Seismic parameters

- Earthquake magnitude M_w
- Peak ground acceleration (PGA)
- Frequency content

  - Duration related to M_w
  - Duration also depends on fault mechanism, distance, and local geologic conditions

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PGA

A single cycle of high PGA at a high frequency (in the range of 0.25 to 0.45g at a predominant frequency of 25 Hz) will likely not be as significant as a larger number of cycles of lower acceleration (in the range of 0.10 to 0.15g at 1Hz)

The reason for this is that for a dam to be significantly excited by earthquake ground motion, some portion of the ground motion must be close to the predominant frequency of the dam

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Predominant frequency of tailing dams

A simple method is Makdisi and Seed (1977)

- For H = 100 - 400ft (30 - 122m)
- Vs = 500 – 1,600 ft/sec (152 – 490 m/sec)
- Fundamental frequency = 0.5 – 6.0 Hz
- Fundamental period = 0.17 – 2.0 seconds

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Seismic hazard analysis procedures

Probabilistic Seismic Hazard Analysis (PSHA)

Incorporate range of uncertainties (e.g., seismo-tectonic model, occurrence frequency, ground-motion attenuation)

Deterministic Seismic Hazard Analysis (DSHA)

Relates specific seismic scenario and earthquake, and results in Maximum Credible Earthquake (MCE)

Simplified Minimum Earthquake Design Parameters

Use of USGS Probabilistic Hazard Maps to establish conservative PGA and Magnitude

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Design earthquakes

- Maximum Credible Earthquake (MCE)
- Maximum Design Earthquake (MDE) or Safety Evaluation Earthquake (SEE)
- Operating Basis Earthquake (OBE)

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Maximum credible earthquake (MCE)

- The MCE is the largest earthquake magnitude that could occur along a recognized fault or within a particular seismotectonic province or source area under the current tectonic framework
- The MCE might be represented by more than one earthquake event (i.e., from near-field and far-field sources)

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Maximum design earthquake (MDE) or Safety evaluation earthquake (SEE)

- Produces the maximum level of ground motion for which a structure is to be designed or evaluated
- The MDE or SEE can be set equal to the MCE or to a design earthquake less than the MCE
- Perform without catastrophic failure but with significant damage or economic loss
- Size of MDE or SEE depend on:
  - Hazard potential classification of dam
  - Criticality of the project function (water supply, recreation, flood control, protection of environment, etc.)
  - Turnaround time to restore facility to operability

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Operating basis earthquake (OBE)

- Site ground motions expected during service life
- Little or not damage and without interruption of function
- Goal: protect against economic losses from damage or loss of service
- Return period may be based on economic considerations (475 years)

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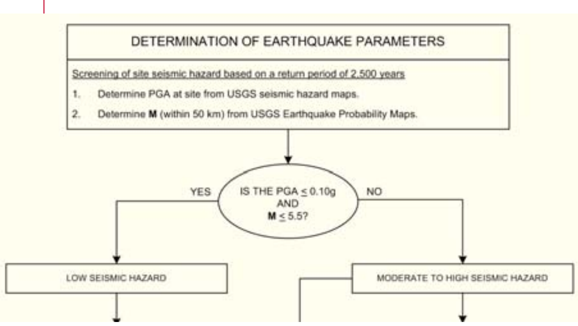
Determination of earthquake parameters



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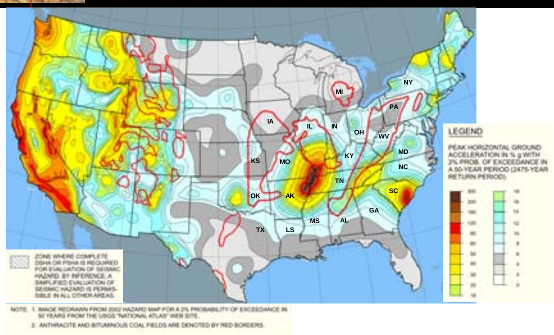
Moderate- to high-hazard regions



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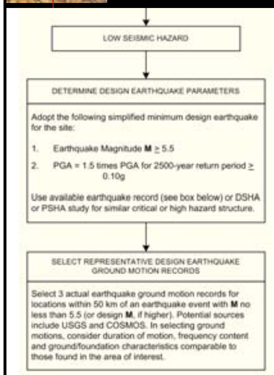
Low seismic hazard areas



Adopt simplified minimum design earthquake, or perform seismic hazard analysis

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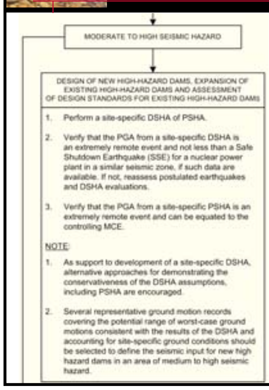
Moderate- to high-seismic hazard areas



Perform site-specific seismic hazard analysis

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Location of nuclear power plants with respect to coal fields (MSHA 2009)

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SSE PGA for US nuclear power plants

Plant	SSE PGA (g)	Plant	SSE PGA (g)
Arkansas Nuclear 1, 2	0.21	Millstone 2, 3	0.17
Beaver Valley 1, 2	0.13	Monticello	0.13
Braidwood 1, 2	0.19	Nine Mile Point, 1, 2	0.15
Browns Ferry 1, 2, 3	0.21	North Anna, 1, 2	0.13
Brunswick 1	0.17	Oconee 1, 2, 3	0.11
Byron 1, 2	0.19	Oyster Creek	0.27
Callaway	0.19	Palisades	0.19
Calvert Cliffs 1, 2	0.15	Palo Verde 1, 2, 3	0.19
Catawba 1, 2	0.17	Peach Bottom, 2, 3	0.15
Clinton	0.21	Perry 1	0.15
Columbia Generating Station	0.25	Pilgrim 1	0.15
Comanche Peak 1, 2	0.13	Point Beach 1, 2	0.13
Cooper	0.21	Prairie Island 1, 2	0.13
Crystal River 3	0.11	Quad Cities 1, 2	0.27
D.C. Cook 1, 2	0.21	River Bend 1	0.11
Davis-Besse	0.15	Robinson 2	0.19
Diablo Canyon 1, 2	0.80	Saint Lucie 1, 2	0.11
Dresden 2, 3	0.21	Salem 1, 2	0.21
Farley 1, 2	0.11	San Onofre 2, 3	0.63
Fermi 2	0.15	Seabrook 1	0.25
FitzPatrick	0.15	Sequoyah 1, 2	0.17
Fort Calhoun	0.19	South Texas 1, 2	0.11
Ginna	0.19	Summer	0.15
Grand Gulf 1	0.15	Surry 1, 2	0.15
Harris 1	0.15	Susquehanna 1, 2	0.11
Hatch 1, 2	0.15	Three Mile Island 1	0.15
Hope Creek 1	0.19	Turkey Point 3, 4	0.15
Indian Point 2, 3	0.15	Vermont Yankee	0.19
Kewaunee	0.13	Vogtle 1, 2	0.19
La Salle 1, 2	0.21	Waterford 3	0.11
Limerick 1, 2	0.15	Watts Bar 1	0.19
McGuire 1, 2	0.15	Wolf Creek 1	0.13

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Classification of hazard potential (FEMA 333)

Hazard potential: the possible adverse incremental consequences that result from the release of water or stored contents due to failure of the dam or mis-operation of the dam or appurtenances

Hazard potential classification: a system that categorizes dams according to the degree of adverse incremental consequences of a failure or mis-operation of a dam. The hazard potential classification does not reflect in any way on the current condition of the dam (e.g., safety, structural integrity, flood routine capacity)

Hazard Potential Classification	Loss of Human Life	Economic, environmental, lifeline losses
Low	None expected	Low and generally limited to owner
Significant	None expected	Yes
High	Probable. One or more expected	Yes (but not necessary for this classification)

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Seismic hazard assessment recommendations

		Seismic Hazard Assessment	
Dam Hazard Potential Classification	**Maximum Design Earthquake (MDE)**	**Low-Seismic-Hazard Area**	**Moderate- to High-Seismic-Hazard Area**
High Hazard Potential	Maximum Credible Earthquake (MCE)	Minimum EQ and Simplified Design Ground Motion or Site-specific DSHA supported by PSHA	Site-specific DSHA supported by PSHA
Significant Hazard Potential	MDE ~ 2500 return period	USGS EQ Hazard Maps or Site-specific PSHA	USGS EQ Hazard Maps or Site-specific PSHA

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Deterministic seismic hazard analysis (DSHA)

1. Develop a seismotectonic model, 322-km radius (susceptibility of fine tailings to liquefaction from large, distant earthquakes)
2. Review seismicity (plot epicenters on a map)
3. Relate epicenters to seismotectonic model
4. Identify conceivable MCEs as the most severe earthquake from each source that could be larger than the largest historical earthquake and "relocate" on the source nearest to the site

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Deterministic seismic hazard analysis (DSHA)

5. Using attenuation relations, estimate PGA at the dam site
6. From the various PGAs, identify the most severe ground motion as the MCE. Not a single event may control
7. Associate the MCE ground motion(s) to time history(ies) of ground motion consistent with the magnitude of the source and, with lesser emphasis, the calculated PGA from that source

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Probabilistic seismic hazard analysis (PSHA)

- Same basic input as DSHA: seismotectonic model and attenuation models, except:
- Source geometry: determines the probability distribution of distance R from the earthquake to the site $f_R(r)$
- Seismicity: rate of occurrence ν and the magnitude distribution $f_M(m)$ of earthquakes within each seismic source
- Attenuation functions: same as DSHA but with uncertainties incorporated

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Ground motions records

- Actual
- Synthetic

- If actual strong motion records are used as the basis for defining the MCE, it is recommended that at least 3 records be selected
- If the site is in an area of medium to high seismic hazard, more than three time histories should be used

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