Seismic Design and Public Policy in Western Kentucky: Issues and Alternatives

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CEUS Sources Workshop for the USGS National Seismic Hazard Maps
22-23 February 2012
Memphis, TN

Outline

- Introduction – Issues in Western Kentucky
- Probabilistic Seismic Hazard Analysis (PSHA)
- Alternative Approach – Scenario Seismic Hazard Analysis
- Summary

Development of NEHRP Provisions

Science

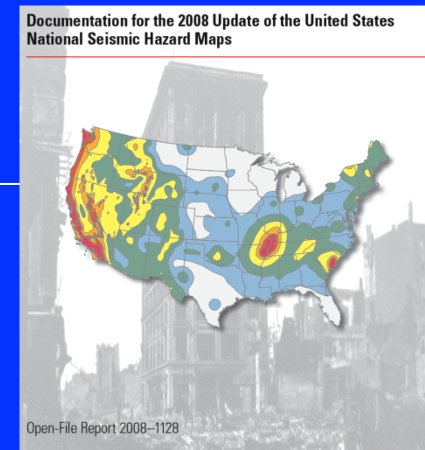
Seismic Hazard Map (USGS)

BSSC – Seismic Design Procedures Reassessment Group (SDPRG)

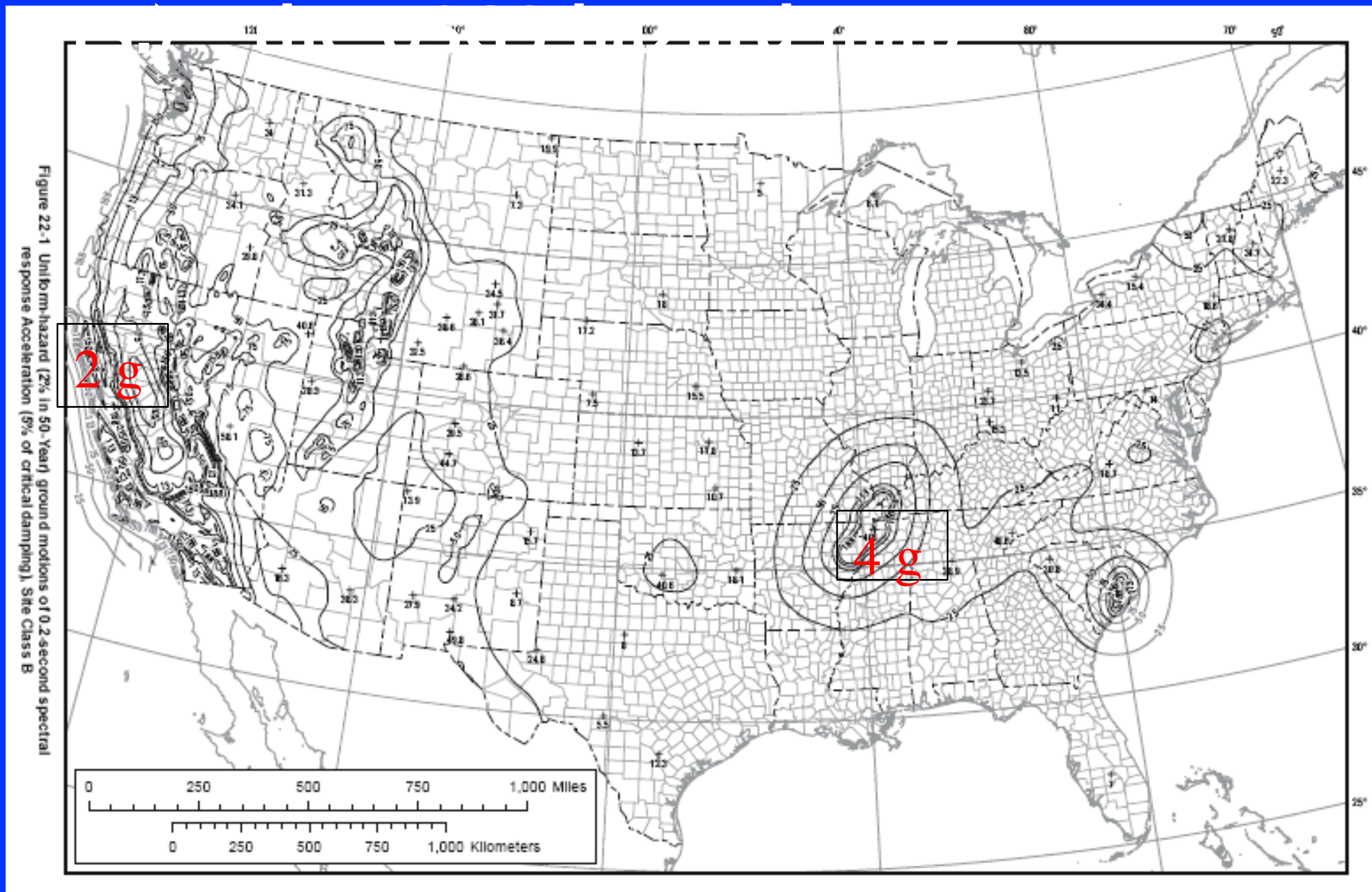
Policy

Seismic *Design Ground Motions* (FEMA)

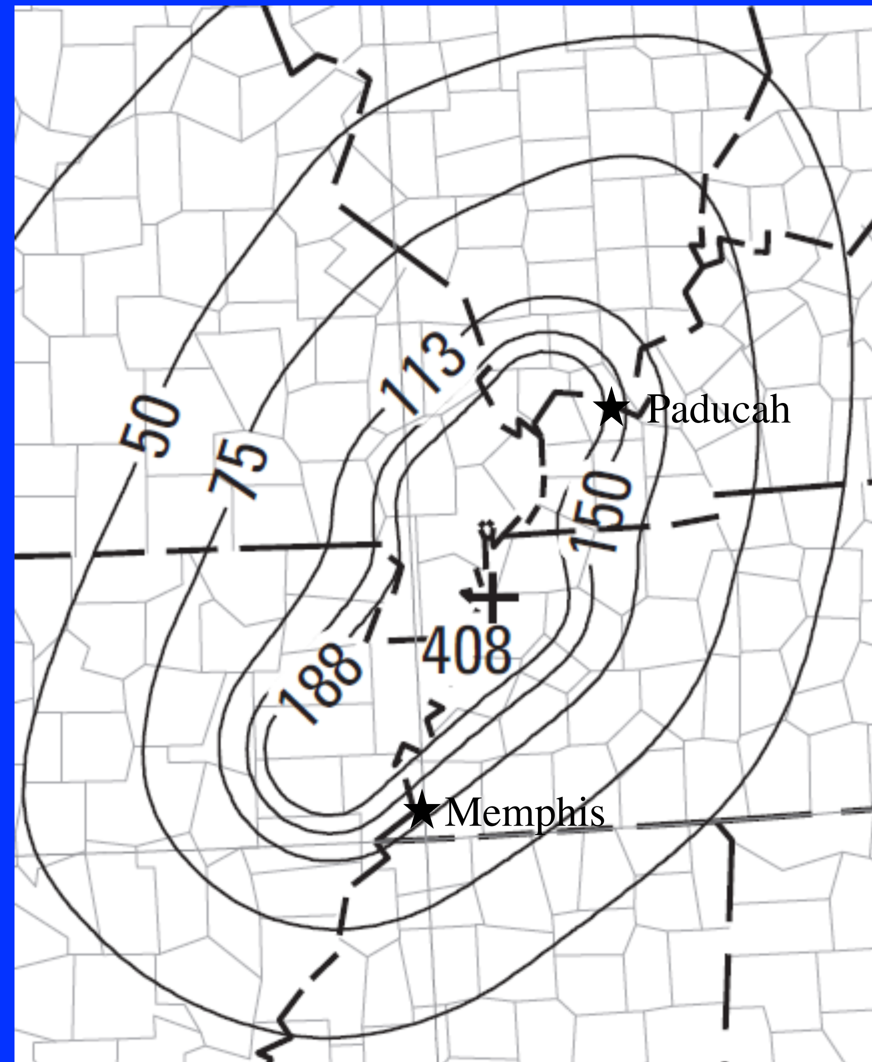
Federal agencies | State Agencies | Other organizations



NEHRP 0.2 sec Spectral Response Acceleration for the U.S. (2% PE in 50



(2009 NEHRP Provisions)



(2009 NEHRP Provisions)

Issues in the western Kentucky

WHEREAS, the NSHM influences building codes, insurance rates, risk assessments, federal facilities siting decisions and other public policy issues; and

- The City of Paducah

Because of USGS's current designation for this area, construction costs are extraordinarily high, especially when compared to communites in fairly close proximity. As a result of this seismic rating, this region has lost economic development opportunities that would provide replacement jobs for these workers. Industrial sites that have been negatively impacted include the Ohio River Triple Rail Megapark and I-24 Logistics Park in McCracken County and the West Kentucky Megasite in Graves County as well as individual community industrial sites in this region.

- Paducah Area Chamber of Commerce

Paducah Gaseous Diffusion Plant

C-746-U Landfill Design Ground Motion

	Activity	Comments	Date
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B	Seismic Design of the C-746-U Contained Landfill was performed using a PGA of 0.4g (Solid Waste Landfill Technical Application)	After applicant submitted the three phase application process, regulators approved operation of the landfill in November 1996 via Permit No. 073-00045.	1994 through 1995
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(Beavers, 2010)

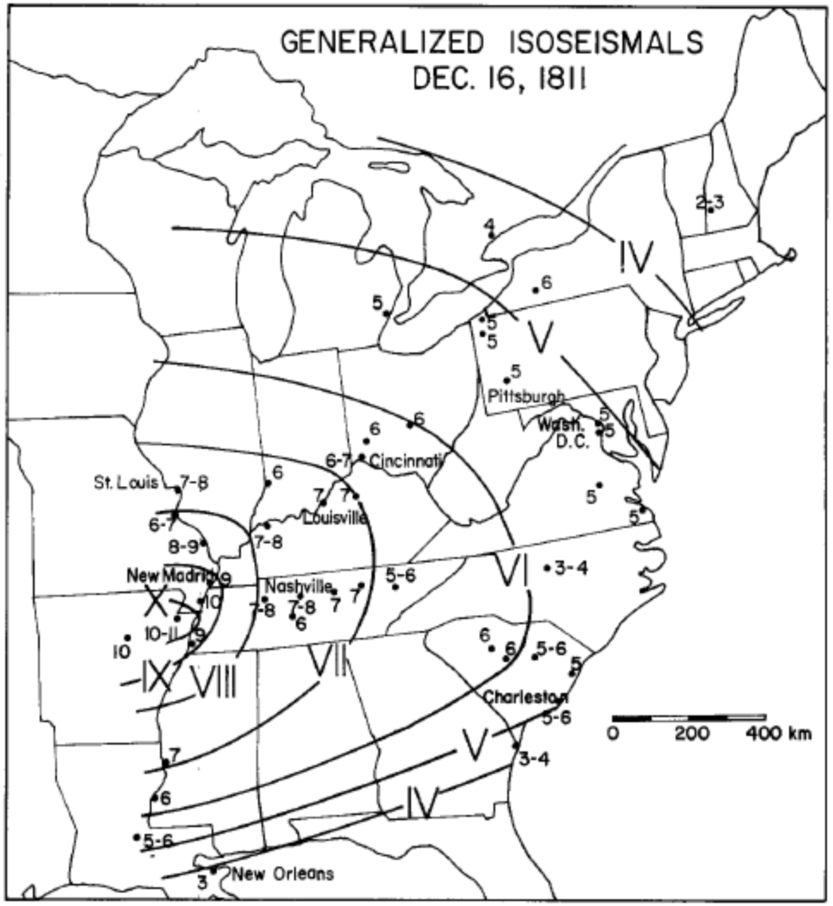
Subtitle D (40 CFR) mandates: Minimum design ground motion of 2% PE in 50 years or 2,500 years return period.

USGS-1996 maps (2% in 50yrs)
PGA of 1.2g (B/C)
PGA of 0.8g (hard rock)

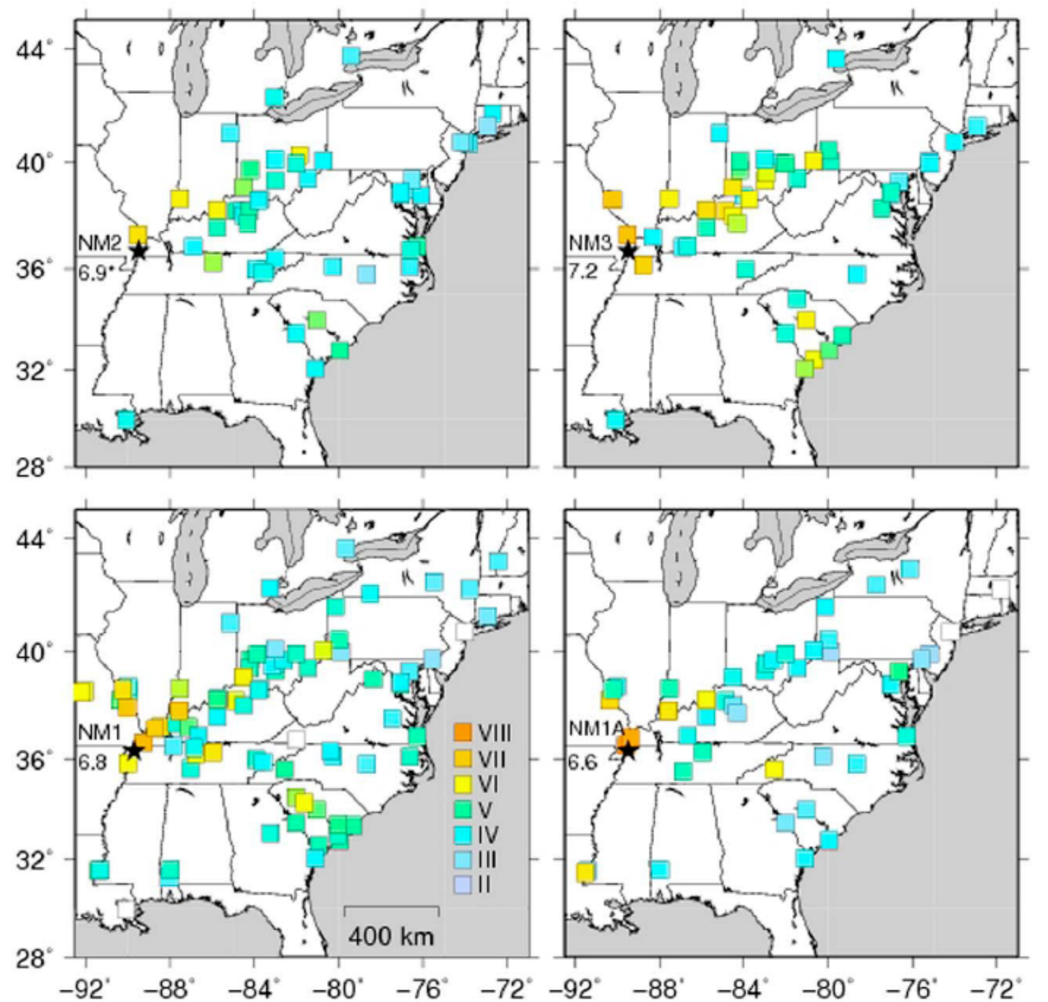
Cramer's Recommendation (2001)
PGA of 0.7g (2% in 50yrs)

There is no landfill in US that has been designed for 0.7/0.8g PGA.

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

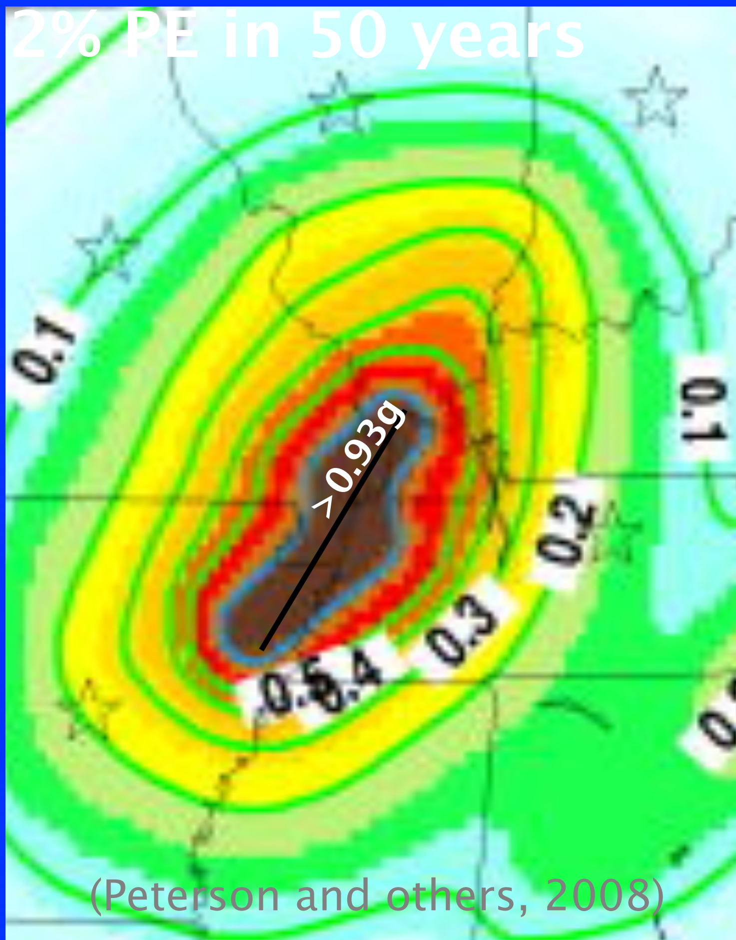


(Nuttli, 1973)



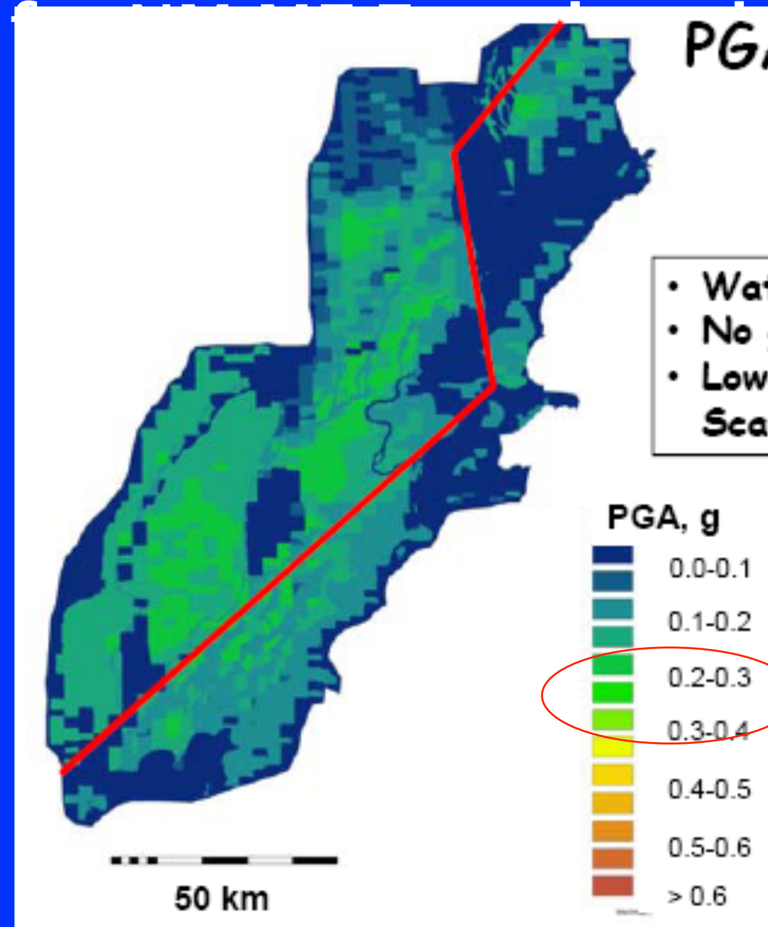
(Hough and Page, 2010)

National Seismic Hazard map for Central U.S. – PGA with 2% PE in 50 years



(Peterson and others, 2008)

PGA inferred from liquefaction



(Holzer and others, 2010)

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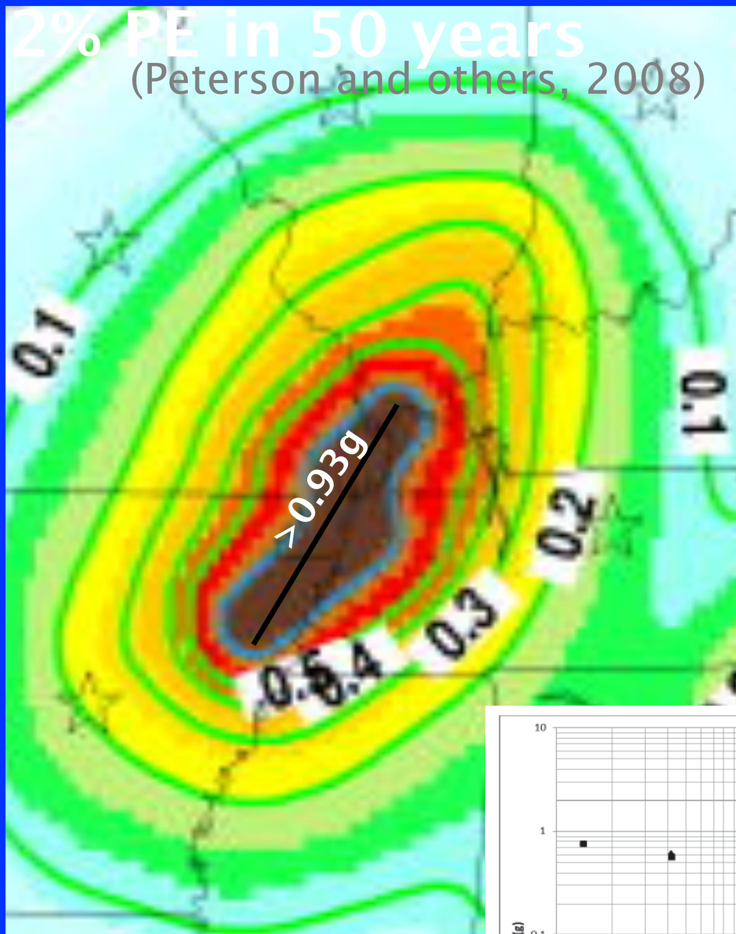
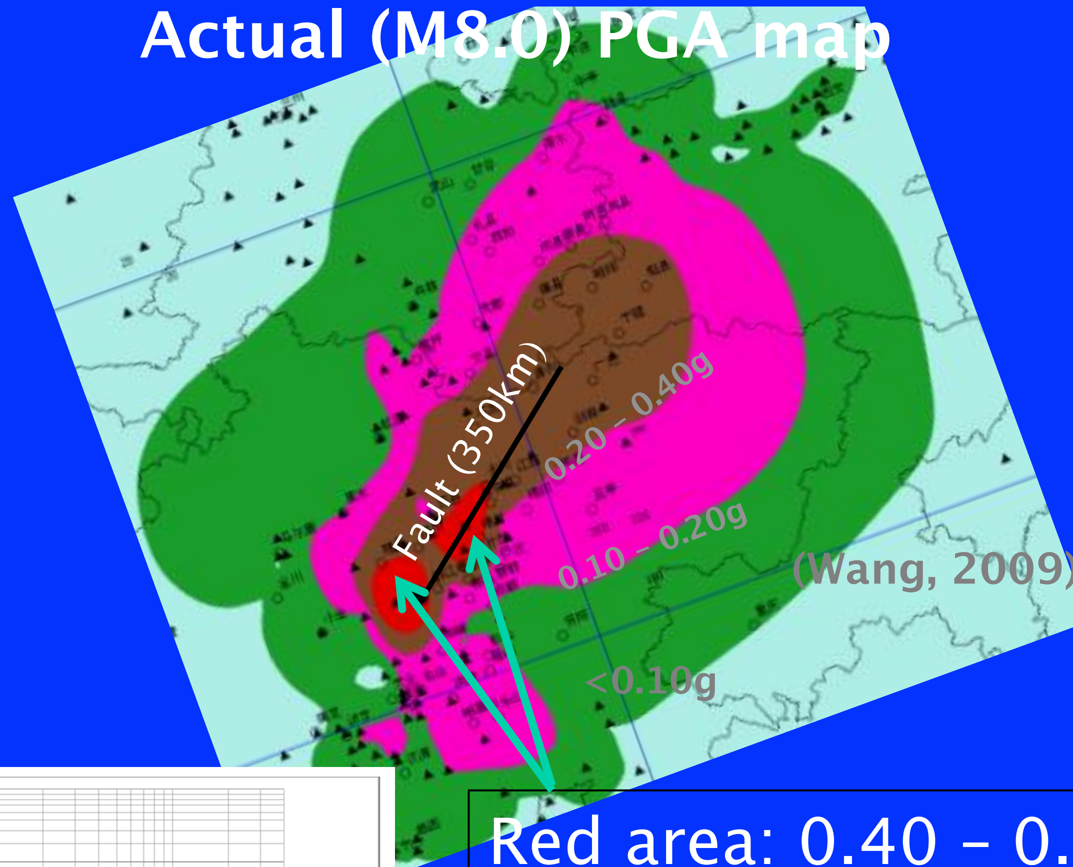


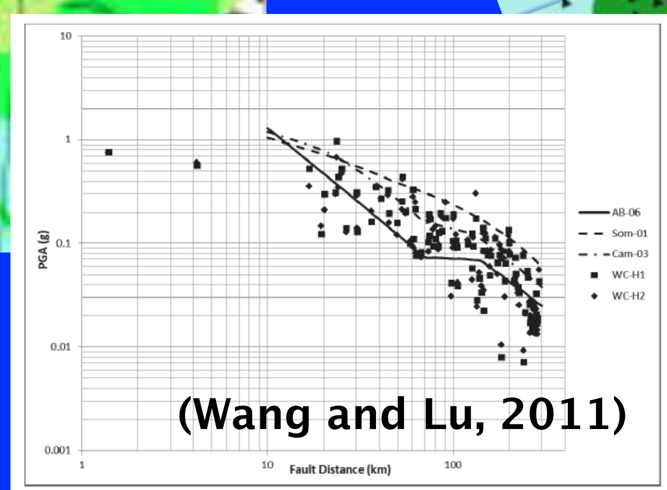
(Peterson and others, 2008)

China – Wenchuan earthquake Actual (M8.0) PGA map



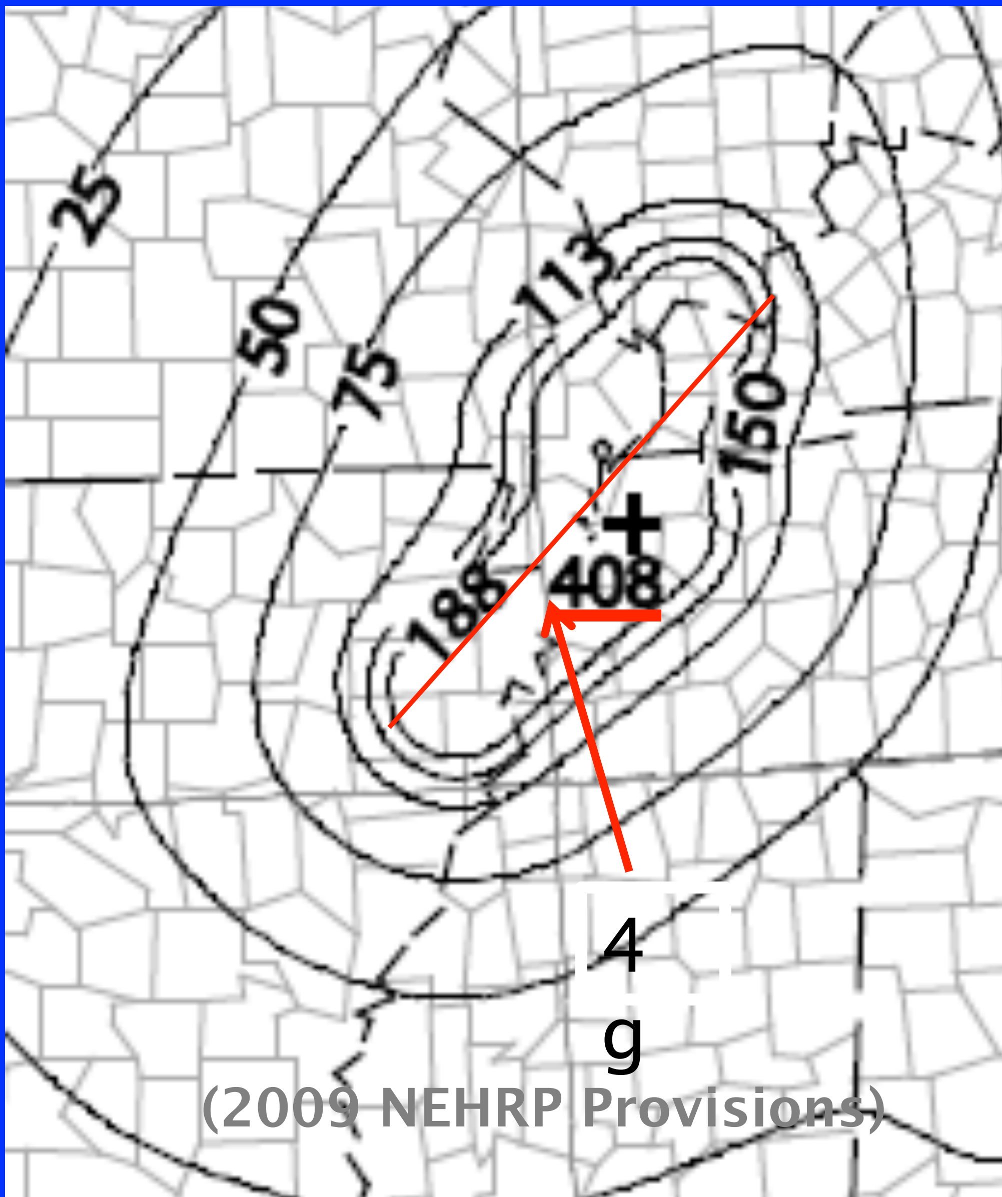
(Wang, 2009)

Red area: 0.40 – 0.8

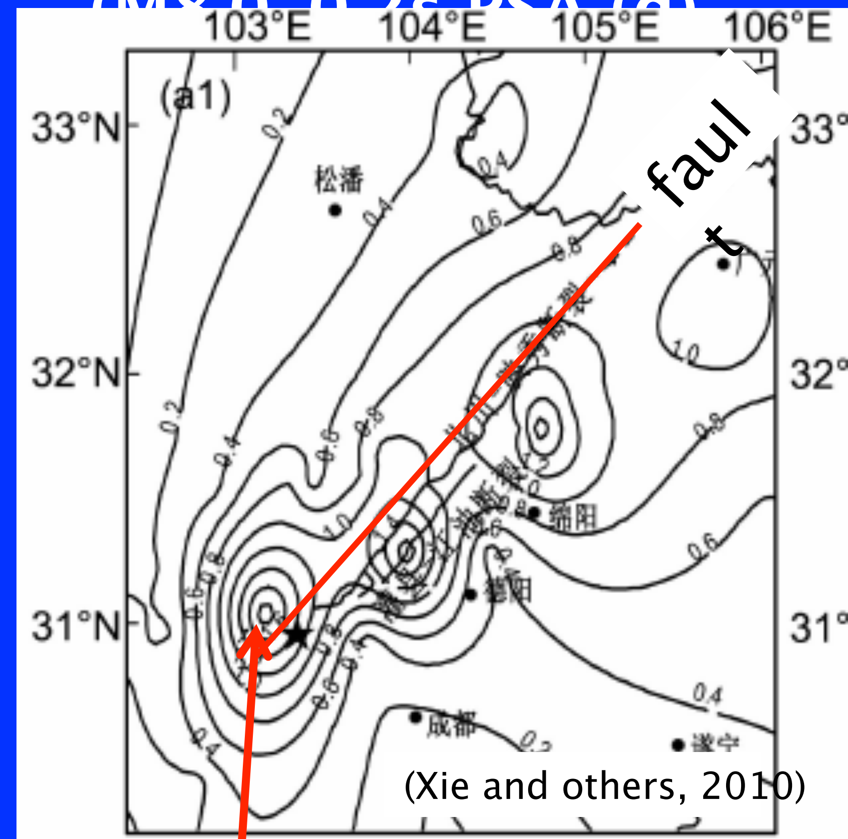


(Wang and Lu, 2011)

NEHRP 0.2 sec PSA (%g, with 2% PE in 50 years)



Actual record 2008 Wenchuan earthquake (M8.0, 0.2s PSA (g)



1.8 g

The National Seismic Hazard Maps

Inputs

Scientific data

Modeling (computer)

PSHA

Outputs

Hazard curves and maps

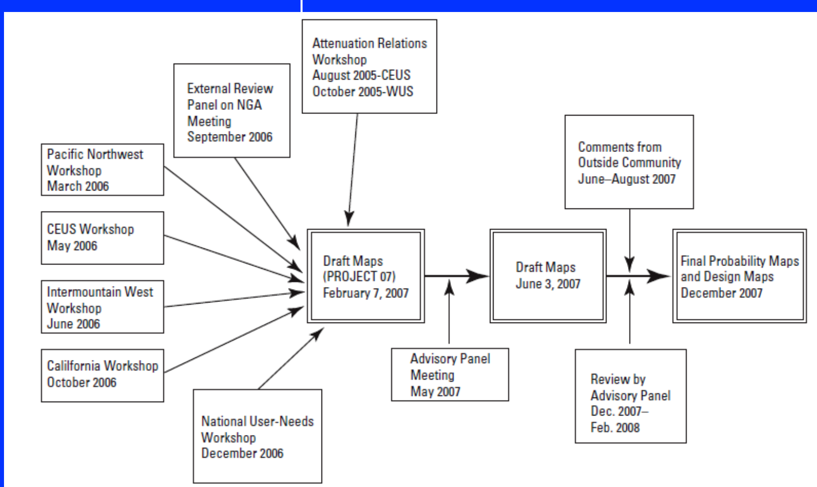
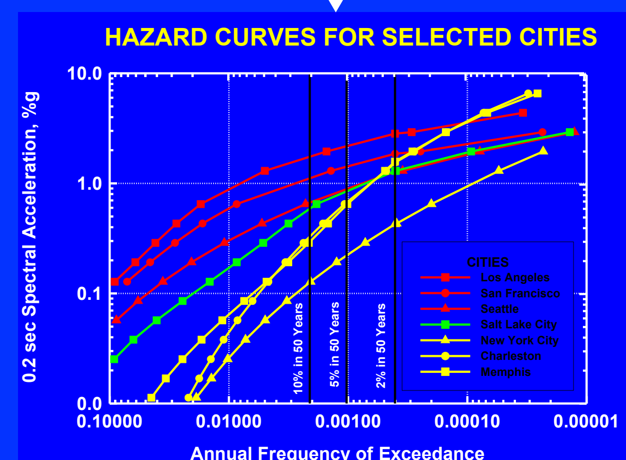


Figure 1. Process for developing the 2008 USGS National Seismic Hazard Maps. CEUS, Central United States; WUS, Western United States.



Probabilistic Seismic Hazard Analysis – PSHA

--- "PSHA is a creature of the engineering sciences, not the Earth sciences, and most of its top practitioners come from engineering backgrounds" (Hanks, 1997).

--- the Yucca Mountain PSHA: 11g PGA at 10^{-8} per year – the 2011 SSA Joyner Lecture (Hanks, 2011)

--- There is a debate on PSHA at the 2012 SSA
Debate #2 - PSHA Methodology (3:30 – 5:00pm on Wednesday, April 18, 2012)

--- PSHA is a mathematical formulation derived from a rigorous probability analysis on distributions (statistical relationships) of earthquake magnitudes, locations, and ground motion attenuation (McGuire, 2008).

(McGuire, 2008)

The basic formulation of PSHA was generalized in the 1970s using the 'total probability theorem':

$$P(Y > y) \simeq \sum \nu_i \iint P[Y > y|M,R] f_{M,R}(m,r)\, \mathrm{d}m\, \mathrm{d}r \quad (6)$$

(McGuire, 2004)

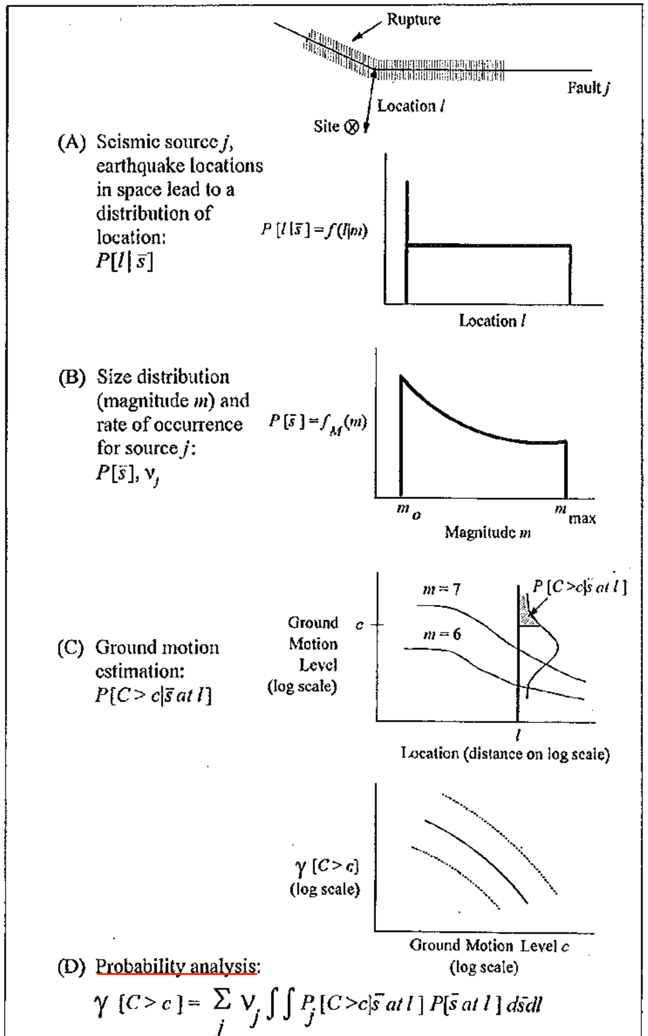


Figure 2. The steps in performing a PSHA.

13

Probability = Frequency (1/yr.)?

$$\gamma_j(C \text{ exceeds } c) = \gamma_j(C > c)$$
$$= \nu_j \iint P_j[C > c|\bar{s} \text{ at } l] P[\bar{s} \text{ at } l] d\bar{s} dl \quad (4)$$

where

γ_j = the frequency with which c is exceeded from earthquakes at source j

$\bar{s}$ = a vector of source properties

ν_j = the rate of occurrence of earthquakes of interest at source j

$P_j[C > c|\bar{s} \text{ at } l]$ = the probability that c is exceeded at the site, conditional on an earthquake at source j, with properties $\bar{s}$ at location l (the vertical line means "given that")

$P[\bar{s} \text{ at } l]$ = the probability that an earthquake with source properties $\bar{s}$ occurs at location l

12

are those which cause an intensity at the site in excess of some value i. The probability, p_i, that any event of interest ($M \geqq m_0$) will be a special event is given by equation 12.

$$p_i = P[I \geqq i] = \frac{1}{l} CG \exp\left[\frac{-\beta}{c_2} i\right]. \qquad (19)$$

$$P[I_{\max}^{(t)} \leq i] = P[N = 0] = e^{-p_i \nu t}. \qquad (21)$$

If we let $I_{\max}$ equal $I_{\max}^{(1)}$, the *annual* maximum intensity, $t = 1$, and

$$F_{I_{\max}^{(i)}} = e^{-p_i \nu} = \exp\left[-\nu CG \exp\left(-\frac{\beta}{c_2} i\right)\right] \qquad i \geqq i' \qquad (22)$$

(Cornell, 1968)

If the annual probabilities of exceedance are small enough (say ≤ 0.05), the distribution of $I_{\max}$ can be approximated by

$$\begin{aligned} 1 - F_{I_{\max}^{(i)}} &= 1 - e^{-p_i \nu} \cong 1 - (1 - p_i \nu) \\ &\cong p_i \nu \\ &\cong \nu CG \exp\left(-\frac{\beta}{c_2} i\right) \qquad i \geqq i'. \end{aligned} \qquad (23)$$

The average return period, T_i, of an intensity equal to or greater than i is defined as the reciprocal of $1 - F_{I_{\max}^{(i)}}$ or

$$T_i \cong \frac{1}{\nu CG} \exp\left(\frac{\beta}{c_2} i\right) \qquad i \geqq i' \qquad (24)$$

(Cornell, 1968)

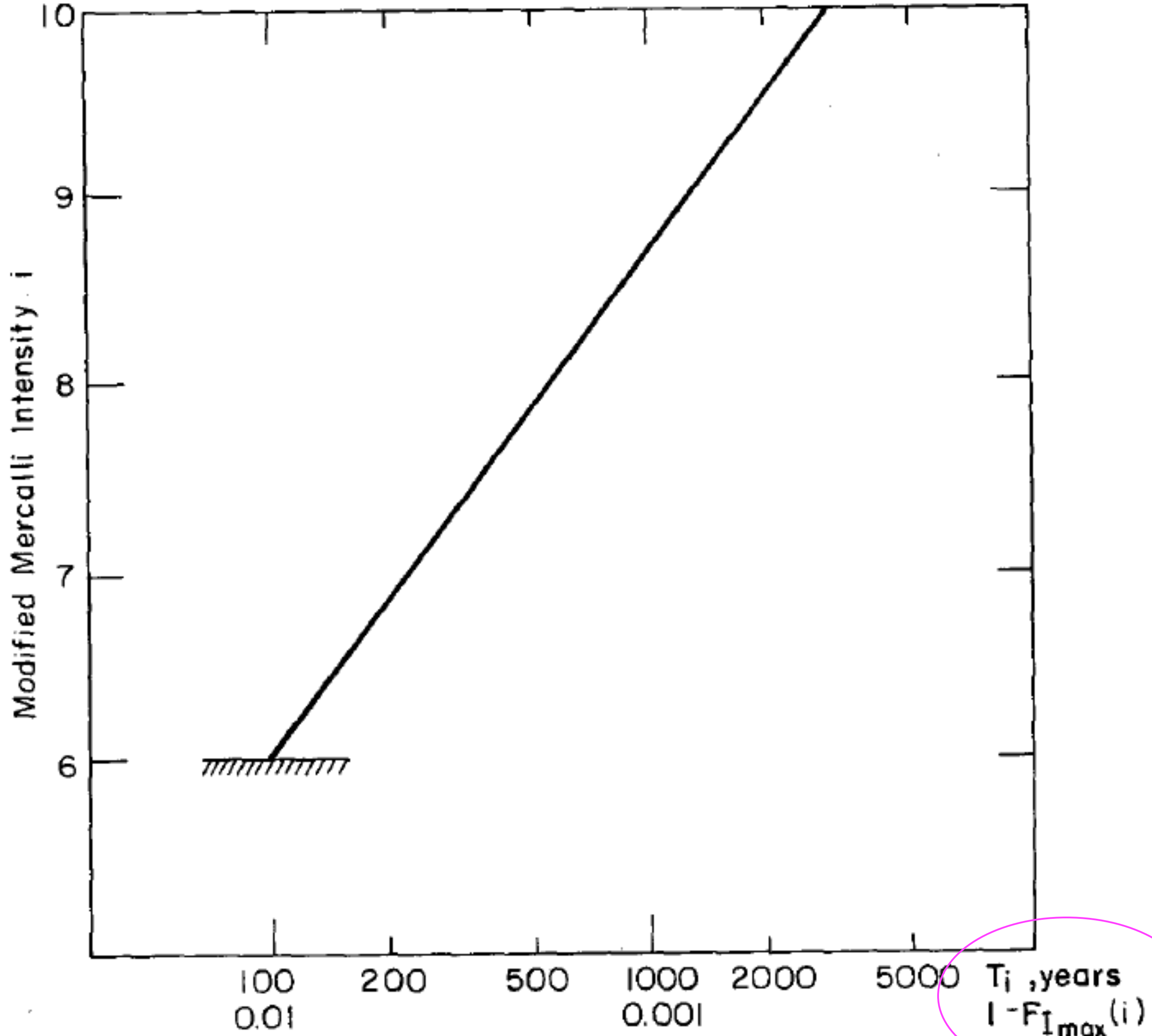
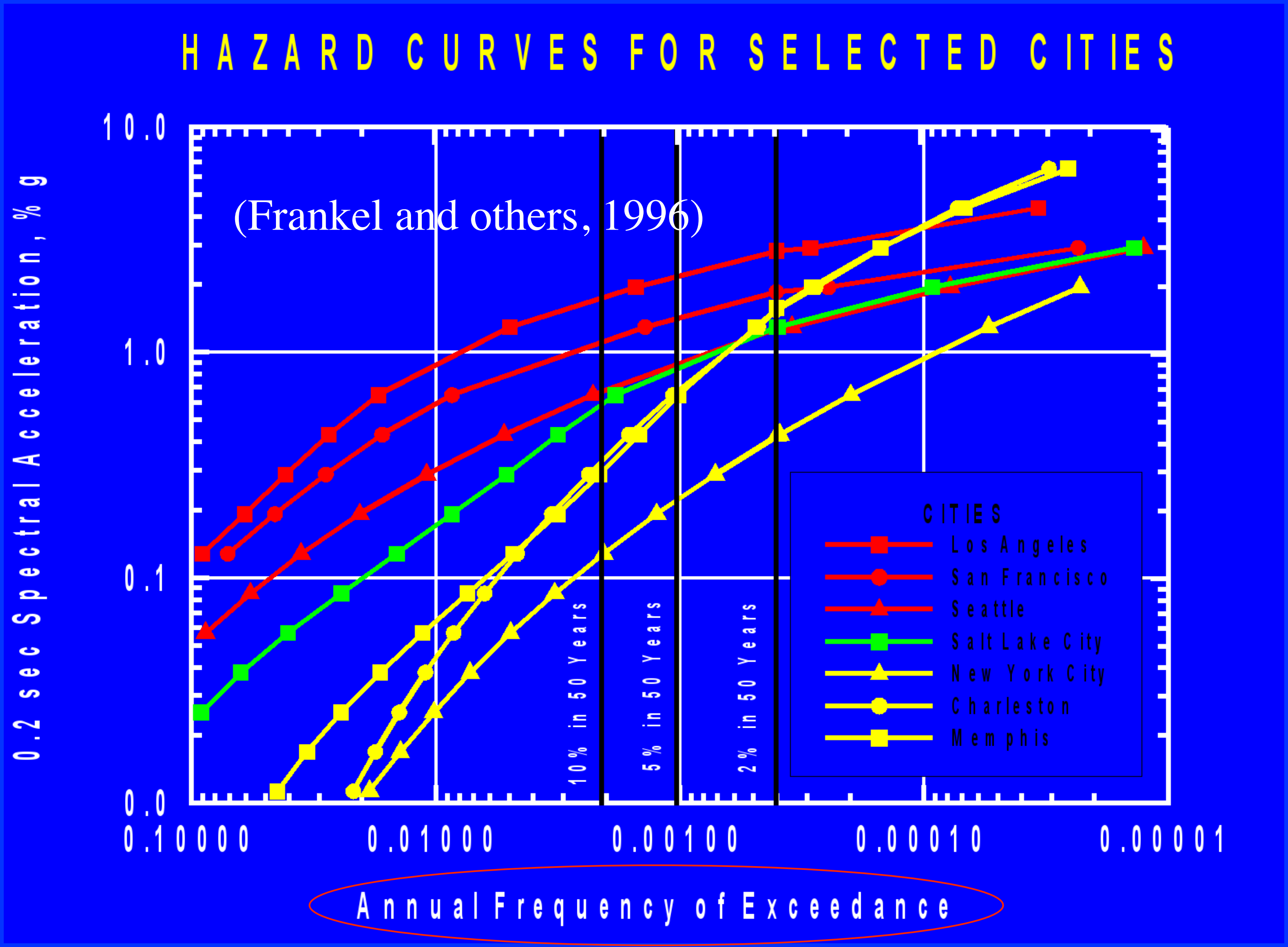


FIG. 4. Numerical example: Intensity versus return period.


HAZARD CURVES FOR SELECTED CITIES
(Frankel and others, 1996)
10.0
1.0
0.1
0.0
0.2 sec Spectral Acceleration, % g
0.10000
0.01000
0.00100
0.00010
0.00001
10% in 50 Years
5% in 50 Years
2% in 50 Years
CITIES
Los Angeles
San Francisco
Seattle
Salt Lake City
New York City
Charleston
Memphis
Annual Frequency of Exceedance

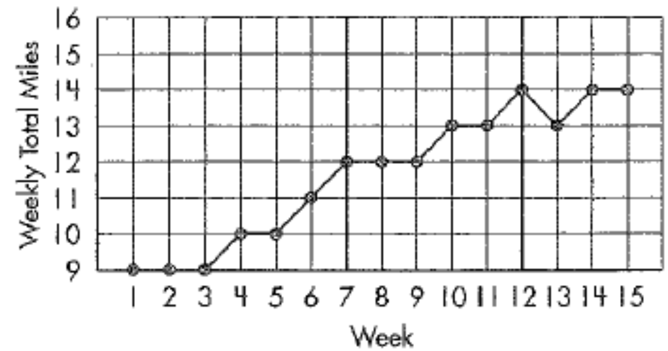
(1/yr.)

Probability ≠ Frequency (1/yr.) – Grade School Math

Answer the questions by interpreting data from the line graphs.

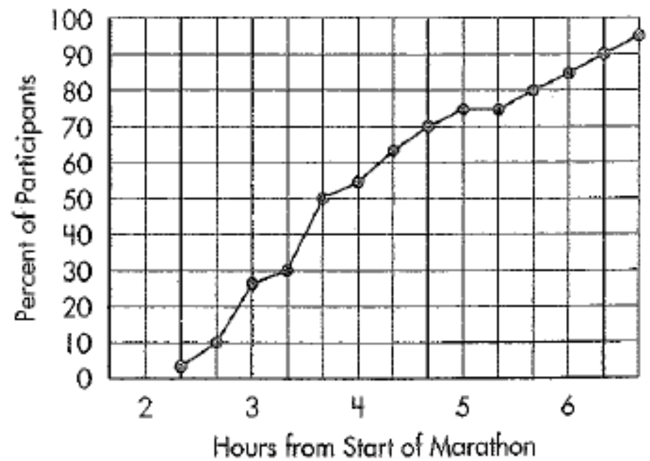
1. For how many weeks did Joel track his weekly running totals? 15 wks
2. How far did Joel run during week 3? 9 mi
3. How many more miles did Joel run in week 6 than in week 5? 1 mi
4. How many miles in all did Joel run during weeks 5, 6, 7, and 8? 45 mi

Joel's Weekly Running Totals



5. What was the earliest that anyone finished the marathon? $2\frac{1}{3}$ hrs
6. Approximately what percent of the people had finished after $3\frac{1}{2}$ hours? 40%
7. Approximately what percent of the people had finished after 6 hours? 85%
8. By what time had more than 50% of the people finished? $3\frac{2}{3}$ hrs

Marathon Times



(6^{th} grade math test)

The National Seismic Hazard Maps

Inputs

Good Scientific data

→

Modeling (computer)

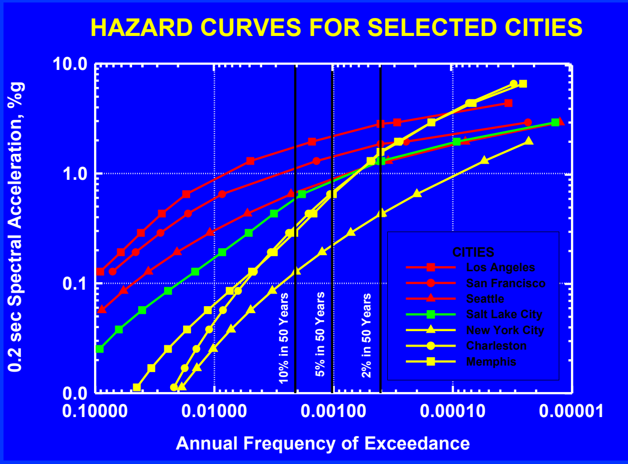
PSHA
?

Math Is Wrong

→

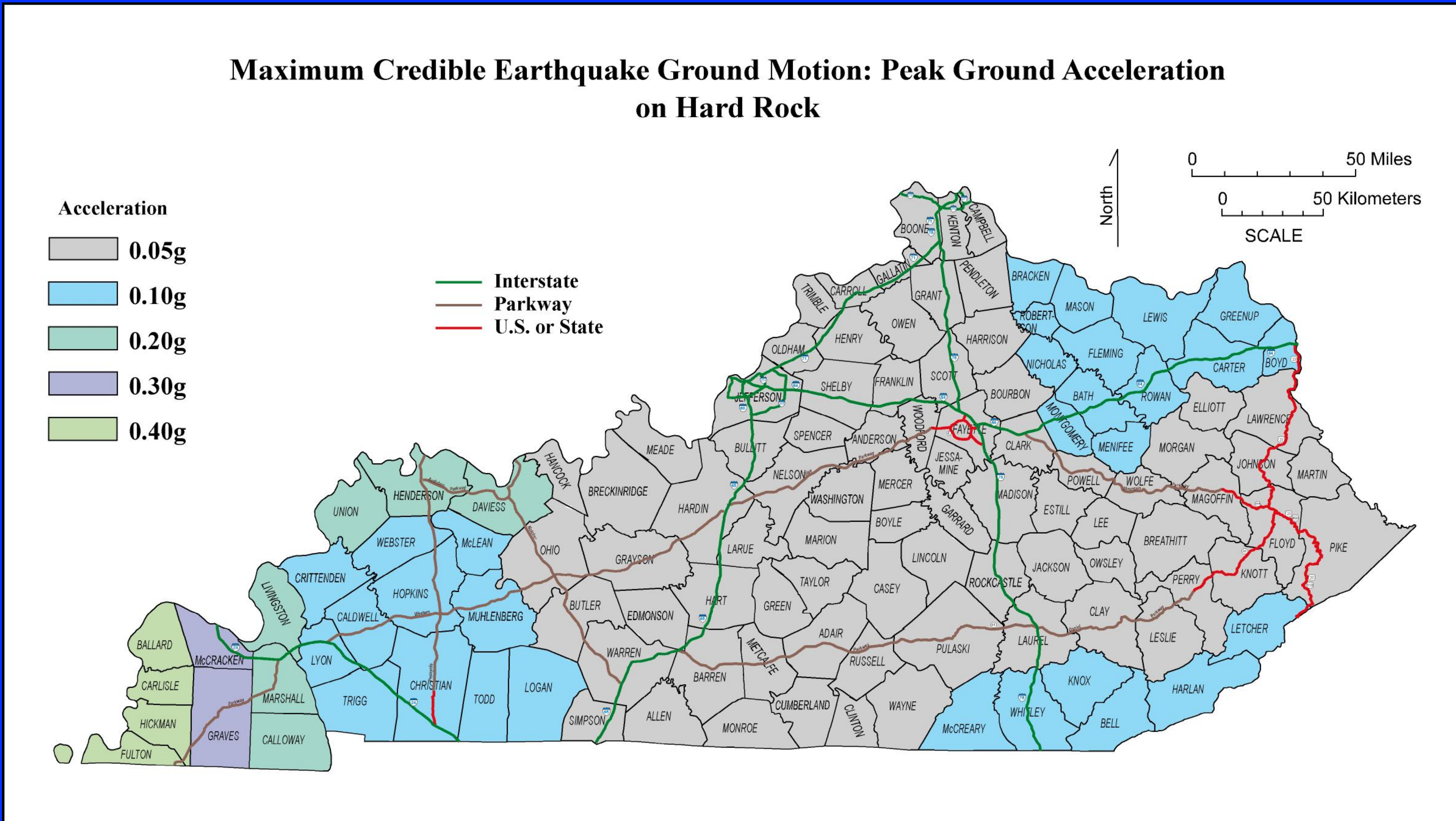
Outputs

Hazard curves and maps ?



The problem is the methodology - PSHA

The KGS Scenario/Deterministic Ground Motion Hazar



1. Seismic design of bridge and highway facilities
2. Seismic design of Landfills and other facilities
3. Basis for revision of the Kentucky Residential Code

C-746-U Landfill Design Ground Motion

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(Beavers, 2010)

One of Alternatives: Scenario Hazard Analysis

Scenario hazard analysis (Cramer, 2010):

PGA of 0.36g (bedrock)

Design PGA: 0.33g (surface)

Summary

- The National Seismic Hazard Maps have significant impacts on the society.

- The NSHM input data reflects "the best available sciences"

- However, the hazard curves and maps might not be scientific because the methodology – PSHA
  - The math is not correct
  - 1% (0.01) = 1% (0.01) per year (simply wrong)

- Scenario/Deterministic seismic hazard analyses is a good alternative

Thank you!