An Overview of Criteria Used by Various Organizations for Assessment and Seismic Remediation of Earth Dams

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FMSM ENGINEERS

Presentation Overview

- Purpose
- Background
- Issues
- Approach to This Study
- Interpretation by Various Agencies
- Comparison of Agency Criteria
- Summary

Purpose of This Study

- How do you assess liquefaction?
- How do you assess resulting deformations?
- How do you adequately remediate for predicted seismic damage?
- What do USACE guidance documents suggest?
- What do other dam safety entities suggest?

Purpose of This Study

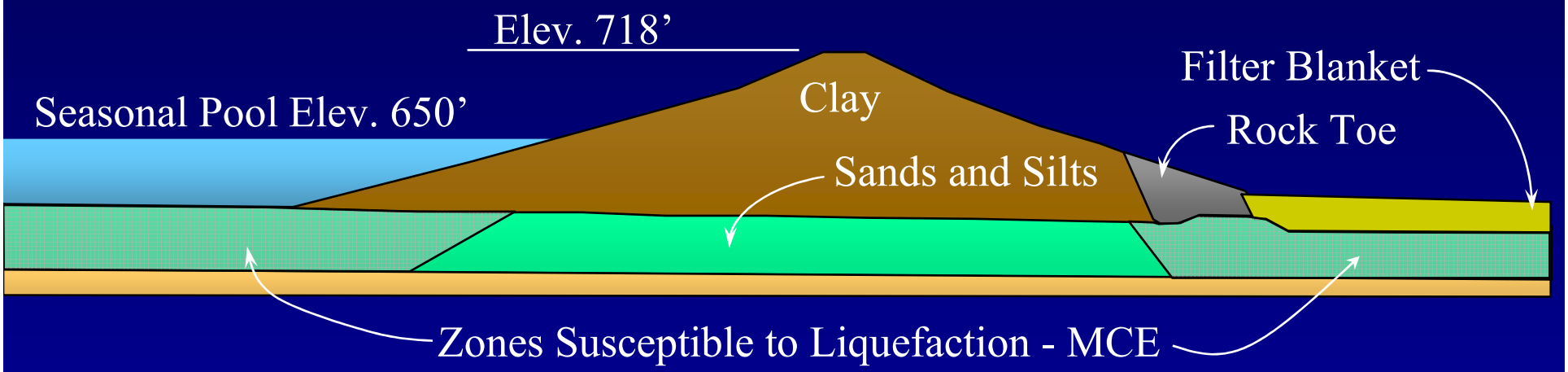
Dewey Dam

Big Sandy River Basin

Prestonsburg, Kentucky

USACE Huntington District

Purpose of This Study



What qualifies as failure?
What level do I remediate to?

The Issues

- Liquefaction Triggering Potential
- Residual Soil Strengths and Post-Earthquake Stability
- Expected Permanent Deformations
- Adequacy of Solution (i.e., assessing risk)

Complex Failure Mechanisms +
Sensitive Response to Input Parameters +
Risk of Catastrophic Failure +
Huge Remediation Costs =
A Challenging Problem

Liquefaction Triggering

$$FS = \frac{\text{Cyclic Resistance Ratio, CRR}}{\text{Cyclic Stress Ratio, CSR}}$$

$$CRR = \left(\frac{\tau}{\sigma'_{vo}}\right)_{Liquefy}$$

$$CSR = \left(\frac{\tau}{\sigma'_{vo}}\right)_{Loading}$$

} Same Density & No. of Load Cycles

Liquefaction Triggering

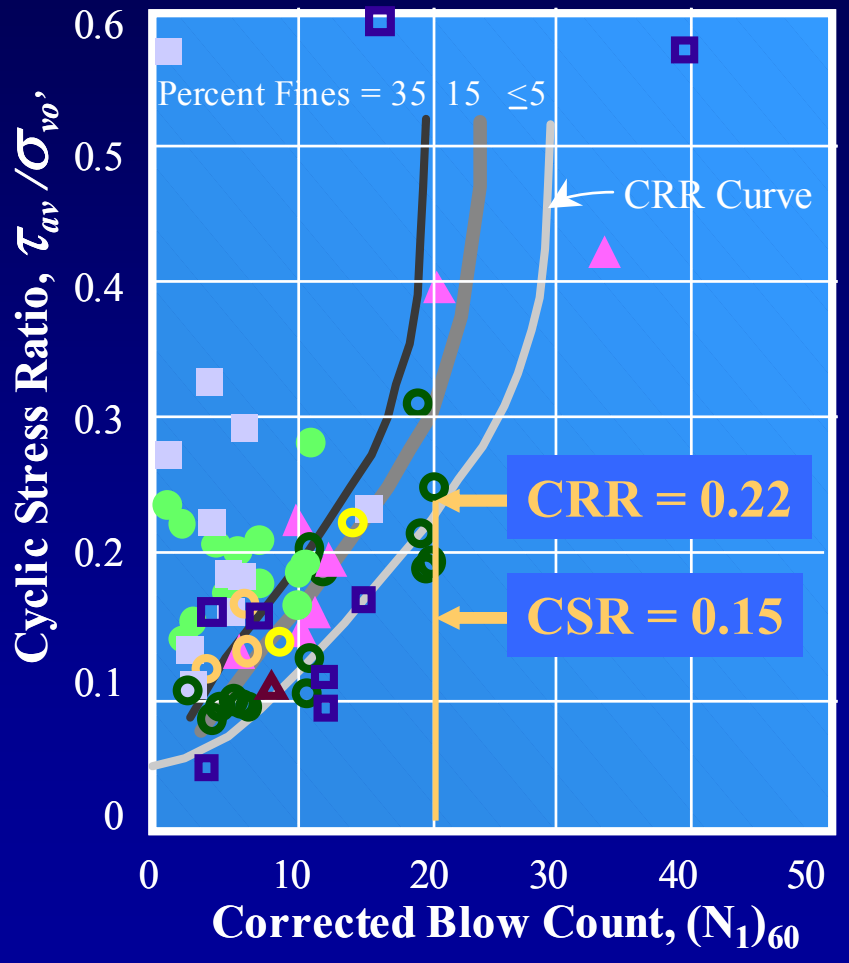
$$FS = \frac{CRR}{CSR} \times MSF \times K_{\alpha} \times K_{\sigma}$$

MSF = Magnitude Correction

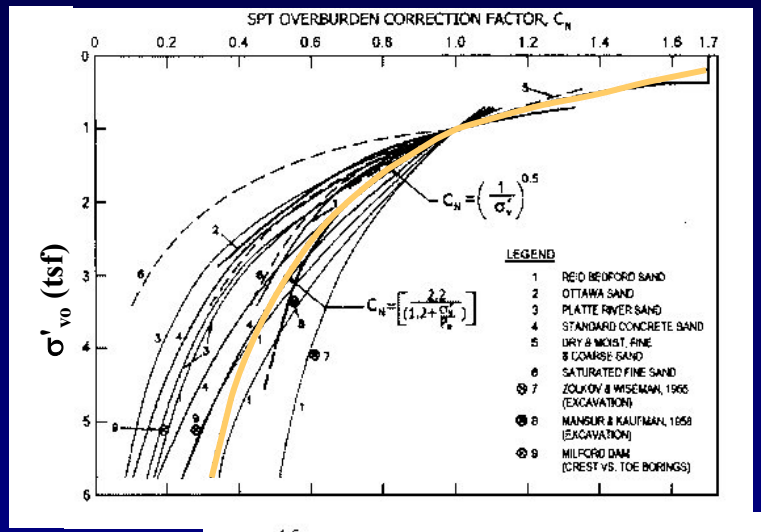
K_{σ} = Confinement Correction

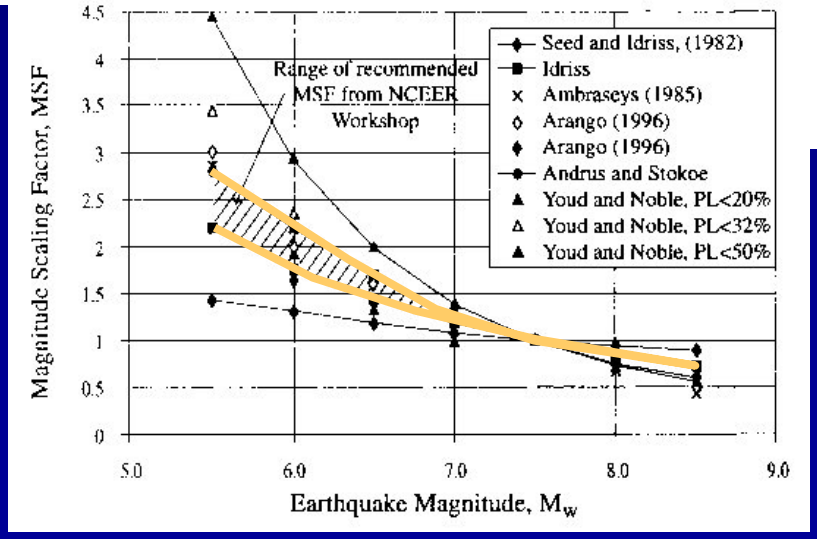
K_{α} = Shear Stress Correction

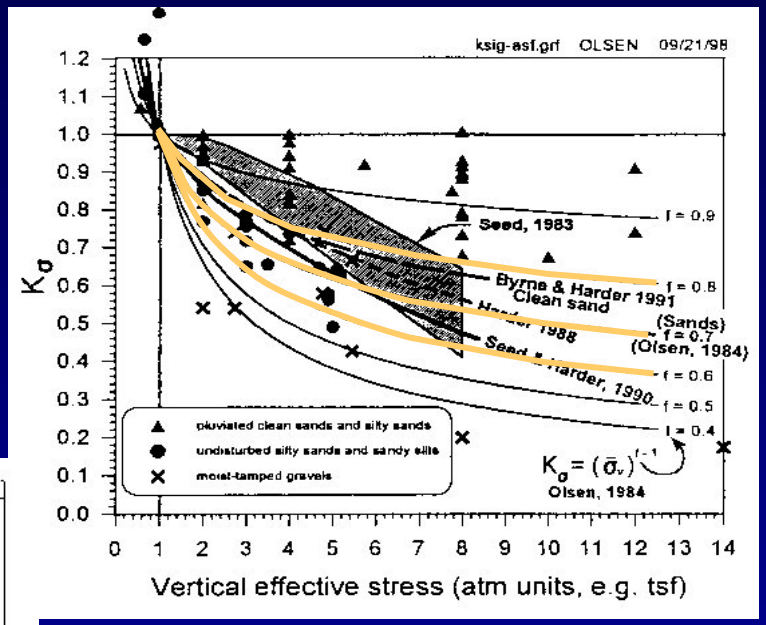
$$\mathbf{FS = \frac{0.22}{0.15} = 1.5 \times \ldots}$$



Liquefaction Triggering

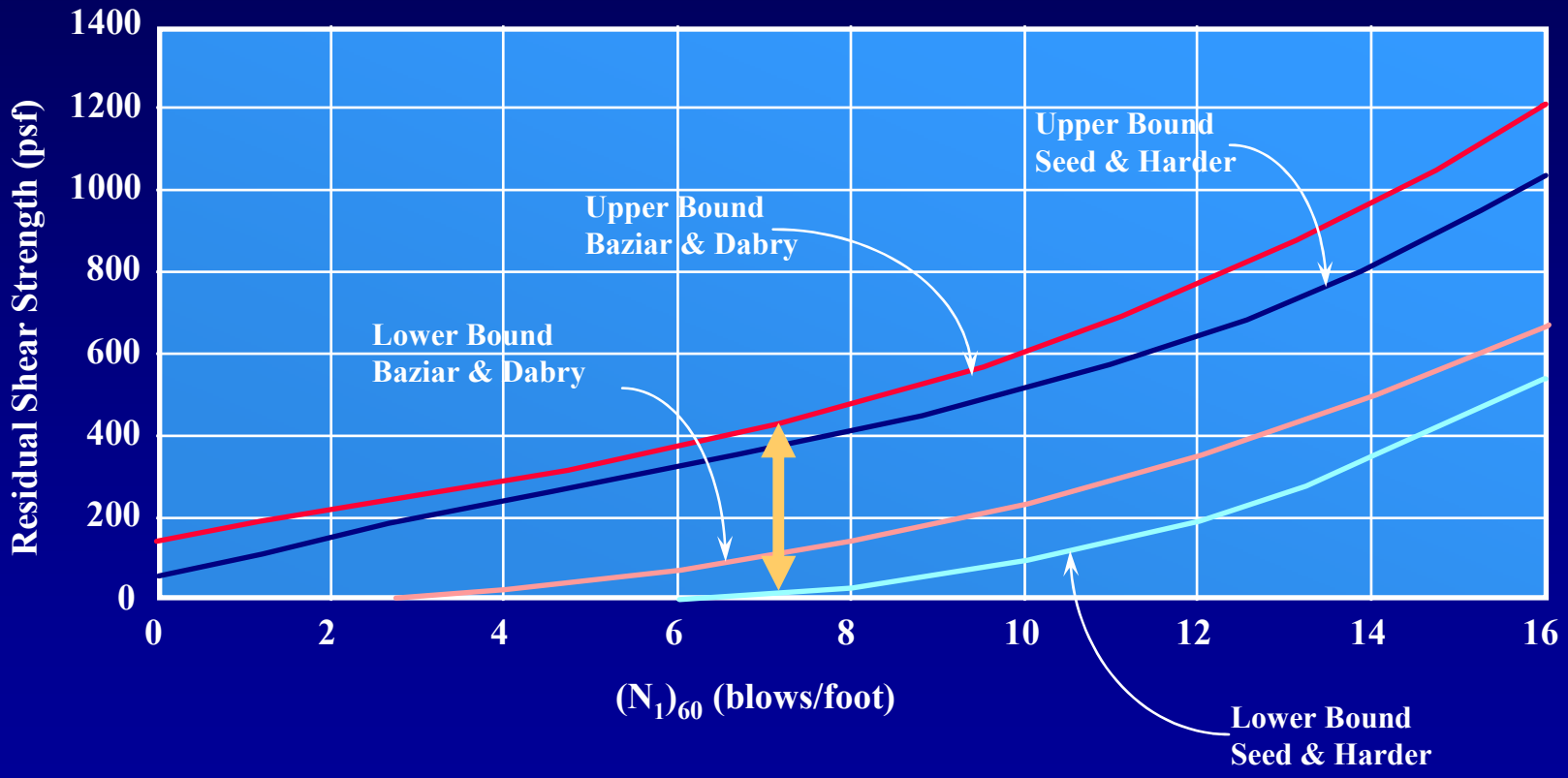




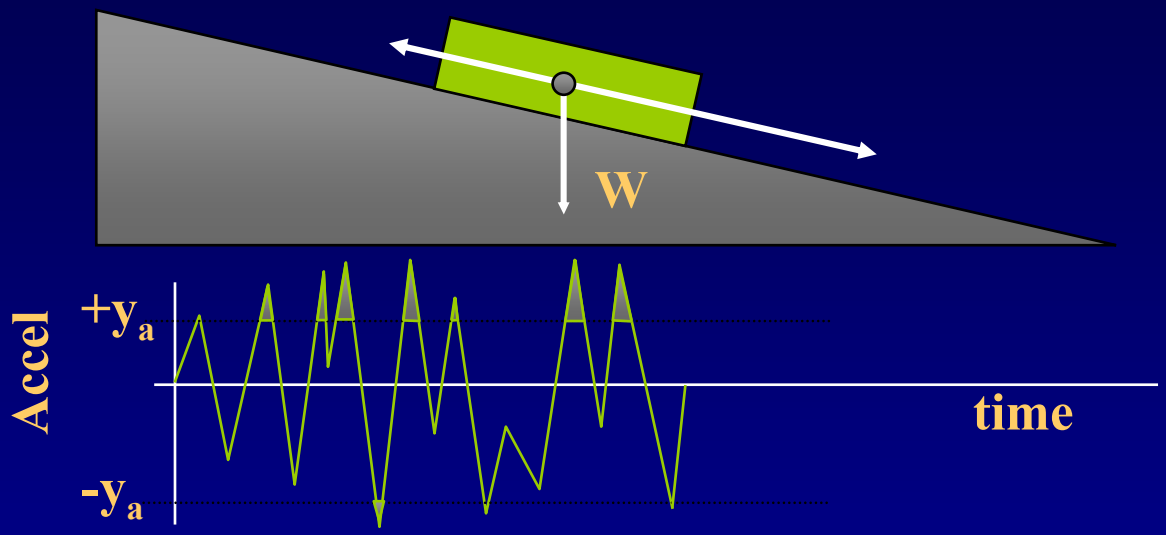


ASCE, JGGE, 10/2001

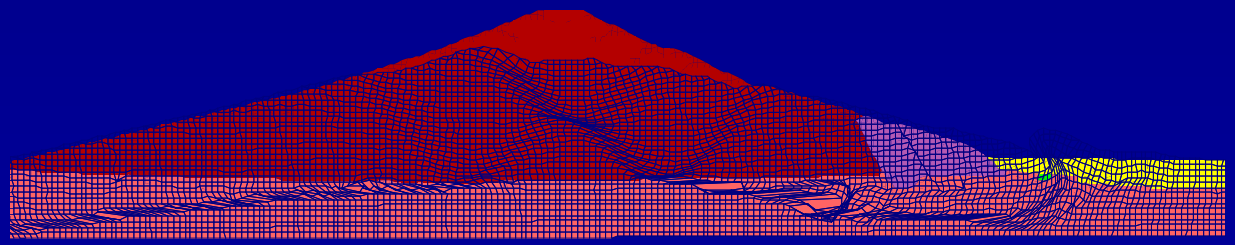
Residual Soil Strengths



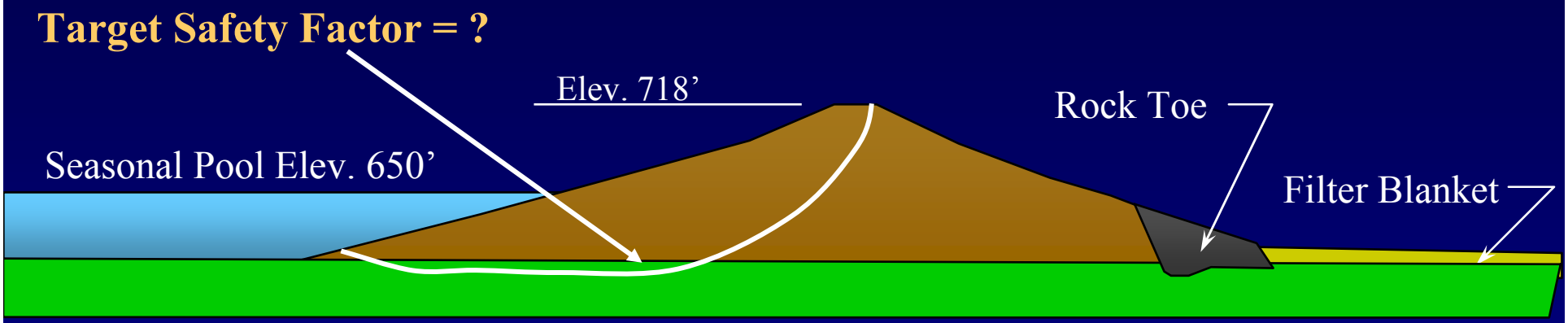
Permanent Deformations

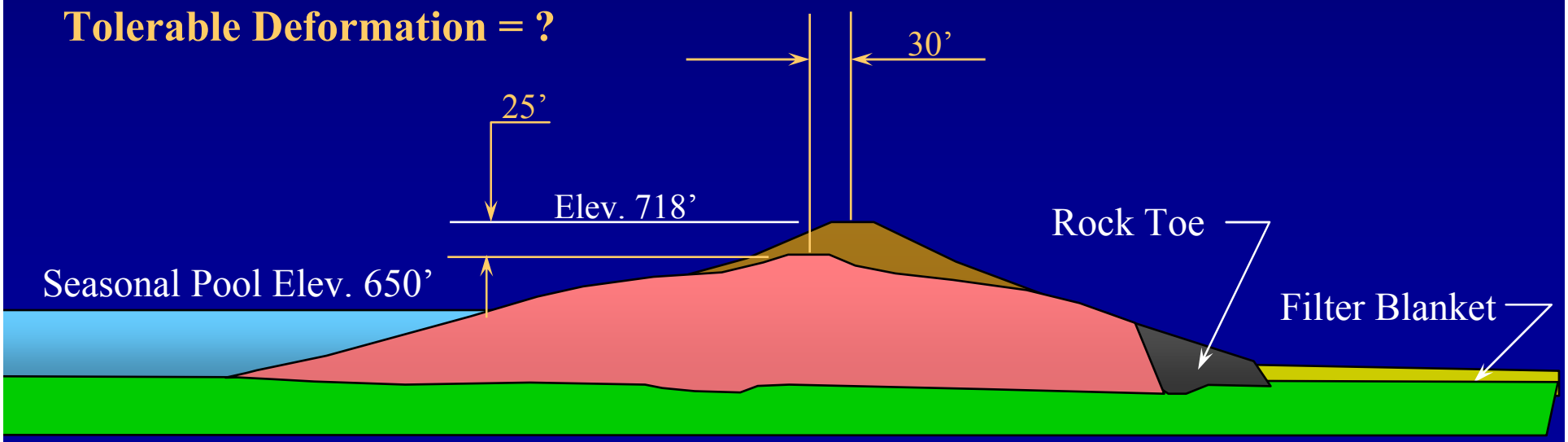


Newmark's Method or Numerical Modeling?



Judging Adequacy of Analyses or Designs





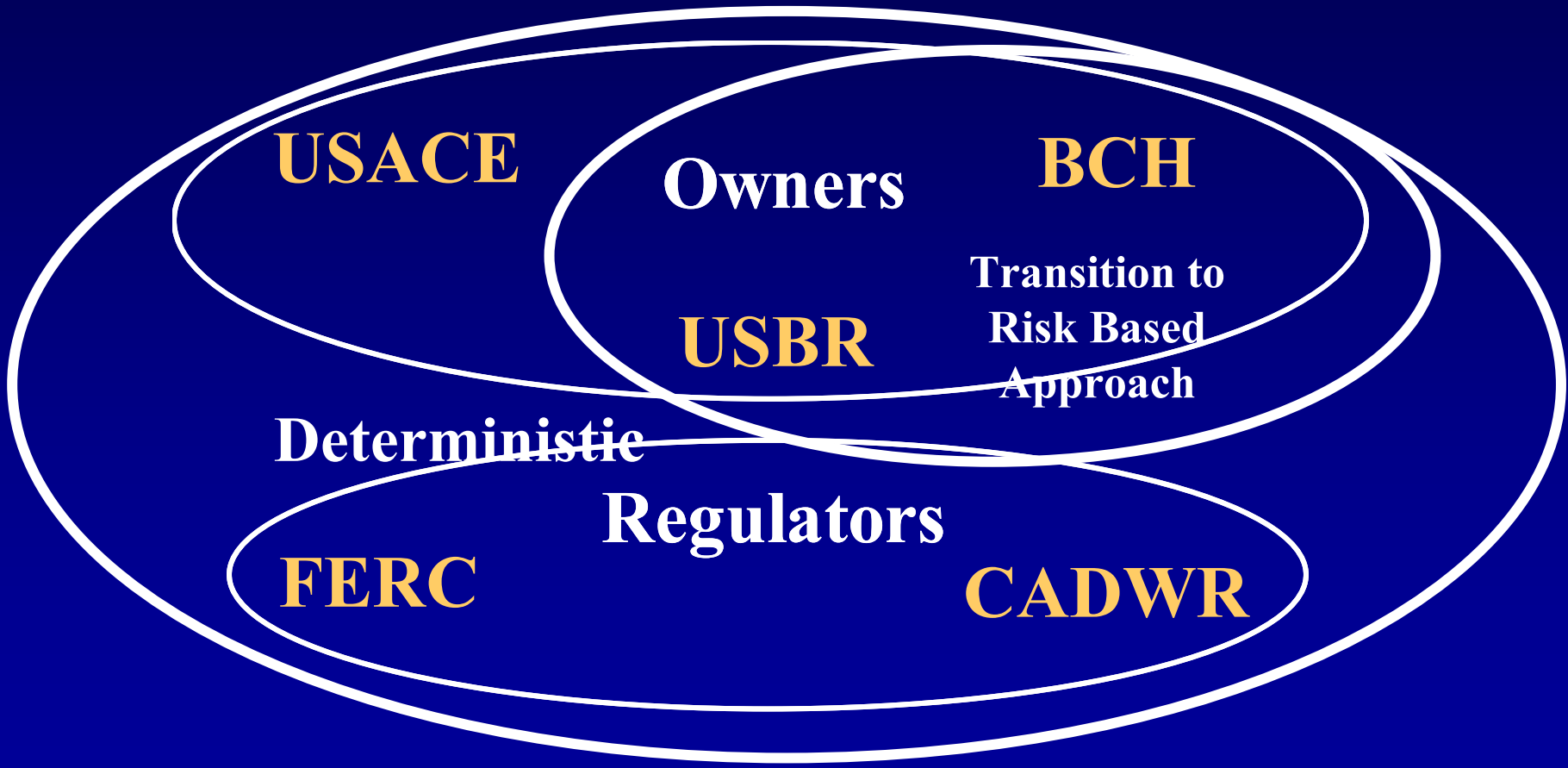
Approach to This Study

- Research how USACE and other agencies address the following:
  - Liquefaction Triggering Assessment
  - Liquefied Soil Residual Strength Assessment
  - Permanent Deformation Assessment
  - Adequacy Assessment for Existing or Remediated Structure
- Interviews, Review of Guidance Documents and Other Publications
- Current as of 2001

The Agencies

- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Reclamation (USBR)
- Federal Energy Regulatory Commission (FERC)
- California Department of Water Resources (CADWR)
- British Columbia Hydro (BCH)

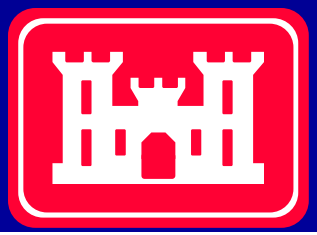
Criteria of Various Agencies



USACE Approach

Phase II Special Study

- Gather required data.
- Deterministic analysis for MCE.
- Complete liquefaction analyses.
- Establish post-liquefaction strengths.
- Perform static limit equilibrium (LE) analyses.
- Perform finite element (FE) deformation analyses.
- Use LE and FE to evaluate remediation alternatives.



USBR Approach

- Incorporating risk based methodologies.
  - MCE (Probabilistic or Deterministic)
  - Potential fatalities
  - Confidence in data
- Ground motion frequency content "matched" to structure
- Use total stresses to evaluate liquefaction potential.
- Require higher post-earthquake LE safety factors.
- Remediate based on probability and consequences of failure.

FERC Approach

- Deterministic analysis for MCE.
- Low confidence in numerical modeling, relying on Newmark type analyses.
- Deformations limited to 2 feet (some exceptions).
- Deformations considered valid only for Post-Earthquake Limit Equilibrium FS > 1.0

CADWR Approach

- Deterministic analysis for MCE.
- Low confidence in numerical modeling, relying on Newmark type analyses.
- No observed performance to compare with numerical model predictions.
- Deformations considered valid only for Post-Earthquake Limit Equilibrium FS > 1.0.
- Often dealing with gravels, use BPT.

BCH Approach

- Probabilistic analysis for MCE.
- Incorporate variability in input parameters.
- Do employ numerical modeling.

Comparison of Approaches

Comparison of Criteria Proposed by Various Agencies.					
	USACE	**USBR**	**FERC**	**CADWR**	**BCH**
Basis for MCE	Determin-istic	Both	Determin-istic	Determin-istic	Probabil-istic
Total or Effective	Effective	Total	Effective	Total	Total
Safety Factor	>1.0[1]	1.05 to 1.20[2]	>1.0	>1.0	>1.0
Newmark or Num. Modeling	Both	Both	Newmark	Newmark	Both

[1]Exceptions made on a case by case basis.

[2]SF=1.20 is applicable when best estimate of post-earthquake strengths. SF=1.05 is used for worst case estimate of post-earthquake strengths.

Summary

- Challenging and Inexact Analyses
- Owners vs. Regulators
- Probabilistic vs. Deterministic
  - Selecting Ground Motion
  - Quantifying Loss of Life
  - Evaluating Risk Among Different Structures
  - Evaluating Critical Failure Modes
- Deformation Analyses vs. Observed Performance

Speaker Information

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