Earthquake Hazard Assessment in the Pacific Northwest: Site Response

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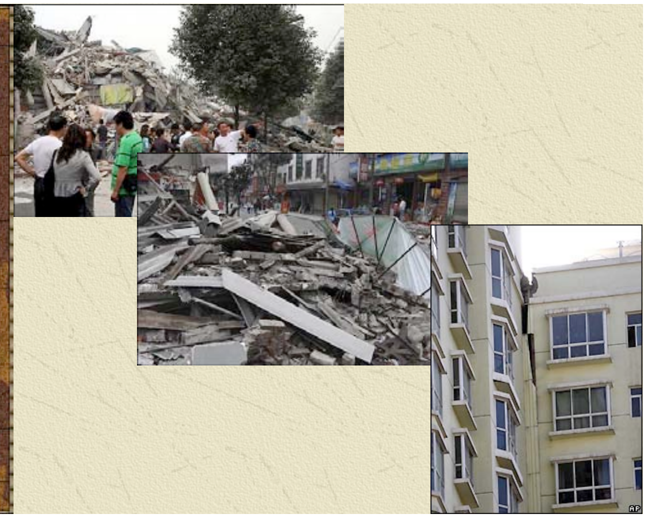


Earthquakes are inevitable: How do we deal with their effects?

- Design buildings to an appropriate level of safety
- Prepare emergency services to respond
- Inform citizens how to prepare and respond

Need to know:

- How often are different types of earthquakes likely to occur?
- How strong will the shaking be?
- How will the shaking vary across the region?
- At what frequencies will the ground shake?

Estimating the ground shaking from earthquakes

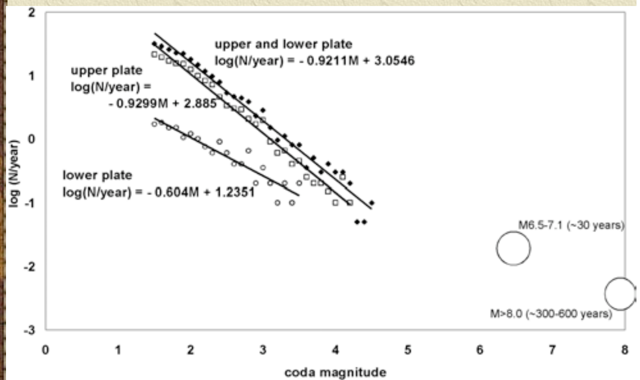
- Probabilistic Hazard Maps
  - Peak Ground Acceleration likely in a given time interval
  - Example:
    - 2% chance of 0.25g acceleration being exceeded in a 50-year time span

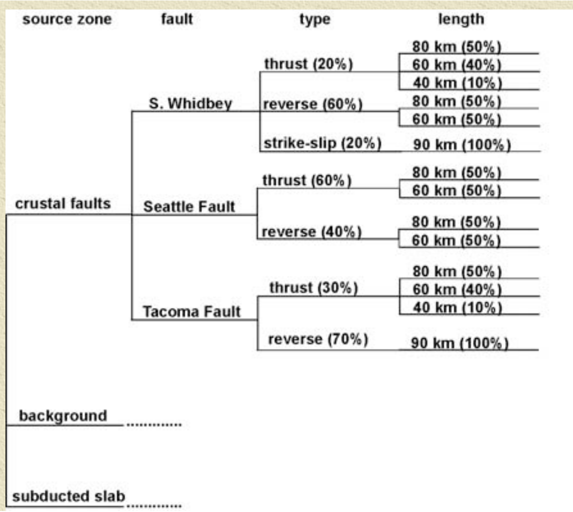
Earthquake Hazard Analysis

- Plate motions
- GPS
- EQ monitoring (PNSN)
- Geophysics (SHIPS)
- Geology
- LIDAR
- Paleoseismology

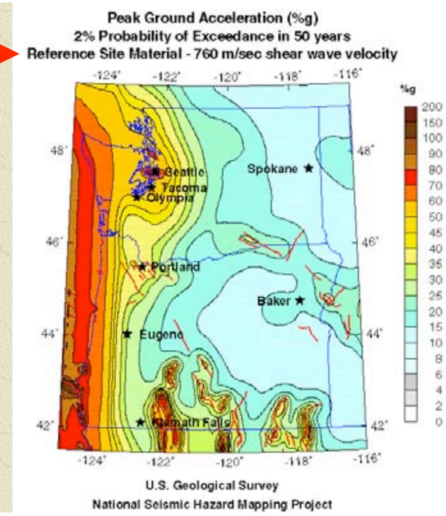
→ Probabilistic Hazard Maps

Washington State EQs





Probabilistic hazard map



Buildings and Resonant Frequency

1-story building (house) ~ 0.1 sec period = 10 Hz

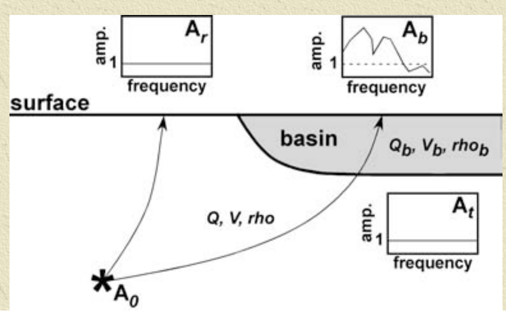
10-story building ~1 sec period = 1 Hz [e.g., library]

35-story building ~ 3.5 sec = 0.3 Hz [e.g., Smith Tower]

75-story building ~ 5 sec = 0.13 Hz [e.g., Columbia Tower]

Probabilistic Hazard Maps → Ground Motion Modeling → Building Design

Probabilistic Hazard Maps → Site Response Estimates → Building Design

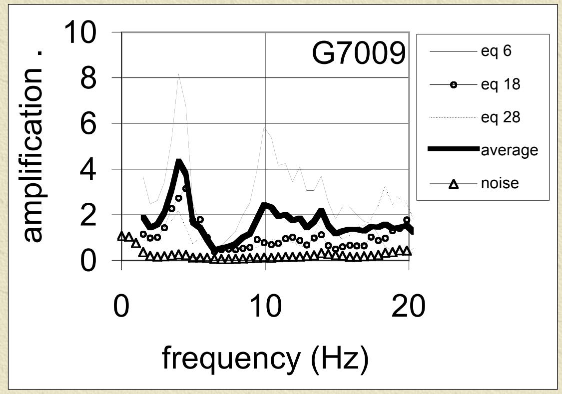


Spectral ratios (to eliminate source signature)

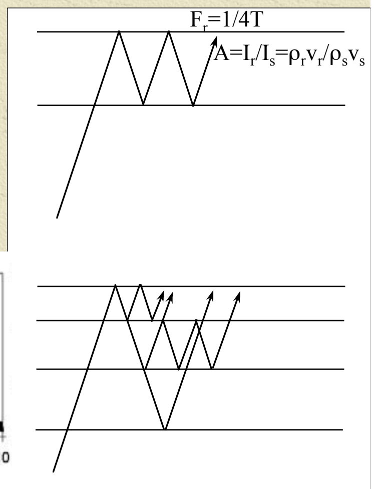
- Simple Spectral Ratio – site/bedrock site
- H/V ratio (horizontal/vertical recording)

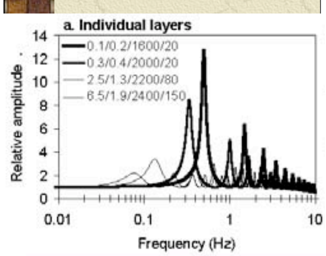
$\frac{\text{Horizontal site}}{\text{Horizontal bedrock}}$ $\frac{\text{Horizontal site}}{\text{Vertical site}}$

site response curve

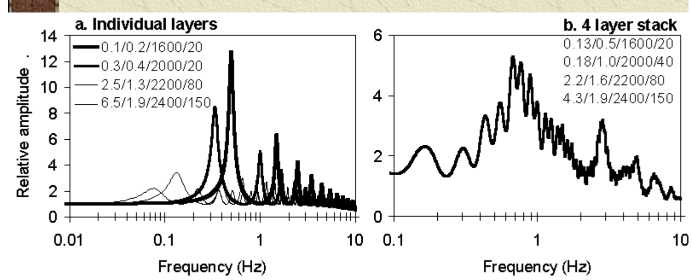


resonance, impedance changes

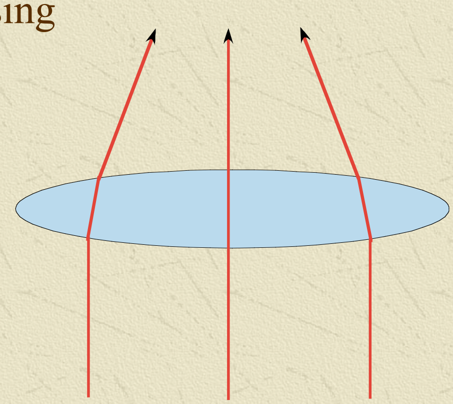




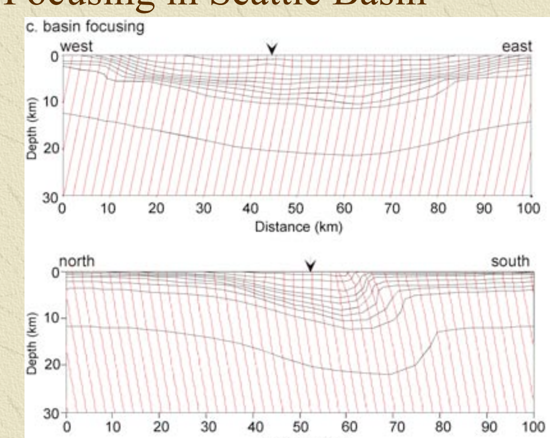
Resonance models



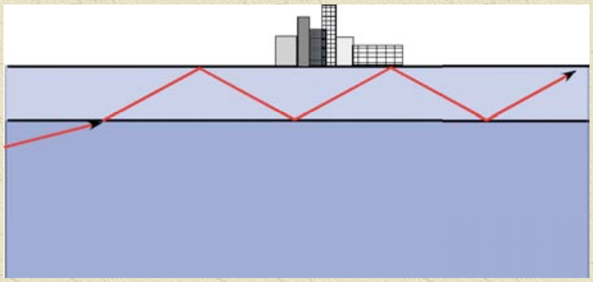
Focusing



Focusing in Seattle Basin



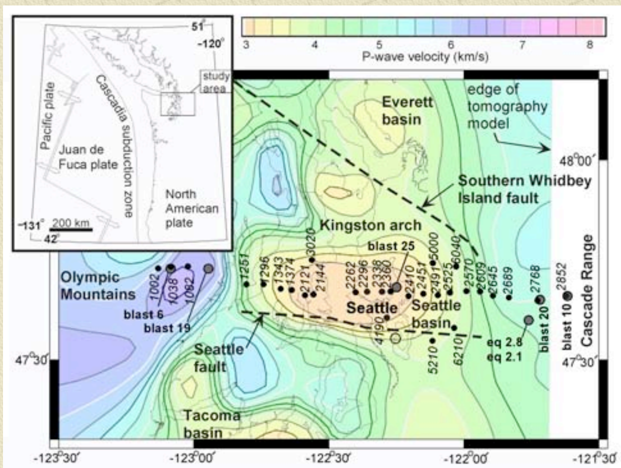
Surface Waves



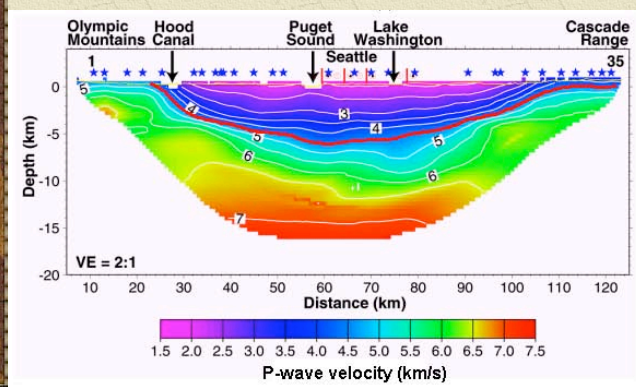
movie

Puget Lowland

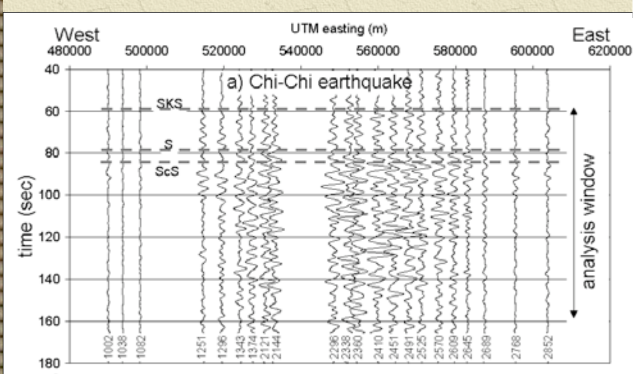
1999 “Dry” SHIPS



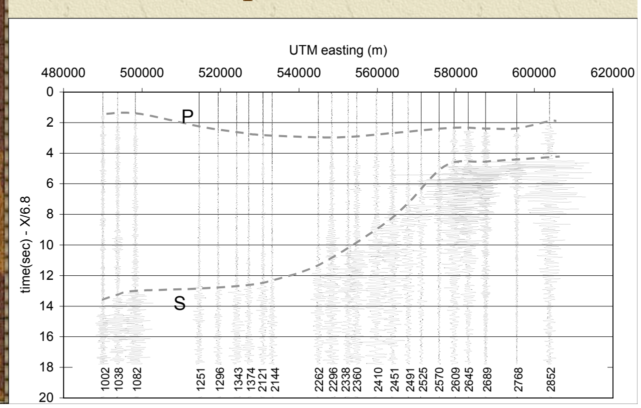
Geophysical data



Chi-Chi earthquake

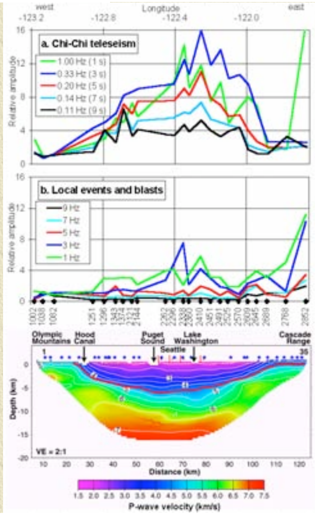


Local earthquake, M2.8

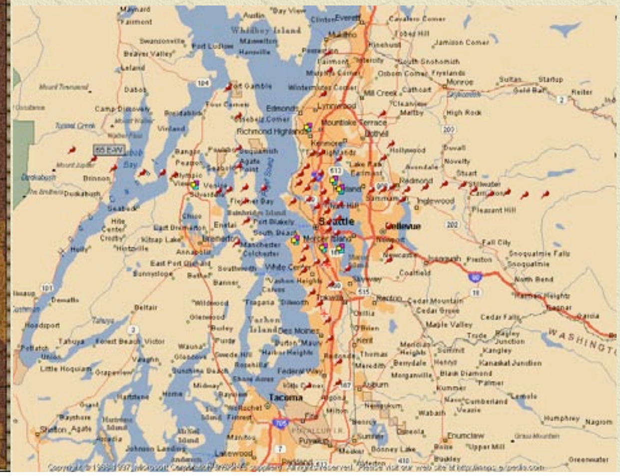


Low freqs: large over Seattle Basin

High freqs: Small over Seattle Basin



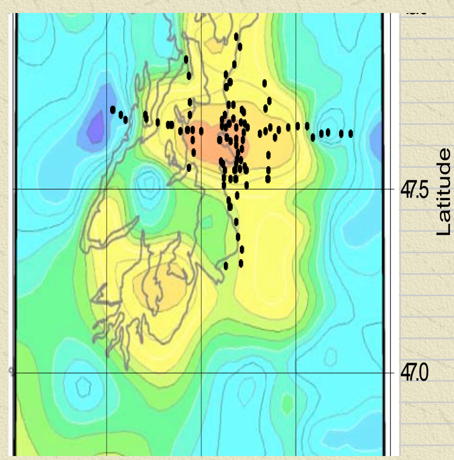
Seattle SHIPS 2002

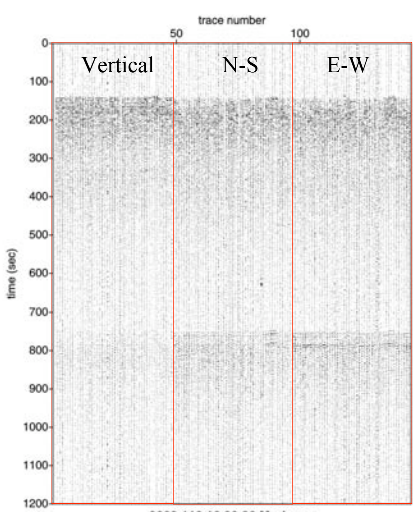


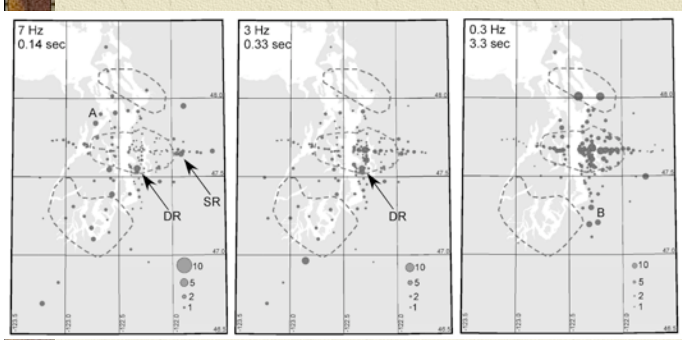
Seattle SHIPS (site response)

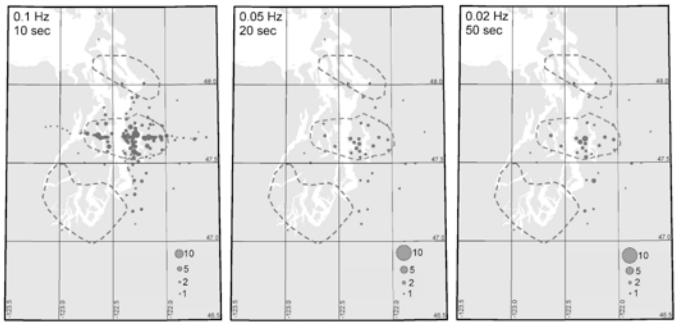
- 90 seismometers (3-component) recording continuously from Jan 27 to May 24, 2002
- Identical instrumentation with 2 Hz sensors
- Local: magnitude 2.0 to 2.1 or greater visible across array (~every 3 days?)
- Teleseisms: magnitude 7.0 to 7.3 or greater visible across array (~15-20/year)

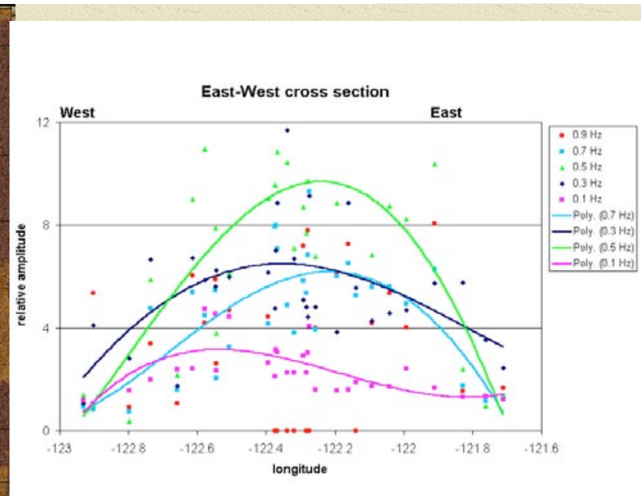
Seattle SHIPS 2002



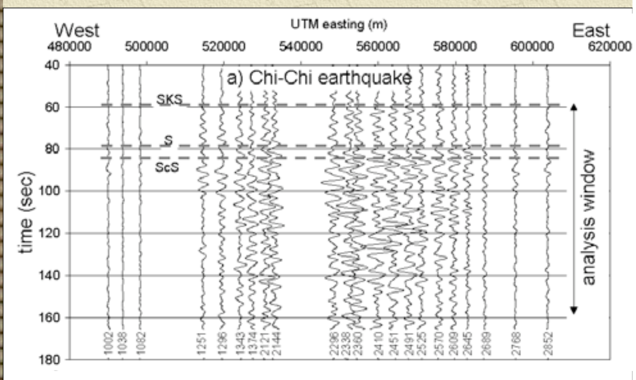








Chi-Chi earthquake (surface waves = long durations)

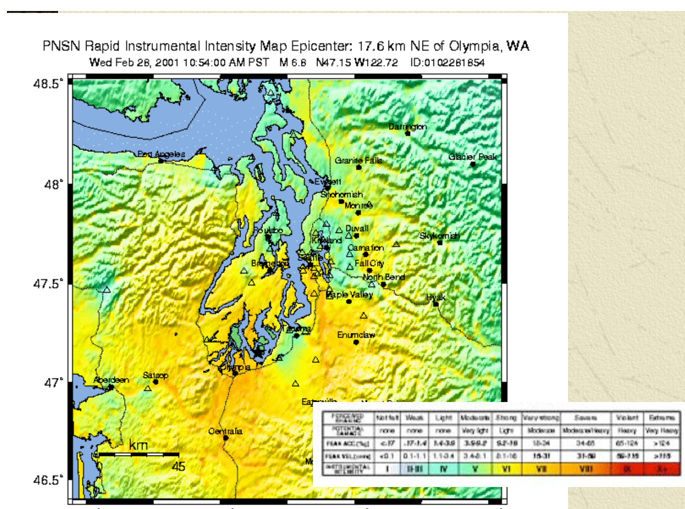


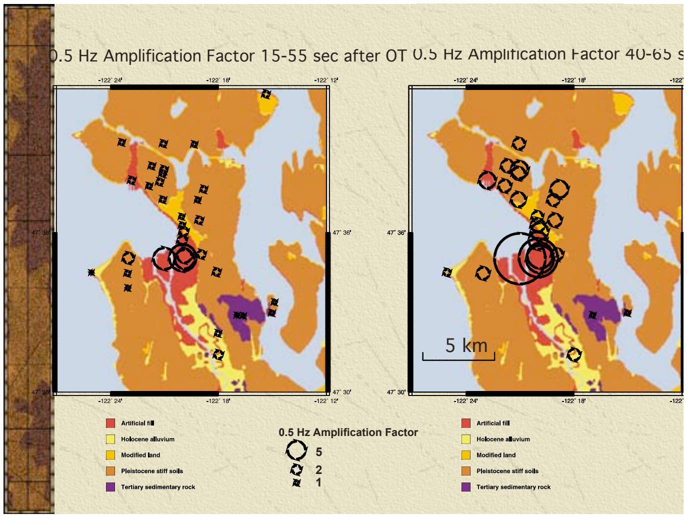
Kingdome SHIPS

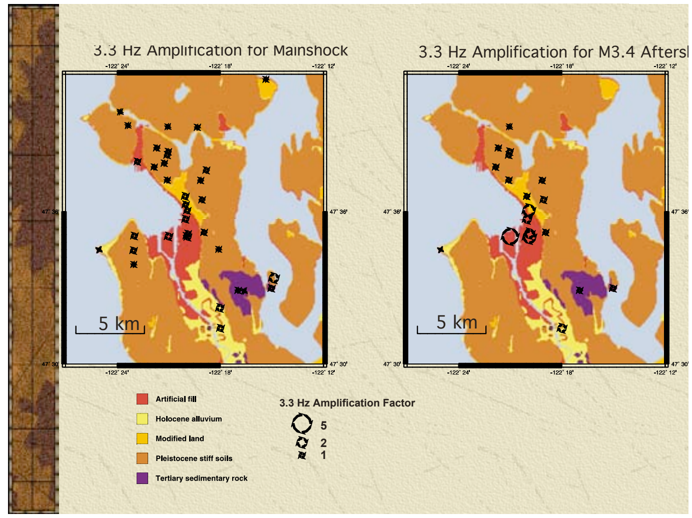
- Kingdome demolition
- Movie

Nisqually Earthquake

- Effects of surface waves
- Relatively modest ground motions
  - Maximum PGA of 0.27g
- Non-linear soil response
  - Amplifications much smaller for strong ground motions (mainshock versus aftershock)







Results from SHIPS/Nisqually

- Seattle Basin characterized by amplifications of 8 to 12 at low frequencies
  (0.3 to 0.8 Hz (3.33 sec to 1.25 sec periods)
- At higher frequencies (5 to 10 Hz) the basin causes decreased shaking
- Amplification is time variant
  - (direct arrivals versus surface waves?)
- Amplifications of 5 could come from resonance in the shallow deposits (<500 m)
- Amplifications from focusing likely <2
- Surface waves within the basin cause amplifications of as much as 16
- Non-linear effects come into play at moderate ground accelerations

END