Probabilistic Seismic Hazard Assessment
Seismic Failure Modes

- Sliding failure through weak lift line
- Horizontal cracking
- Liquefaction of dam or foundation
- Cracking from severe shaking
- Surface fault displacement through the foundation
- Overtopping from landslide failure into reservoir
Liquefaction induced flow slide from M 6.6 event @ ~ 14 km; 0.5 g
Fault surface rupture – Chelongpu fault
M 7.6 Chi-Chi earthquake, Taiwan
Probabilistic seismic hazard analysis (PSHA) is a methodology that estimates the likelihood that various levels of earthquake-caused ground motions will be exceeded at a given location in a given future time period. The results of such an analysis are expressed as estimated probabilities per year or estimated annual frequencies.”
While there is considerable information on earthquake ground motions and potential future locations of earthquakes, there is also considerable uncertainty in the inputs to the analysis.”
“Recognizing the need to identify and address these uncertainties as part of a PSHA, the Senior Seismic Hazard Analysis Committee (SSHAC, 1997) established the goal for all PSHA’s to quantitatively assess these uncertainties and to represent the distribution of the informed technical community of alternative models and parameter values.”
PSHA

- Considers the contribution from all potential sources of earthquake shaking collectively
- Considers the likelihood of those events
- Uncertainty is treated explicitly
- Annual probability of exceeding specified ground motions is computed
Steps in PSHA

(A) Seismic source \( f \), earthquake locations in space lead to a distribution of location:

\[ P[I | f] = f(I | f) \]

(B) Size distribution (magnitude \( m \)) and rate of occurrence for source \( f \):

\[ P[M] = f_M(m) \]

(C) Ground motion estimation:

\[ P[C > c] \text{ at } I \]

(D) Probability analysis:

\[ \gamma[C > c] = \sum_j \nu_j \int \int P[C > c | \xi] P[\xi | I] d\xi dl \]

Source: McGuire, 2004
Basic Components of a PSHA & All Seismic Hazard Analyses

I  Seismic source characterization
II  Development of hazard curves
III  Development of uniform hazard spectra (UHS)
IV  Development of acceleration time histories
SEISMIC SOURCE CHARACTERIZATION

- Known faults
- Areal or Background sources (i.e., random seismicity)
SEISMIC HAZARD CURVES

- Produced from several available computer codes
- Incorporate uncertainties in slip rate, magnitude, faults lengths
- Use ground motion attenuation relationships that relate PGA and SA to distance between source and site and earthquake magnitude - NGA Next Generation Attenuation models
- Site conditions very important; i.e., “soil” versus “rock”
Mean Hazard Curves by Source
Mean & Fractile Curves for PHA

- Mean
- 16th Percentile
- 50th Percentile
- 84th Percentile

Annual Probability of Exceedance vs. Peak Horizontal Acceleration (g)
Site Response

- **Period of structure-**
  - Concrete (sensitive to short period, 0.2-0.4-sec SA) verses Embankment (sensitive to long period, 1-sec SA)

- **Site conditions-**
  - Soil verses rock

- **Shear wave velocity (V_{s30})** – Shear wave velocity in upper 100 ft - Important, because most NGA relationships now incorporate this)
Uniform hazard spectra (UHS) are computed or developed from the seismic hazard curves. This is done by developing hazard curves (i.e. spectral acceleration vs. exceedance probability) for several vibration periods to define the response spectra. Then, for a given exceedance probability or return period, the ordinates are taken from the hazard curves for each spectral acceleration, and an “equal hazard” response spectrum is generated.
SEISMIC HAZARD RESULTS FOR SITE 2 FOR (a) PGA, (b) 0.2 SEC SA, AND (c) 1.0 SEC SA
TIME HISTORIES

- For higher level studies, accelerograms, or acceleration time histories, are developed for the site that represents the seismic hazard at the return periods of interest.
- The suites of motions at each return period are usually selected to span the likely variability in spectra responses at different periods, and to account for differences in distance, magnitude, and site conditions. The selected ground motions are then used for dynamic analyses using programs such as FLAC, SHAKE, or LS-DYNA.
Fault Displacement Hazard Analysis (PFDHA)

- Some sites it may be a major concern (i.e., Lauro & Terminal Dams, CA; Helena Valley Dam, MT)

- Hazards calculations are analogous to probabilistic ground motion methodology

- Methodology originally set forth by Stepp and others (2001) for Yucca Mtn
Lauro Dam
Fault Investigations
Rupture Length vs Displacement

Fault Model:
- Minor Fault: SRL=15
  - Average: 0.2
  - Max: 0.2
- Major Fault: SRL=39
  - Average: 0.4
  - Max: 0.4
- Rupture Length:
  - 15 km
  - 39 km
  - 57 km

Displacement vs Distance:
- No Significant Displacement
- Strike-slip
  - 0.25 (0.05)
  - 0.5 (0.10)
  - 1.0 (0.55)
  - 1.5 (0.15)
  - 2.0 (0.10)
  - 3.0 (0.05)

Pdf vs Displacement, cm:
- SRL=15
- SRL=39
- SRL=57
QUESTIONS?

Sheffield Dam - 1925