USGS National Seismic Hazard Maps: Kentucky Issues

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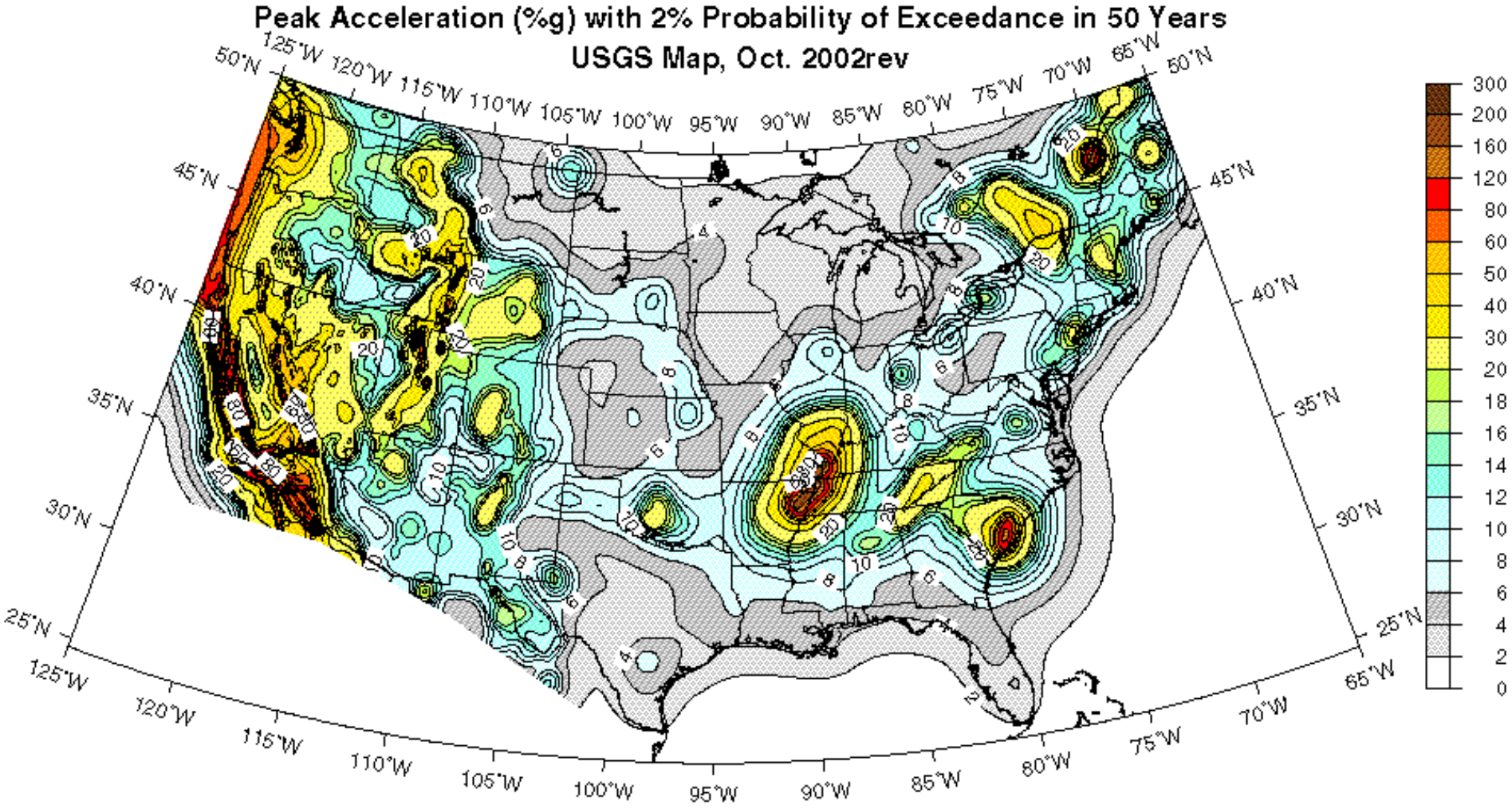
Key points presented at the SESAC meeting on June 3, 2004 in Memphis, TN:

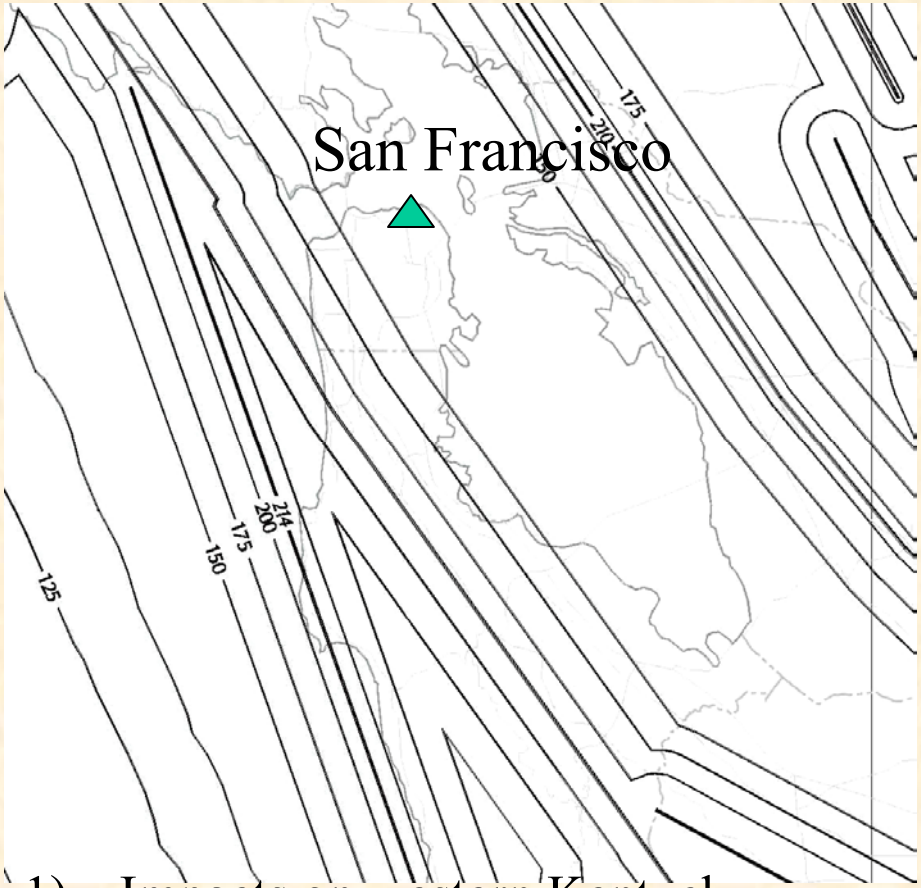
•USGS--"We don't make policy, we just make the maps." Yet the maps become de facto policy because of the IBC and IRC. Federal agencies such as EPA, DOE, and NRC adopt them in their regulations. When the IBC is adopted by a state then the 2% in 50 years map becomes policy.

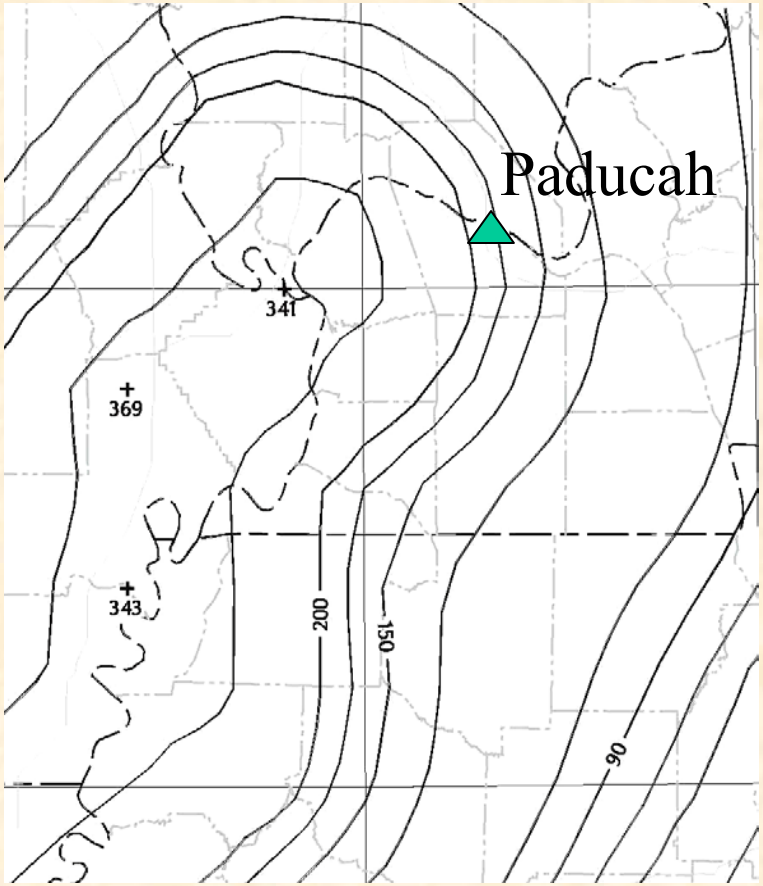
•Policy makers do not understand the maps or how they were made. Very few geologists understand them and the assumptions made in developing them.



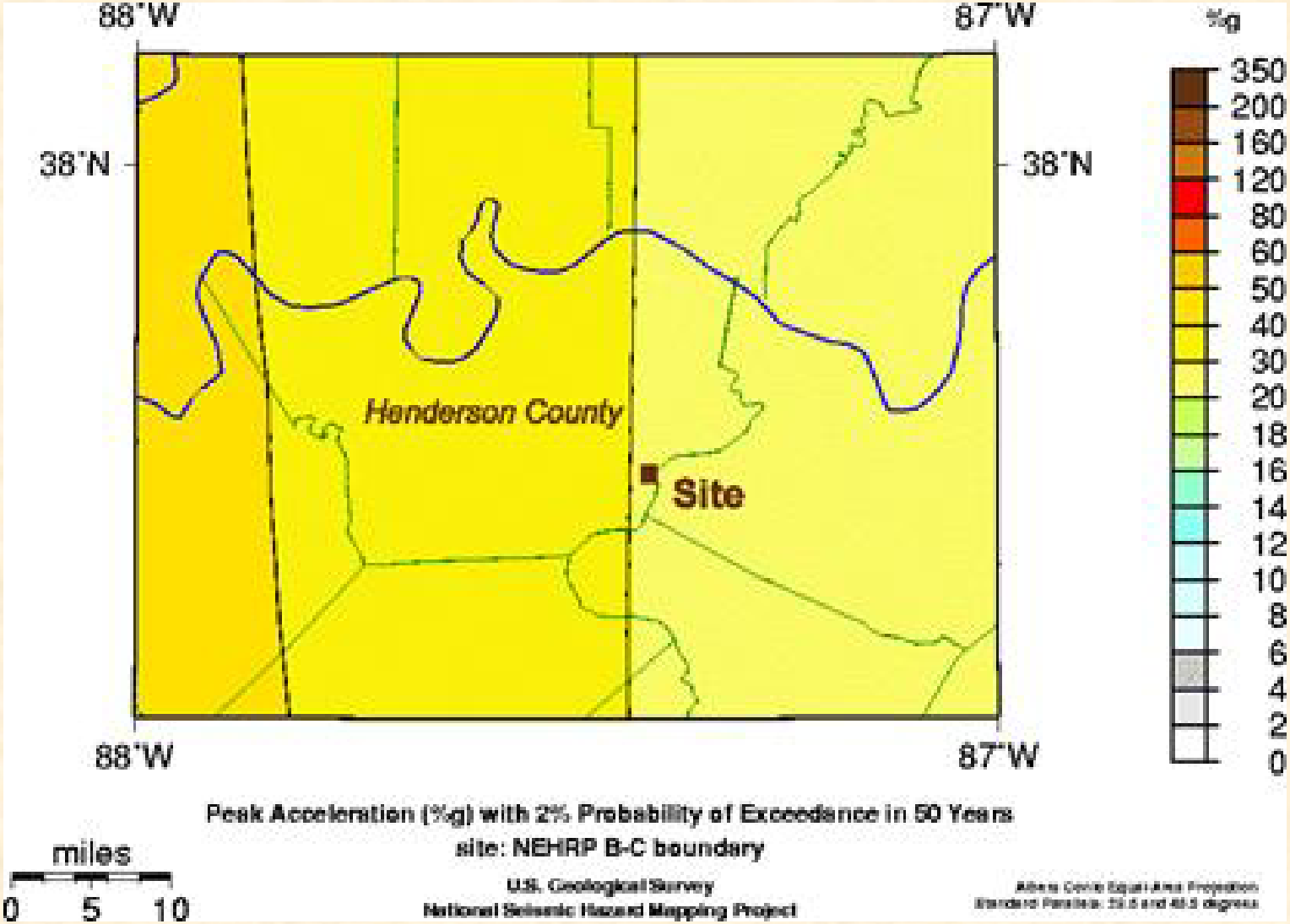
All policies based on or referred to the USGS hazard maps with 2% PE In 50 years

Design Ground Motion (0.2 s) in San Francisco and Paducah





1) Impacts on western Kentucky
    1) Residents in Paducah not be able to build a regular two-story house (without enlisting a design professional).
    2) DOE will not get a permit from KY-EPA to build a landfill at PGDP for clean-up.
    3) One of the main reasons that Kentucky lost the centrifuge facility ($2B) to Ohio.



The site must have low risk from significant seismic events:
PGA < 0.3g based on the USGS hazard maps with 2% PE in 50 years

As the State Geologist of Kentucky, I am called upon to interpret geologic conditions and seismic hazards for state officials, legislative committees, and industry personnel

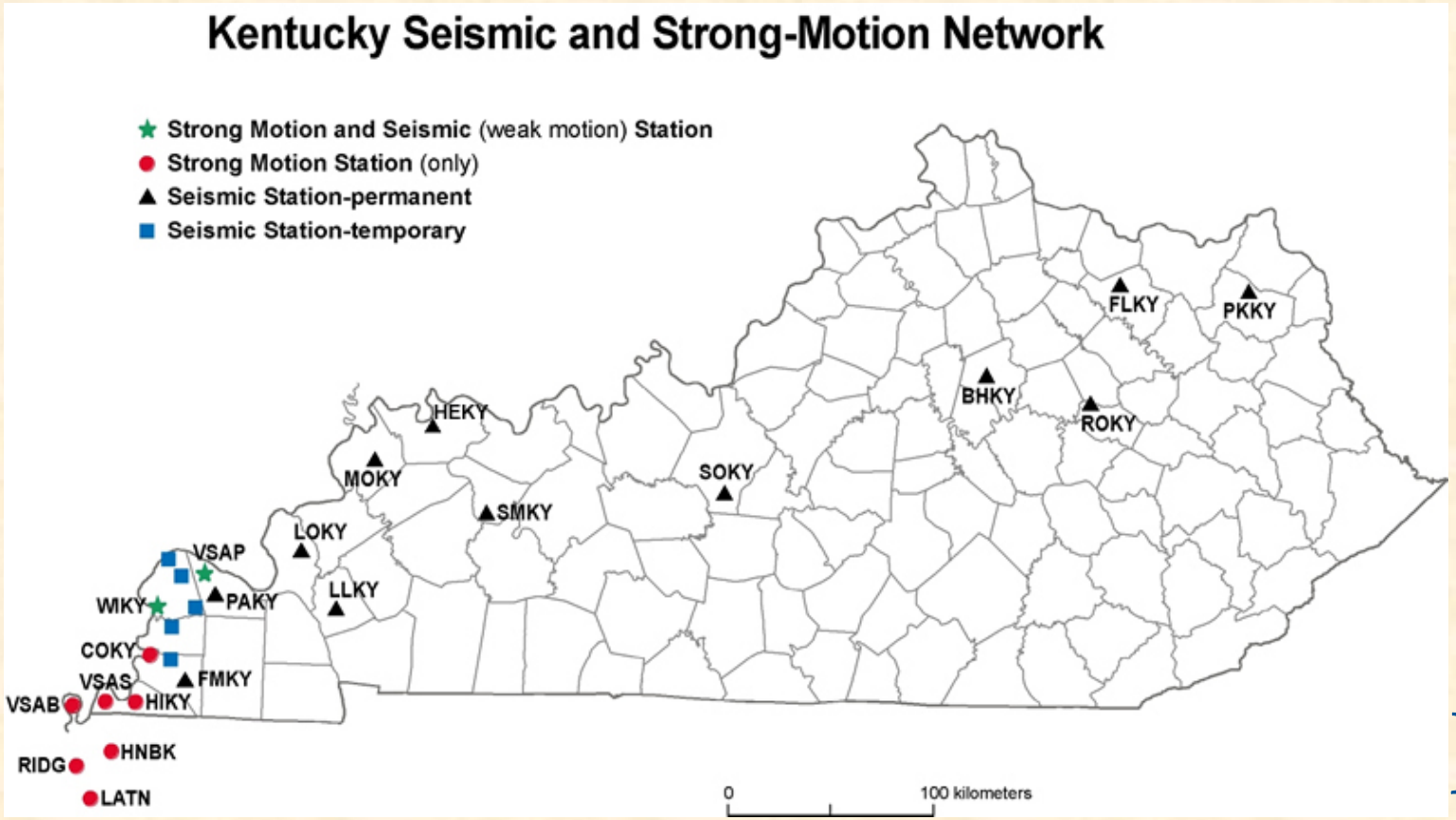
•The issue for Kentucky is what is the seismic hazard for Paducah and McCracken County?

•Earthquake information for the Paducah area is contradictory.

•I have great difficulty explaining the USGS National Seismic Hazard Maps and how they should be applied and what they mean.

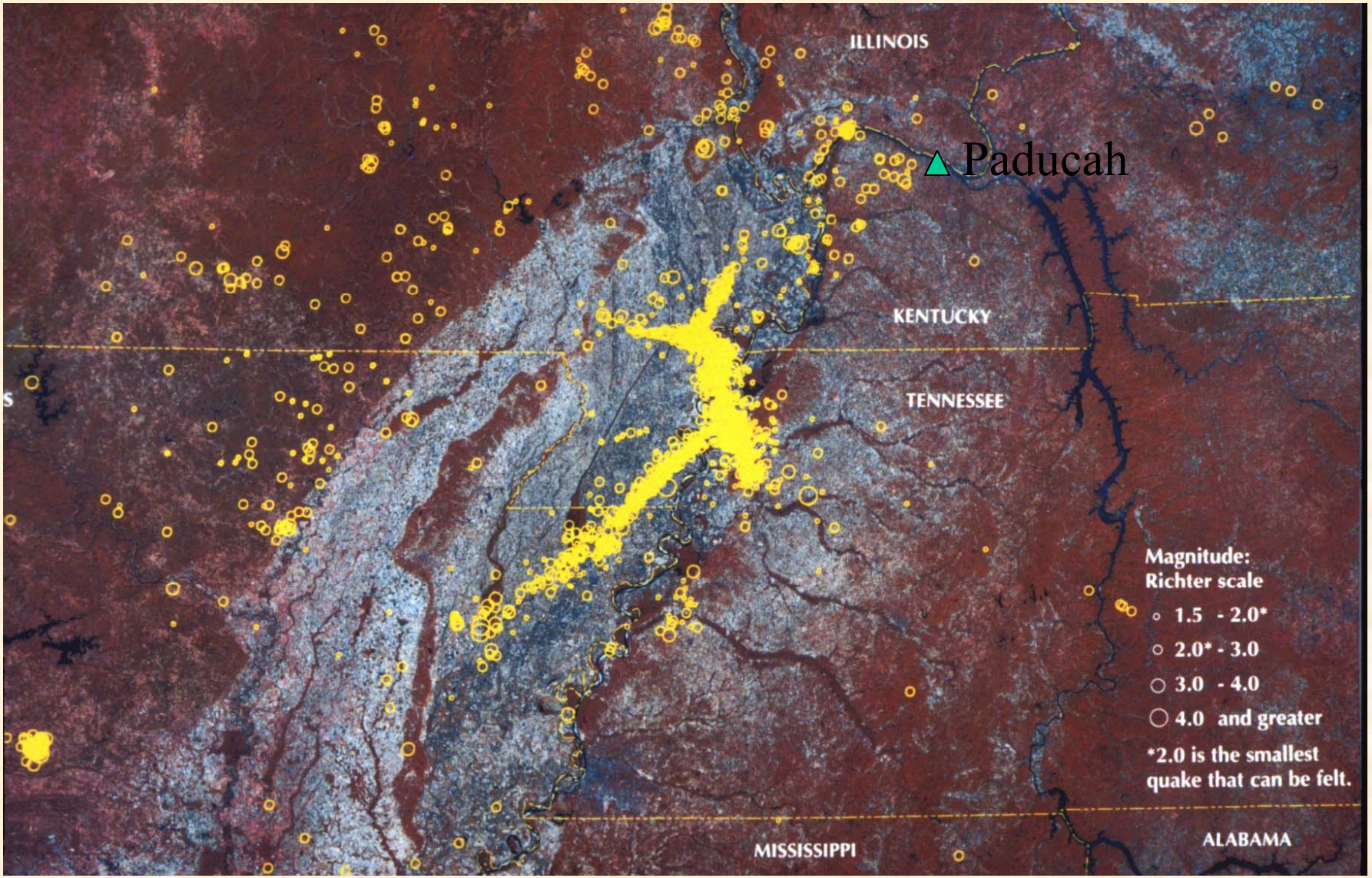
•KGS has current research on these important issues and a network

- 10 strong motion stations
- 12 permanent and 7 temporary seismic stations
- 850, 350, 345, and 120 ft. vertical arrays
- 2,000 ft. deep hole (DOE, USGS, KGS)



Important Unresolved Scientific Issues for Kentucky

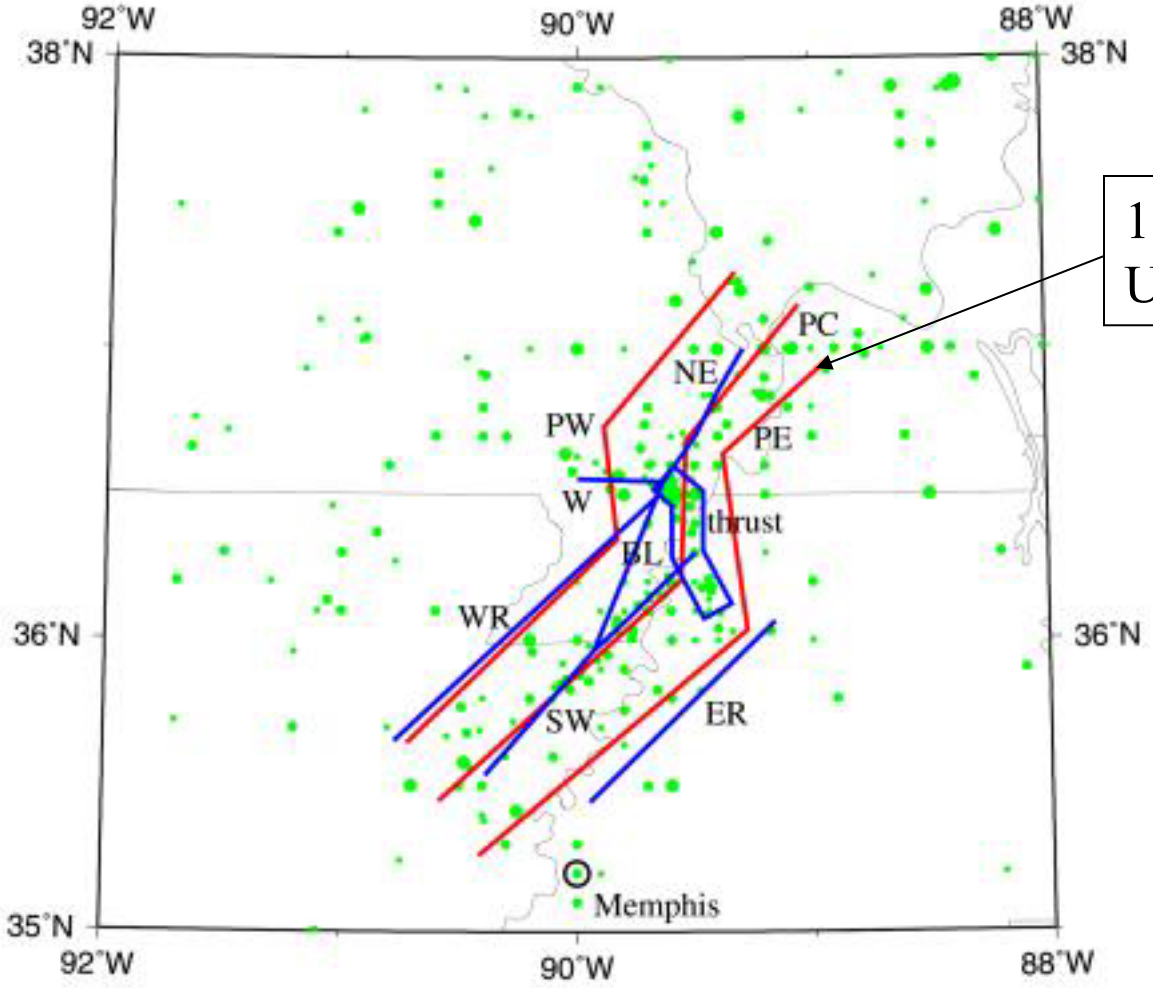
- Fault locations and boundaries, northern extent of NMSZ
- Attenuation factors, many choices and experts differ
- PSHA methodology, mathematical error in the hazard calculation



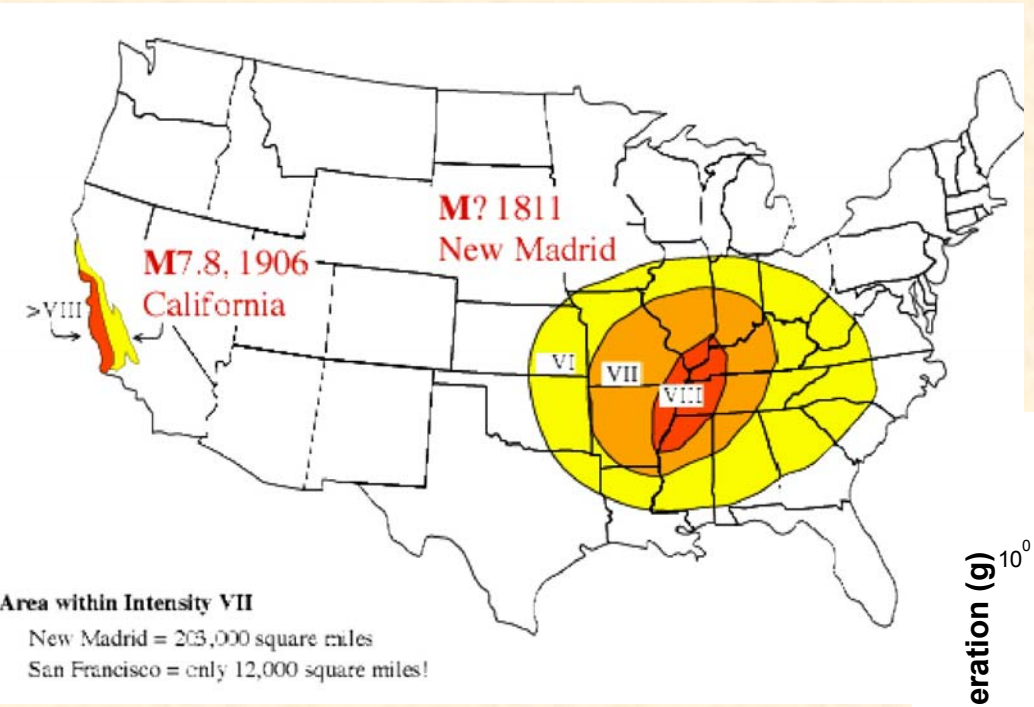
Is Paducah in the NMSZ? Where is the northern boundary of the NMSZ?

NMSZ Alternative Sources

Blue - Actual Flts; Red - Pseudo-Flts; Green - Eqks



1996 and 2002 USGS maps



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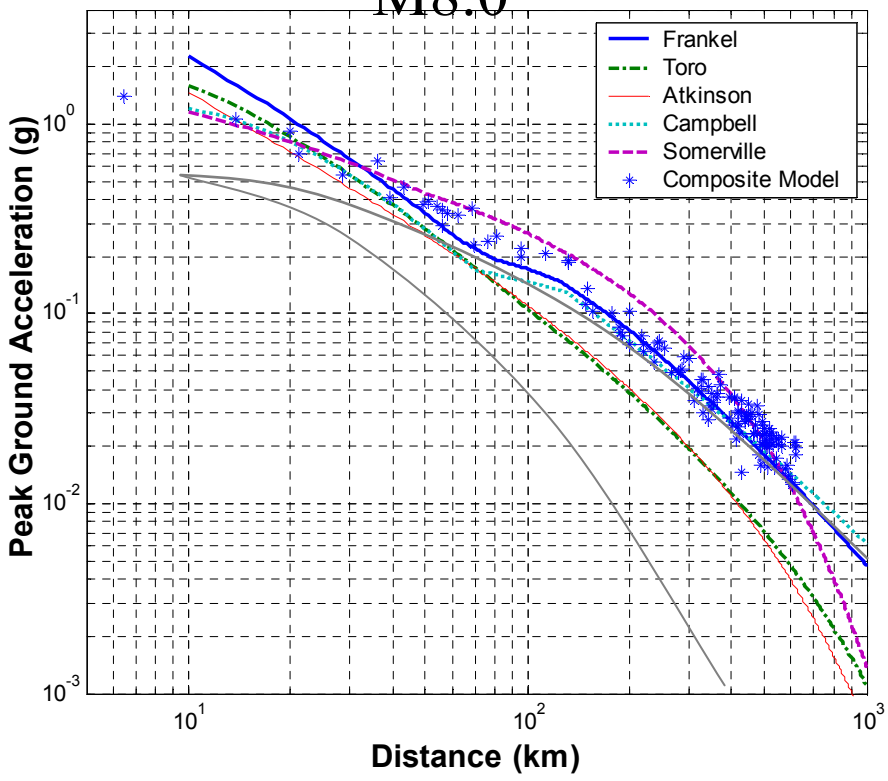


Ground motion attenuation relationship
Conservative near source

- We found

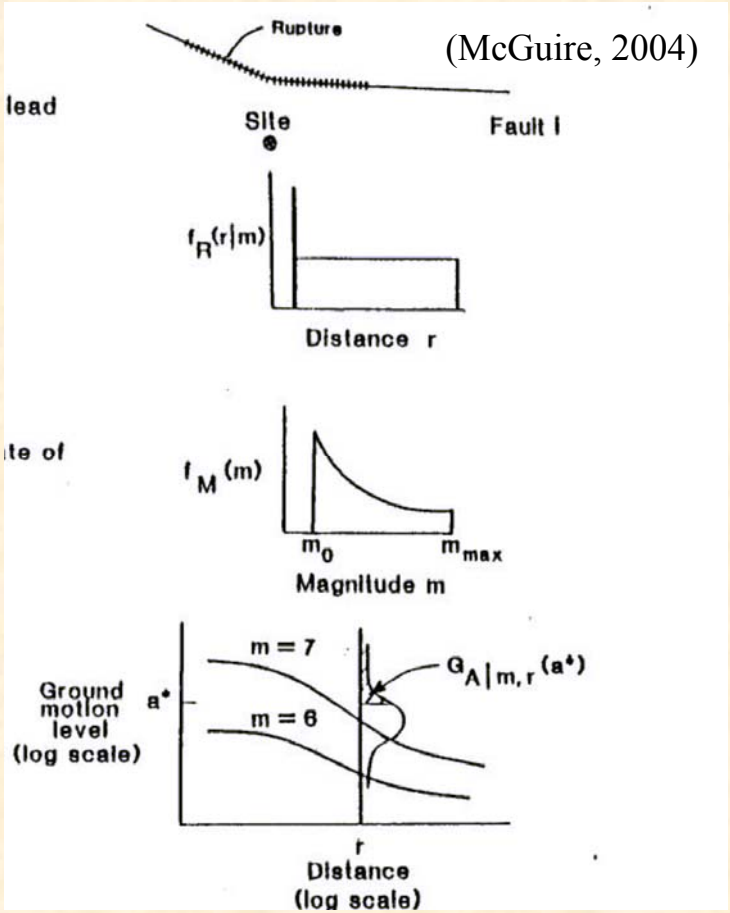
  There is a mathematical error in the NEHRP mapping methodology (PSHA)

  - This error results in
    - Invalid hazard calculation
    - Extrapolating the temporal characteristics of ground motion using the uncertainty of ground motion (spatial characteristics)
    - Difficult to understand and apply the results

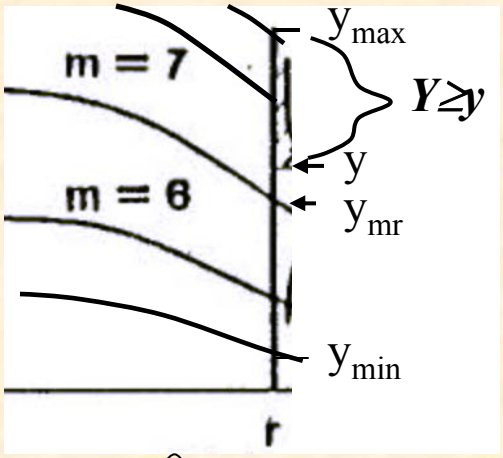
Mathematical error in PSHA

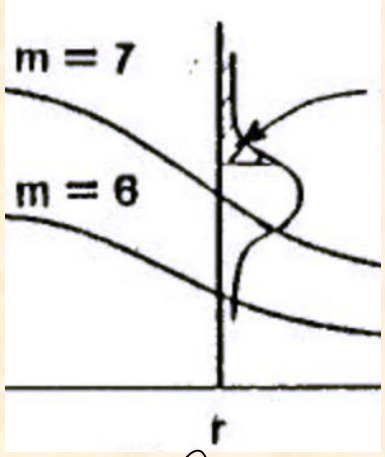
Basic equation for hazard calculation

$$\gamma(y) = \sum_j v_j P_j[Y \geq y] = \sum_j v_j \iint P_j[Y \geq y \mid m, r] f_{M,j}(m) f_{R,j}(r) dm dr$$



(McGuire, 2004)





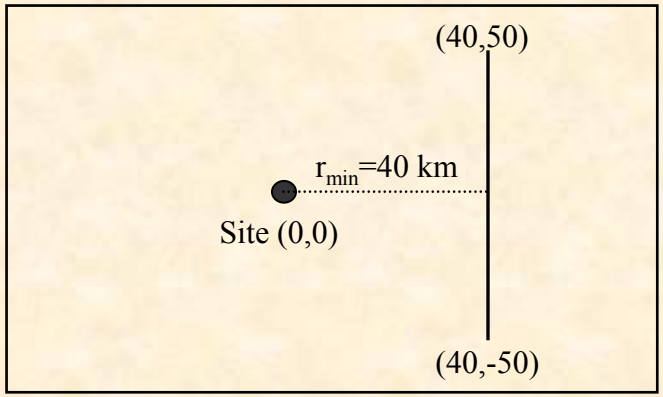
$$P_j[Y \geq y \mid m, r] = 1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,y}} \exp\left(-\frac{(\ln y - \ln y_{mr})^2}{2\sigma_{\ln,y}^2}\right) d(\ln(y))$$

Exceedance probability for ground motion attenuation relationship conditioned at given m and r – a function of m and r $(y_{max}\text{-}y)/(y_{max}\text{-}y_{min})$

Ground motion uncertainty distribution at given m and r – log-normal distribution

$$\ln(y) = \{f(m,r) + \varepsilon\} = \ln(y_{mr}) + \varepsilon$$

$$\ln(y) = f(m,r) + \varepsilon$$



$$f_R(r) = \frac{r}{50\sqrt{r^2 - 40^2}} \quad 40 \le r \le 64$$

$$P[R \ge r] = 1 - F_R(r) = 1 - \frac{1}{50}\sqrt{r^2 - 40^2} \qquad 40 \le r \le 64$$

G-R relation

$$\lambda = \frac{1}{\tau} = e^{\alpha - \beta m} \qquad m_0 \le m \le m_{\max}$$

$$f_M(m) = \frac{\beta e^{-\beta(m - m_0)}}{1 - e^{-\beta(m_{\max} - m_0)}} \qquad m_0 \le m \le m_{\max}$$

$$P[M \ge m] = 1 - F_M(m) = \frac{e^{-\beta[m - m_0]} - e^{-\beta(m_{\max} - m_0)}}{1 - e^{-\beta(m_{\max} - m_0)}} \qquad m_0 \le m \le m_{\max}$$

GM Attenuation relation

$$\ln(y) = f(m, r) + \varepsilon \longrightarrow P[Y \ge y \mid m, r] = h(m, r) = ?$$

AB-97: $\ln(y) = c_1 + c_2(m - 6) + c_3(m - 6)^2 - \ln r - c_4 r + \varepsilon$

Current calculation

$$\gamma(y) = \sum_j \nu_j P_j[Y \geq y] = \sum_j \nu_j \iint P_j[Y \geq y \mid m,r] f_{M,j}(m) f_{R,j}(r) dm dr$$

Error: $$P_j[Y \geq y \mid m,r] = 1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,y}} \exp\left(-\frac{(\ln y - \ln y_{mr})^2}{2\sigma_{\ln,y}^2}\right) d(\ln(y))$$

KY-PSHA

$$\gamma(y_\varepsilon) = \sum_j \nu_j P_j[Y_E \geq y_\varepsilon] = \sum_j \nu_j \int \frac{e^{-\beta_j[g_j(r,y_\varepsilon)-m_0]} - e^{-\beta_j(m_{\max}-m_0)}}{1 - e^{-\beta_j(m_{\max}-m_0)}} f_{R,j}(r) dr$$

For a single characteristic earthquake (m_c~7.7, T~500 yrs for NMSZ)

$$T_P(y) = \frac{T}{1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,c}} \exp\left(-\frac{(\ln y - \ln y_c)^2}{2\sigma_{\ln,c}^2}\right) d(\ln(y))}$$

$$T_p(y_E) = 1/e^{\alpha - \beta m_C} = T$$

(Current PSHA- a curve to infinity)

KY-PSHA – single output

Thank You