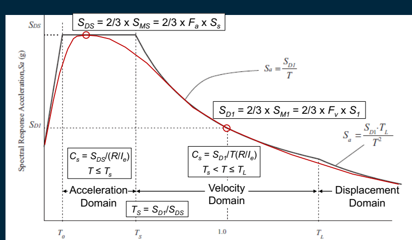

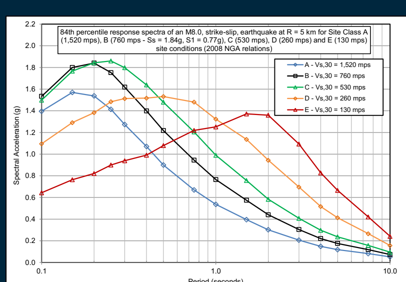

Spectral Shape Problem

- The classic "two-parameter" Newmark & Hall spectrum, in use since ATC3-06 does not match the spectral shape of ground motion from:
  - Large magnitude earthquake (M>7)
  - Soft soil sites (Class D, E, F)
- Solution - Multiperiod Response Spectrum (MPRS)
  - USGS provides Spectral Acceleration values at 20 periods (0, 0.1, ….10 sec)
  - Values are site-class adjusted
  - To minimize the change between sites, new intermediate site classes adopted (A, B, BC, C, CD, D, DE, E, F)
  - F_a and F_v values previously used to adjust S_s and S_1 dropped

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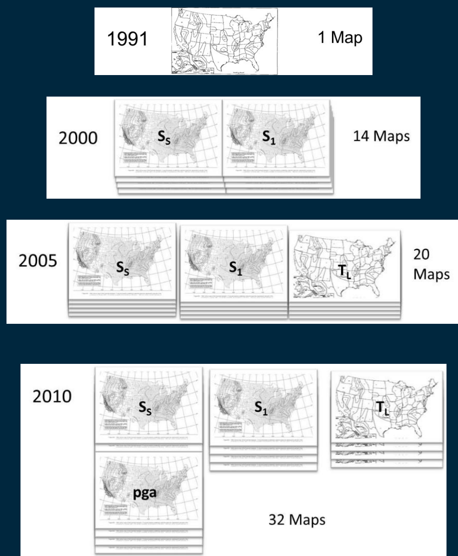

The Map Dilemna

- With the addition of spectral values at 20 periods for each of 9 site classes, nearly 200 maps would be needed
- NEHRP 2020 and ASCE 7-22 use digital conveyance only
- Access available through a free online web tool maintained by ASCE

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Project 17 Director

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Chapter 3 (Section 3.2 - Part 1) The 2018 Update of the USGS National Seismic Hazard Model

2020 NEHRP Provisions Training Materials

Sanaz Rezaeian, Ph.D., USGS

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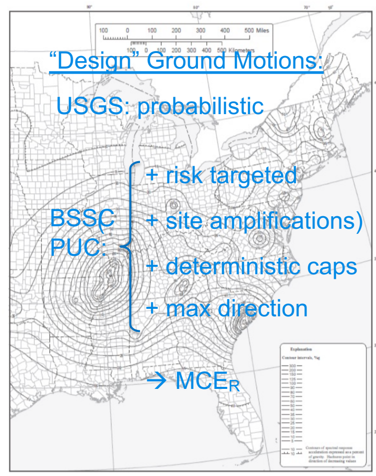
1

Outline

1. Interplay between the USGS hazard models and the BSSC PUC requirements
2. The 2018 USGS National Seismic Hazard Model (NSHM) for Conterminous U.S.
   - Ground motion models in CEUS (e.g. NGA-East)
   - Deep basin effects in WUS
3. Outside of the Conterminous U.S. (HI, AK, PRVI, GNMI, AMSAM)



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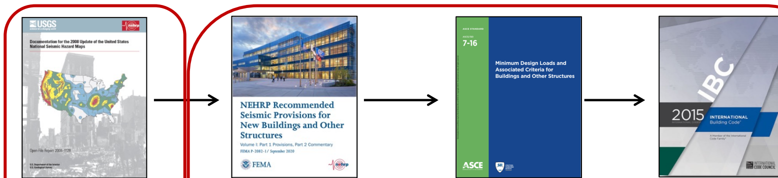
USGS NSHMs & BSSC PUC Requirements

Hazard Model (PSHA) — Site-specific Procedures of Ch21



	USGS NSHM	NEHRP Provisions	ASCE 7 Standards	IBC
PGA, 0.2, 1s 760m/s	1996	1997, 2000	1998,2002	2000, 2003
	2002	2003	2005	2006, 2009
	2008	2009	2010	2012, 2015
	2014	2015	2016	2018
22 Periods 8 Vs30s	**2018**	**2020**	2022*	TBD

Hazard Curves+ (RiskTarget, MaxDir, ~~SiteAmpl~~, DetCaps) → **"Design" Ground Motions**

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Updates to 2020 NEHRP Design Ground Motions in Conterminous US

2018 USGS NSHM

Check for updates

Research paper

EARTHQUAKE SPECTRA

The 2018 update of the US National Seismic Hazard Model: Overview of model and implications

Earthquake Spectra
2020, Vol. 36(1) 5–41
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Mark D. Petersen, M.EERI[1], Allison M. Shumway[1], Peter M. Powers, M.EERI[1], Charles S. Mueller[1], Morgan P. Moschetti, M.EERI[1], Arthur D. Frankel, M.EERI[2], Sanaz Rezaeian[1], Daniel E. McNamara[1], Nico Luco, M.EERI[1], Oliver S. Boyd, M.EERI[1], Kenneth S. Rukstales[1], Kishor S. Jaiswal, M.EERI[1], Eric M. Thompson[1], Susan M. Hoover[1], Brandon S. Clayton[1], Edward H. Field, M.EERI[1], and Yuehua Zeng[1]

Abstract
During 2017–2018, the National Seismic Hazard Model for the conterminous United States was updated as follows: (1) an updated seismicity catalog was incorporated, which includes new earthquakes that occurred from 2013 to 2017; (2) in the central and eastern United States (CEUS), new ground motion models were updated that incorporate updated median estimates, modified assessments of the associated epistemic uncertainties and aleatory variabilities, and new soil amplification factors; (3) in the western United States (WUS), amplified shaking estimates of long-period ground motions at sites overlying deep sedimentary basins in the Los Angeles, San Francisco, Seattle, and Salt Lake City areas were incorporated; and (4) in the conterminous United States, seismic hazard is calculated for 22 periods (from 0.01 to 10 s) and 8 uniform V_{S30} maps (ranging from 1500 to 150 m/s). We also include a description of updated computer codes and modeling details. Results show increased ground shaking in many (but not all) locations across the CEUS (up to ~30%), as well as near the four urban areas overlying deep sedi-

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[2]US Geological Survey, University of Washington, Seattle, WA, USA

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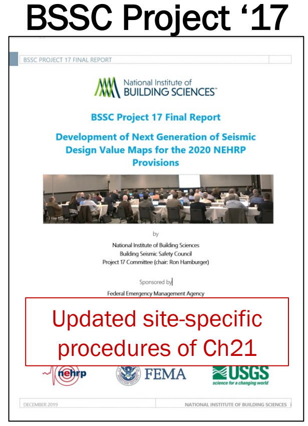
Email: mpetersen@usgs.gov

Updated hazard model (eqk sources, GMMs)

BSSC Project '17



BSSC PROJECT 17 FINAL REPORT

National Institute of BUILDING SCIENCES

BSSC Project 17 Final Report

Development of Next Generation of Seismic Design Value Maps for the 2020 NEHRP Provisions

by

National Institute of Building Sciences
Building Seismic Safety Council
Project 17 Committee (chair: Ron Hamburger)

Sponsored by

Federal Emergency Management Agency

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DECEMBER 2019 — NATIONAL INSTITUTE OF BUILDING SCIENCES

Updated site-specific procedures of Ch21

FEMA — Building Seismic Safety Council — nehrp — USGS science for a changing world

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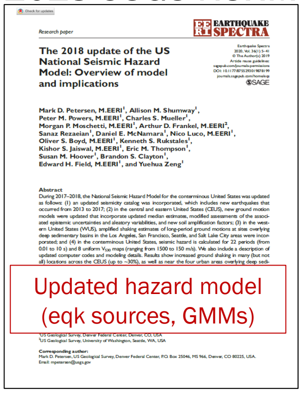
Updates to 2020 NEHRP Design Ground Motions in Conterminous US

2018 USGS NSHM


Check for updates

Research paper

EARTHQUAKE SPECTRA

The 2018 update of the US National Seismic Hazard Model: Overview of model and implications

Earthquake Spectra
2020, Vol. 36(1) 5–41
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Mark D. Petersen, M.EERI[1], Allison M. Shumway[1], Peter M. Powers, M.EERI[1], Charles S. Mueller[1], Morgan P. Moschetti, M.EERI[1], Arthur D. Frankel, M.EERI[2], Sanaz Rezaeian[1], Daniel E. McNamara[1], Nico Luco, M.EERI[1], Oliver S. Boyd, M.EERI[1], Kenneth S. Rukstales[1], Kishor S. Jaiswal, M.EERI[1], Eric M. Thompson[1], Susan M. Hoover[1], Brandon S. Clayton[1], Edward H. Field, M.EERI[1], and Yuehua Zeng[1]

Abstract
During 2017–2018, the National Seismic Hazard Model for the conterminous United States was updated as follows: (1) an updated seismicity catalog was incorporated, which includes new earthquakes that occurred from 2013 to 2017; (2) in the central and eastern United States (CEUS), new ground motion models were updated that incorporate updated median estimates, modified assessments of the associated epistemic uncertainties and aleatory variabilities, and new soil amplification factors; (3) in the western United States (WUS), amplified shaking estimates of long-period ground motions at sites overlying deep sedimentary basins in the Los Angeles, San Francisco, Seattle, and Salt Lake City areas were incorporated; and (4) in the conterminous United States, seismic hazard is calculated for 22 periods (from 0.01 to 10 s) and 8 uniform V_{S30} maps (ranging from 1500 to 150 m/s). We also include a description of updated computer codes and modeling details. Results show increased ground shaking in many (but not all) locations across the CEUS (up to ~30%), as well as near the four urban areas overlying deep sedi-

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Updated hazard model
(eqk sources, GMMs)

➕

BSSC Project '17

No change to risk-targeted calcs

1. Using **m**ulti-**p**eriod multi-Vs30 **r**esponse **s**pectrum **(MPRS)**
2. Modifying **deterministic caps** based on deaggregation of probabilistic hazard
3. Updating the **max-direction** factors

MPRS issue directly influenced the 2018 update of USGS NSHM (GMMs applicable for all periods and site classes)

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Updates to 2020 NEHRP Design Ground Motions in Conterminous US

2018 USGS NSHM

Necessary for MPRS

1. New ground motion models (GMMs), including **NGA-East**, & amplification factors in the Central & Eastern US (CEUS)
2. Deep **basin effects** in Los Angeles, Seattle, San Francisco, and Salt Lake City regions
3. Minor modifications of GMMs (crustal & subduction) in the Western US (WUS)
4. Updating **background seismicity** to include 2013-2017 earthquakes

➕

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Old CEUS Ground Motion Models

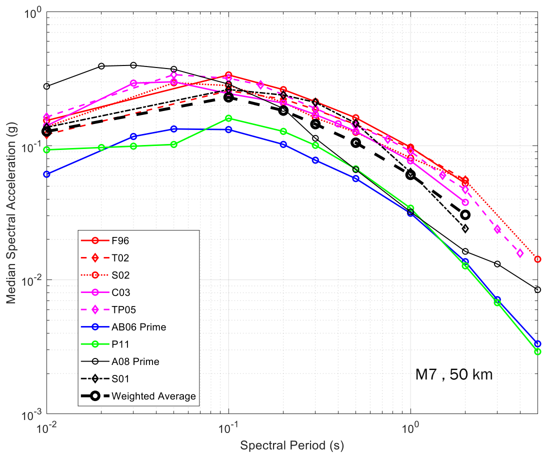

Table from Rezaeian et al. (2021):

2014 CEUS GMMs:	Period Range	Site Classes
AB06'	PGA to 5 s	A, BC (A to E)
A08'	PGA to 5 s	A, BC (A to E)
C03	PGA to 2 s (4 s)	A, BC*
F96	PGA to 2 s	A, BC
P11	PGA to 5 s (10 s)	A, BC*
S02	PGA to 5 s (10 s)	A, BC*
S01	PGA to 2 s (4 s)	A, BC*
TP05	PGA to 4 s	A, BC*
T02	PGA to 2 s	A, BC*

Parentheses indicate the published range when a different range is supported in the USGS codes.
*Through conversion factors.

Figure citation: Rezaeian et al. (2021). "The 2018 update of the US National Seismic Hazard Model: Ground motion models in the central and eastern US," *Earthquake Spectra*. doi: 10.1177/8755293021993837

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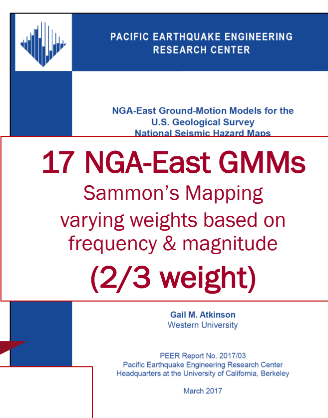
New CEUS Ground Motion Models

14 Updated Seed GMMs
from 19 published plus 2 new
varying weights based on geometric spreading & model type
(1/3 weight)

+



17 NGA-East GMMs
Sammon's Mapping
varying weights based on frequency & magnitude
(2/3 weight)

31 CEUS GMMs

<u>Changes made to:</u>

1. Median ground motions (increases for large M, middle to large distances)
2. Epistemic uncertainty (increased)
3. Aleatory uncertainty (minor)

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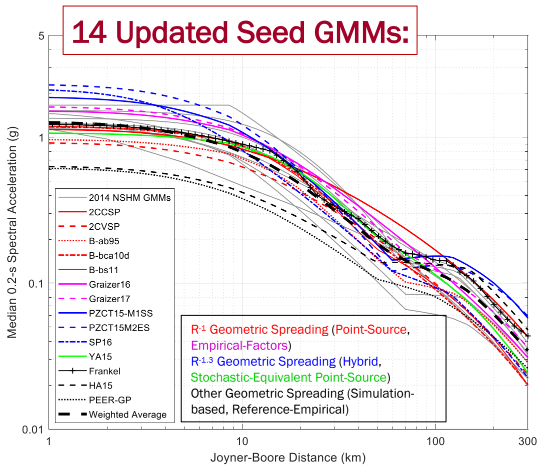
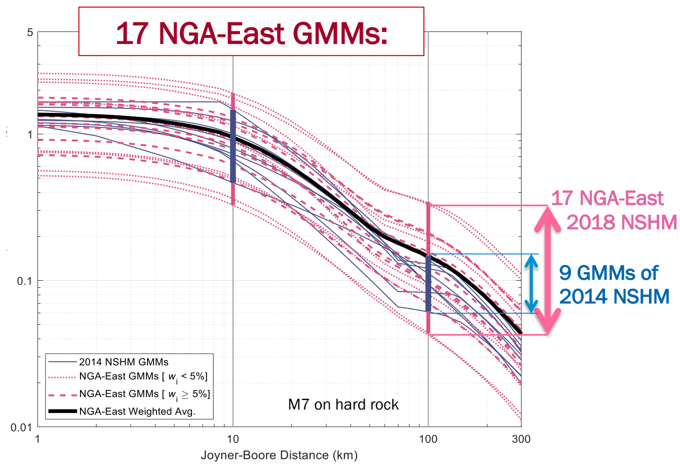
Figure citation: Rezaeian et al., 2021. "The 2018 update of the US National Seismic Hazard Model: Ground motion models in the central and eastern US," *Earthquake Spectra*.

New CEUS Ground Motion Models





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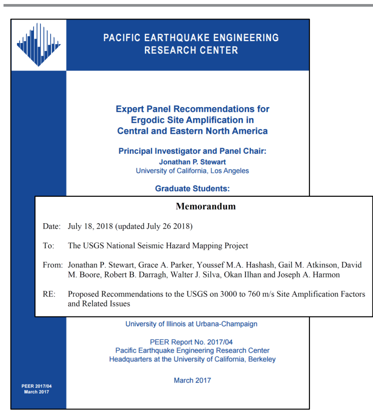
New CEUS Site-Effects Models


PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Expert Panel Recommendations for Ergodic Site Amplification in Central and Eastern North America

Principal Investigator and Panel Chair:
Jonathan P. Stewart
University of California, Los Angeles

Graduate Students:

Memorandum

Date: July 18, 2018 (updated July 26 2018)

To: The USGS National Seismic Hazard Mapping Project

From: Jonathan P. Stewart, Grace A. Parker, Youssef M.A. Hashash, Gail M. Atkinson, David M. Boore, Robert B. Darragh, Walter J. Silva, Okan Ilhan and Joseph A. Harmon

RE: Proposed Recommendations to the USGS on 3000 to 760 m/s Site Amplification Factors and Related Issues

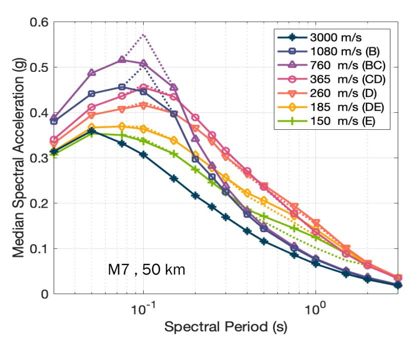
University of Illinois at Urbana-Champaign

PEER Report No. 2017/04
Pacific Earthquake Engineering Research Center
Headquarters at the University of California, Berkeley

March 2017

Later published (and slightly modified) by:
Stewart et al. (2020), *Earthquake Spectra 36(1)*
Hashash et al. (2020), *Earthquake Spectra 36(1)*
Rezaeian et al. (2021), *Earthquake Spectra* (implementation details)

Site Effects = $F_{760} + F_{linear} + F_{nonlinear}$



CEUS has very different spectral shapes compared to WUS, as expected!

This is the first time that site-effects specific to the CEUS have been implemented in the NSHMs (prior NEHRP coefficients were based on WUS)

Figure citation: Rezaeian et al., 2021. "The 2018 update of the US National Seismic Hazard Model: Ground motion models in the central and eastern US," *Earthquake Spectra*.

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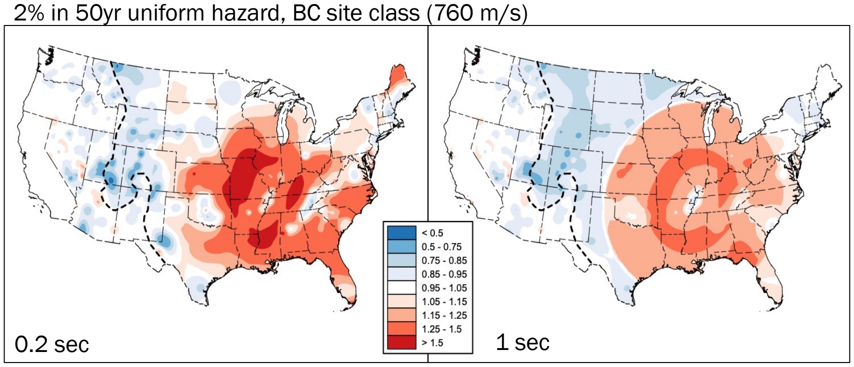
Hazard Changes (CEUS)

Ratio Maps (2018/2014):
2% in 50yr uniform hazard, BC site class (760 m/s)



Medians: more significant increases for large M at mid-large distances

Epistemic uncertainty: increased significantly for large M, more around 70-100 km

Aleatory uncertainty: minor changes

Site-effect model: only F_{760} in this figure

Seismicity catalog updates: outside CA, mostly affecting intermountain west region

Figure citation: Petersen et al., 2021. "The 2018 update of the US National Seismic Hazard Model: Where, why, and how much probabilistic ground motion maps changed," *Earthquake Spectra*.

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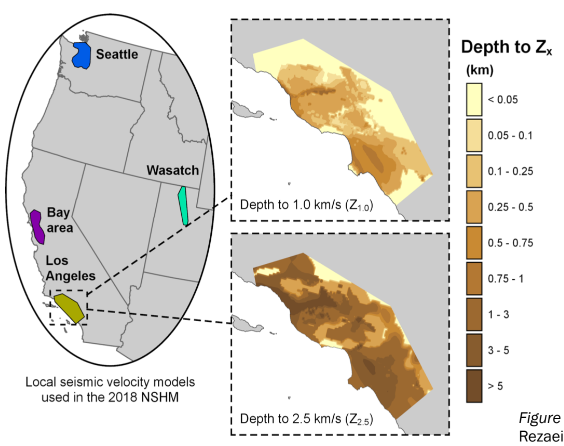
Deep Basin Effects



Categorized by:
basin depth terms $Z_{1.0}$ & $Z_{2.5}$

Within basins:
measurements only in deep portions of basins are used, "default" values are used in shallow depths

Outside basins:
"default" values are used

Figure citation: Map of basin locations from Shumway AM, Petersen MD, Powers PM, Rezaeian S, Rukstales KS, Clayton BS, 2021. "The 2018 update of the US National Seismic Hazard Model: Additional period and site class data," *Earthquake Spectra,* 37(2):1145-1161, doi:10.1177/8755293020970979.

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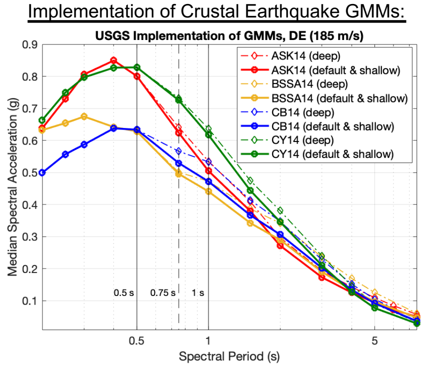
Deep Basin Effects

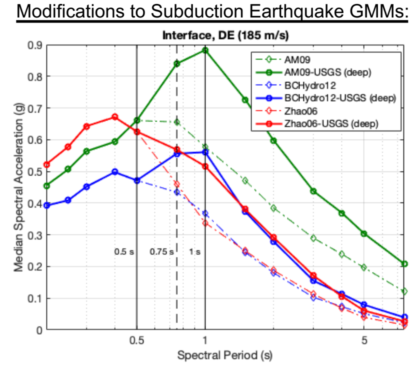
Figure citation: Powers et al., 2021. "The 2018 update of the US National Seismic Hazard Model: Ground motion models in the western US," *Earthquake Spectra*. doi: 10.1177/87552930211011200

Minor modifications made to crustal and subduction models.
Basin effects fully applied at periods above 1 sec:

Implementation of Crustal Earthquake GMMs:



Modifications to Subduction Earthquake GMMs:



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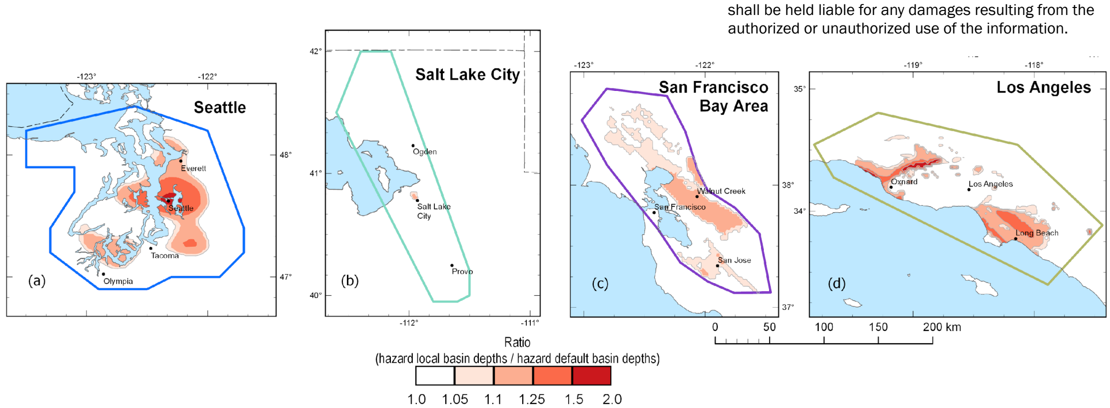
Hazard Changes (WUS)

Ratio Maps (2018 local basin depth/2018 default basin depth):
2% in 50yr uniform hazard, 5 sec, Site Class D (260 m/s)

Disclaimer: This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.



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Outside of Conterminous US (OCONUS)

<u>Developed Generic Spectral Shapes:</u>

FEMA/ATC report, approved by BSSC PUC.

Shapes developed based on WUS data, function(S_S, S_S/S_1, T_L)

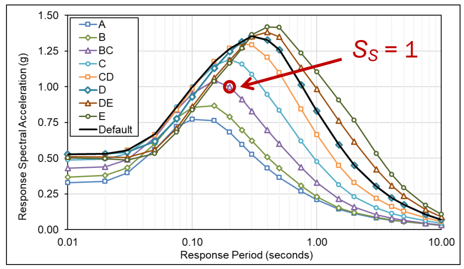
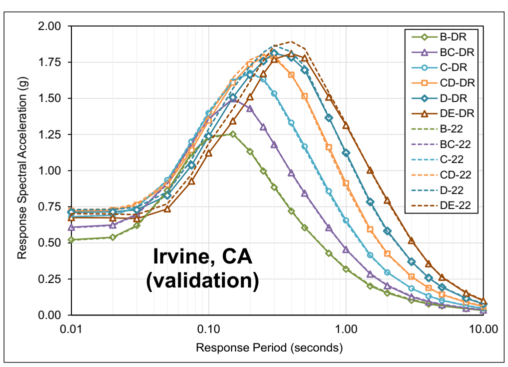


Figure B-17. Plots of probabilistic response spectrum shape parameters (RSSPs) by site class for Table B-17. GTL12S3R2.

Figure citation: Kircher C, Rezaeian S, Luco N – FEMA P-2078 (2020), *Procedures for Developing Multi-Period Response Spectra of Non-Conterminous United States Sites,* FEMA P-2078, prepared by ATC for FEMA, Washington, D.C.

Outside of Conterminous US (OCONUS)



Solid Lines: Predicted values from *Ss* & *S*1
Dashed Lines: Exact values calculated for 2020 NEHRP

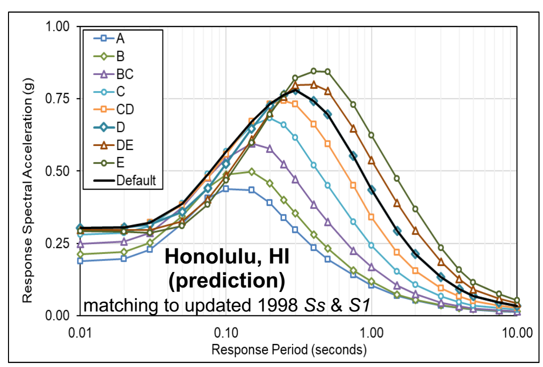


Figure citation: Kircher C, Rezaeian S, Luco N – FEMA P-2078 (2020), *Procedures for Developing Multi-Period Response Spectra of Non-Conterminous United States Sites,* FEMA P-2078, prepared by ATC for FEMA, Washington, D.C.

Summary

- The Multi-Period-Response-Spectra requirement of the BSSC PUC influenced the 2018 update of USGS NSHM because GMMs needed to be applicable for 22 periods and 8 site classes
- The 2018 USGS NSHM updates included: (1) new GMMs in CEUS (14 updated seeds + 17 NGA-East + new site-effects model), (2) incorporation of deep basin effects in WUS, (3) removal of one crustal and one subduction GMM and minor modifications in WUS, and (4) update of seismicity catalog.

1. *Petersen et al. (Feb 2020), Earthquake Spectra* (Overview)
2. *Petersen et al. (2021), Earthquake Spectra* (sensitivity analysis)
3. *Shumway et al. (2021), Earthquake Spectra* (data paper on added Ts and Vs30s)
4. *Rezaeian et al. (2021), Earthquake Spectra* (CEUS GMM details)
5. *Powers et al. (2021), Earthquake Spectra* (WUS GMM and basin effect details)

- Generic spectral shapes used for OCONUS locations in 2020 *NEHRP Provisions* (FEMA P-2078 / ATC 136)

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Questions

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