Seismic Dam Safety & Risk Assessment

SAGE Engineers, Inc.

Marc J. Ryan, PE, GE

Principal Engineer

Innovative Technologies in Water Management

- How is dam safety an innovative technology?
- How is dam safety relevant in the current drought?

Governor's Water Action Plan

STORAGE is a key component:

"The bottom line is we need to increase our state's storage capacity, whether surface or groundwater; whether big or small."

Big: Sites Reservoir and Temperance Flats Reservoir

Small: Ensure full use of existing capacity and dam raises

Small Scale Storage

- Most dams reaching 50-yr design life
- Neglecting regular maintenance can lead to more serious problems…
- …Which can lead to a mandated restriction in storage
- 56 dams are currently under restrictions due to dam safety issues
- 470,000 AF of lost storage

Camanche Reservoir, EBMUD
Total Storage 417,000 AF

Data provided by D. Gutierrez, Chief of the DSOD

Small Scale Storage Advantages

- Existing facilities with sunk capital costs
- Fewer environmental and permitting obstacles
- Minimal real estate acquisition impacts
- Existing internal knowledge of operations and maintenance
- Opportunity to improve recreational activities
- Requires development AND implementation of comprehensive Dam Safety Program

Comprehensive Dam Safety Program

- Construction history
- Performance history
- Instrumentation
- Reporting procedures
- Instrumentation thresholds
- Inundation mapping
- Energy Action Plans
- Institutional knowledge
- Relationship with regulator

Construction of San Pablo Dam, photo from EBMUD

Regulators and Risk

- Indirect Risk Evaluation
  - Maximum credible earthquake
  - Probable Maximum Flood
    - With some statistical considerations
  - Design/retrofit to specified level
  - Moving towards more formal risk based approaches

- Risk Informed Decision Making (RIDM)
  - Probabilistic seismic hazard analysis (PSHA)
  - Probable Maximum Flood
  - Probability of failure
  - Consequence of failure
  - Risk reduction measures

The Two Components of Risk

#1 – Probability of Failure

Define potential failure modes

	Very High Slip Rate 9 or greater mm/yr	High Slip Rate 8.9 to1.1 mm/yr	Moderate Slip Rate 1.0 to 0.1 mm/yr	Low Slip Rate less than 0.1 mm/yr
Extreme Consequence Total Class Weight 31-36	84th	84th	84th	50th to 84th
High Consequence Total Class Weight 19-30	84th	84th	50th to 84th	50th to 84th
Moderate Consequence Total Class Weight 7-18	84th	50th to 84th	50th to 84th	50th
Low Consequence Total Class Weight 0-6	50th	50th	50th	50th

DSOD Consequence-Hazard Matrix

#2 – Consequence of Failure

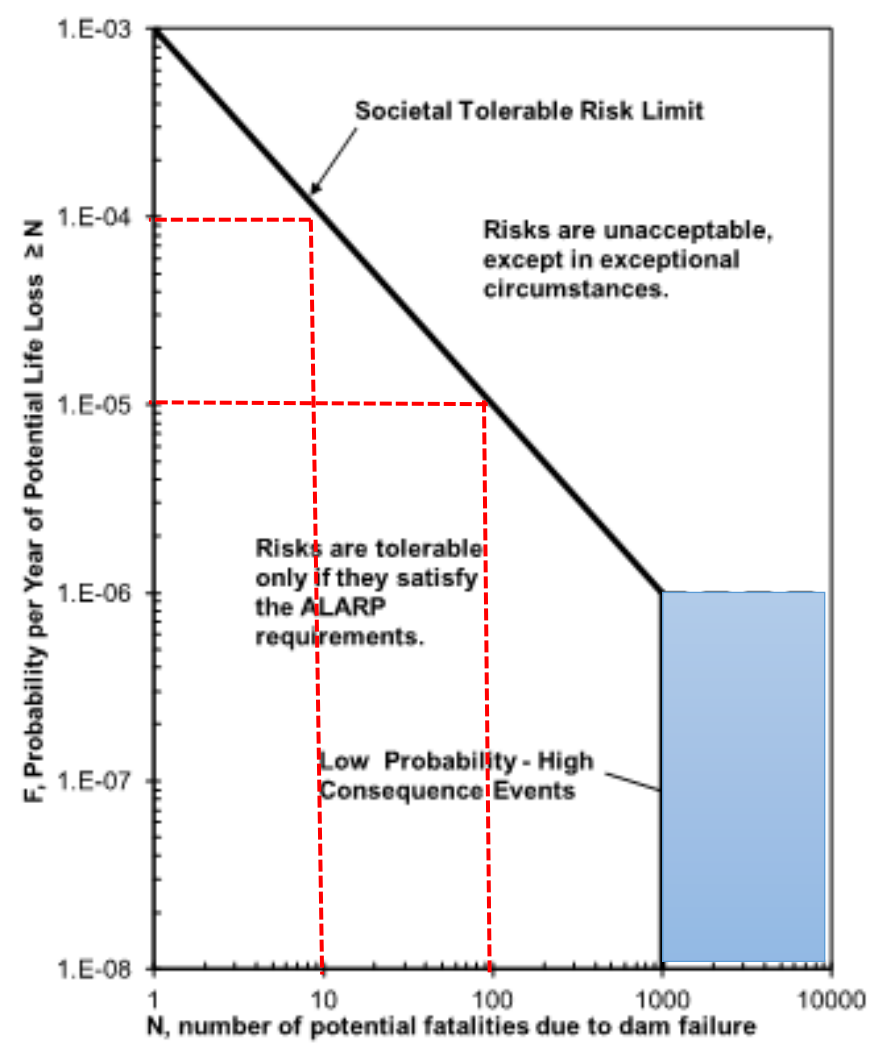
- Loss of life
- Economic loss
  - Operations, irrigation, generation
- Environmental loss
- Loss to infrastructure
- Loss of public trust

Risk Analysis - Scalable

- DSOD: “Indirect” evaluation of risk
- FERC: PFMA – qualitative expert elicitation
  - Category I – Highlighted
  - Category II – Considered but not highlighted
  - Category III – More information needed to classify
  - Category IV – Ruled out
- USACE/BOR/NRC – Quantitative risk analysis
  - Calculation of probability and consequence
  - Even these calculations can be scalable

USACE Tolerable Risk

- 1 in 10,000 of 10 fatalities
- 1 in 100,000 of 100 fatalities
- > 1,000 fatalities **could** only be acceptable if a careful evaluation of tradeoff and costs is performed



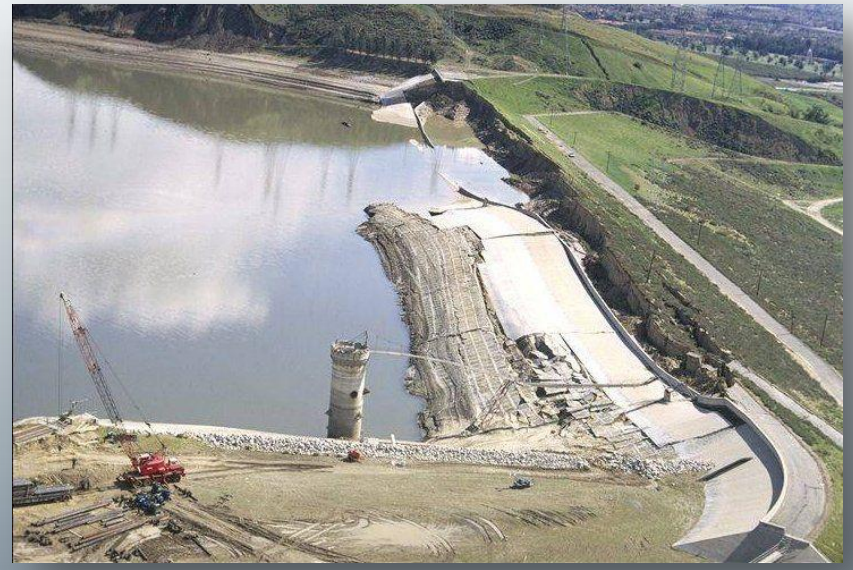
Define Potential Failure Modes

PFM 1 – Overtopping and erosion leading to breach

Probability of Failure

AFE: 7E-5 (1 in 15,000)

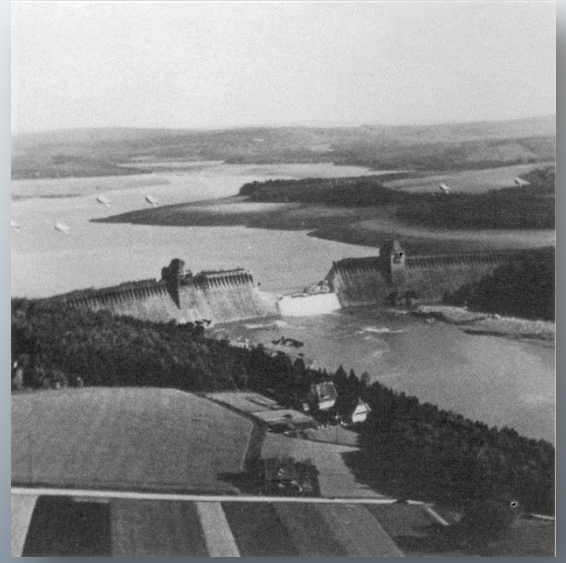
PFM 2 – Earthquake causing liquefaction leading to dam failure



Probability of Failure

AFE: 5E-6 (1 in 200,000)

PFM 3 – Plane crashing and destroying dam



Probability of Failure

AFE: 1E-6 (1 in 1,000,000)

Not All Failures Are Created Equally

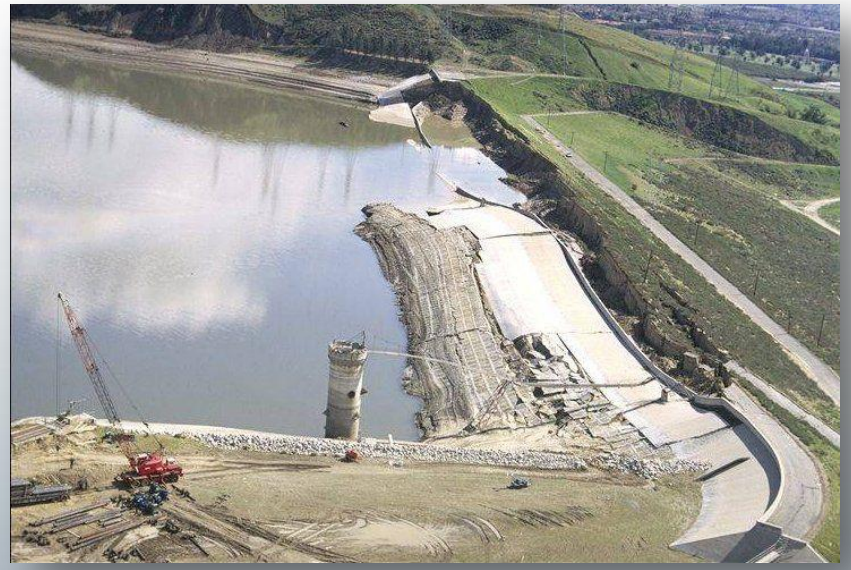
Consequence of Failure: **Low**

Forecast rain

Operational controls

Erosion can be slow failure

FERC Category I

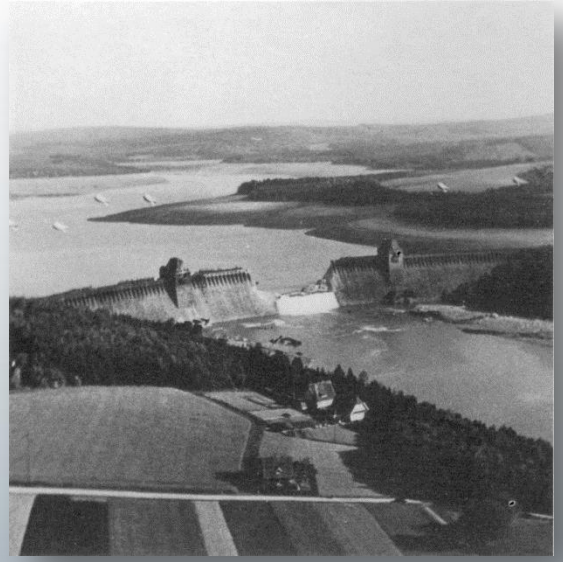


Consequence of Failure: **Moderate**

No warning

Piping, seepage leading to breach may take minutes to hours

FERC Category II



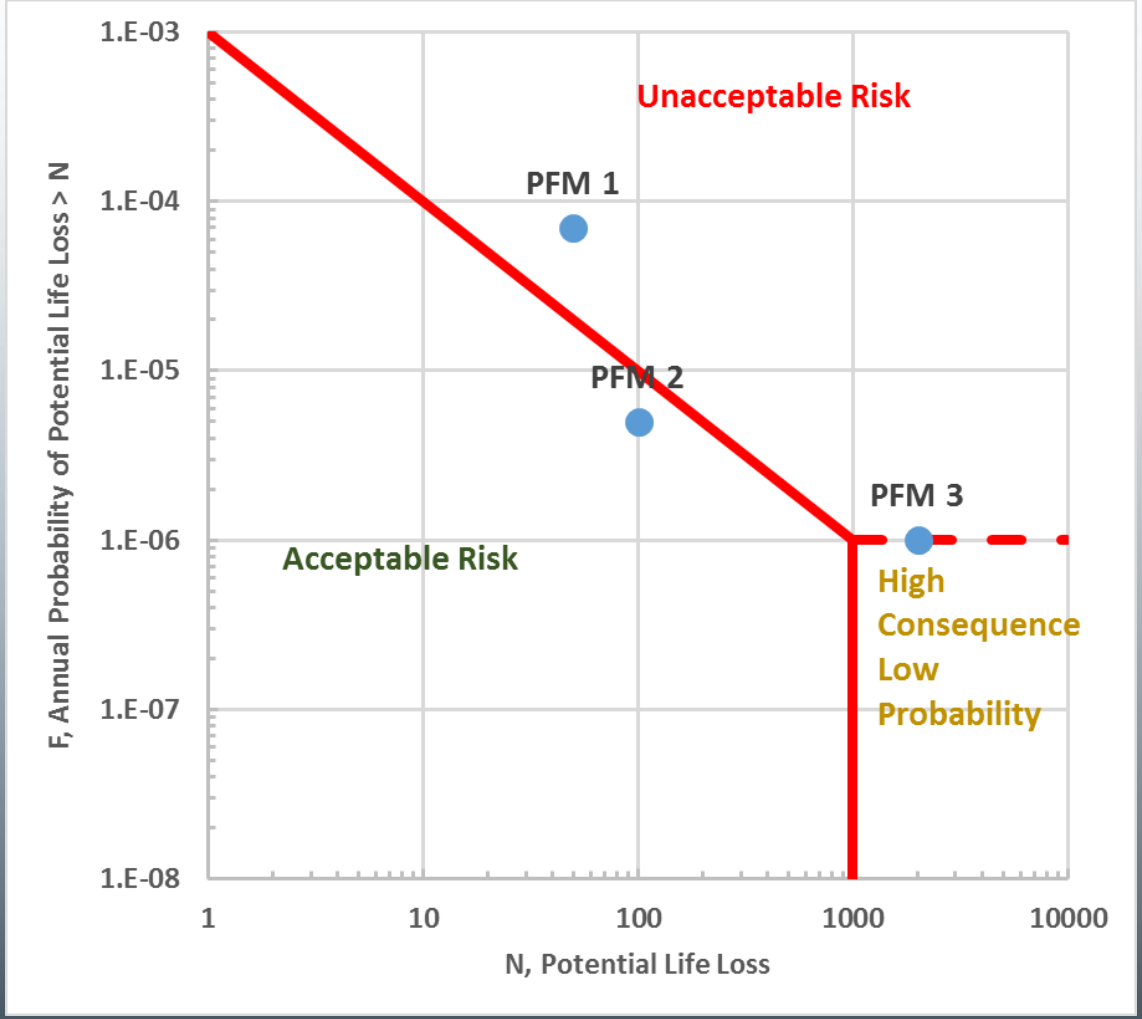
Consequence of Failure: **High**

No warning

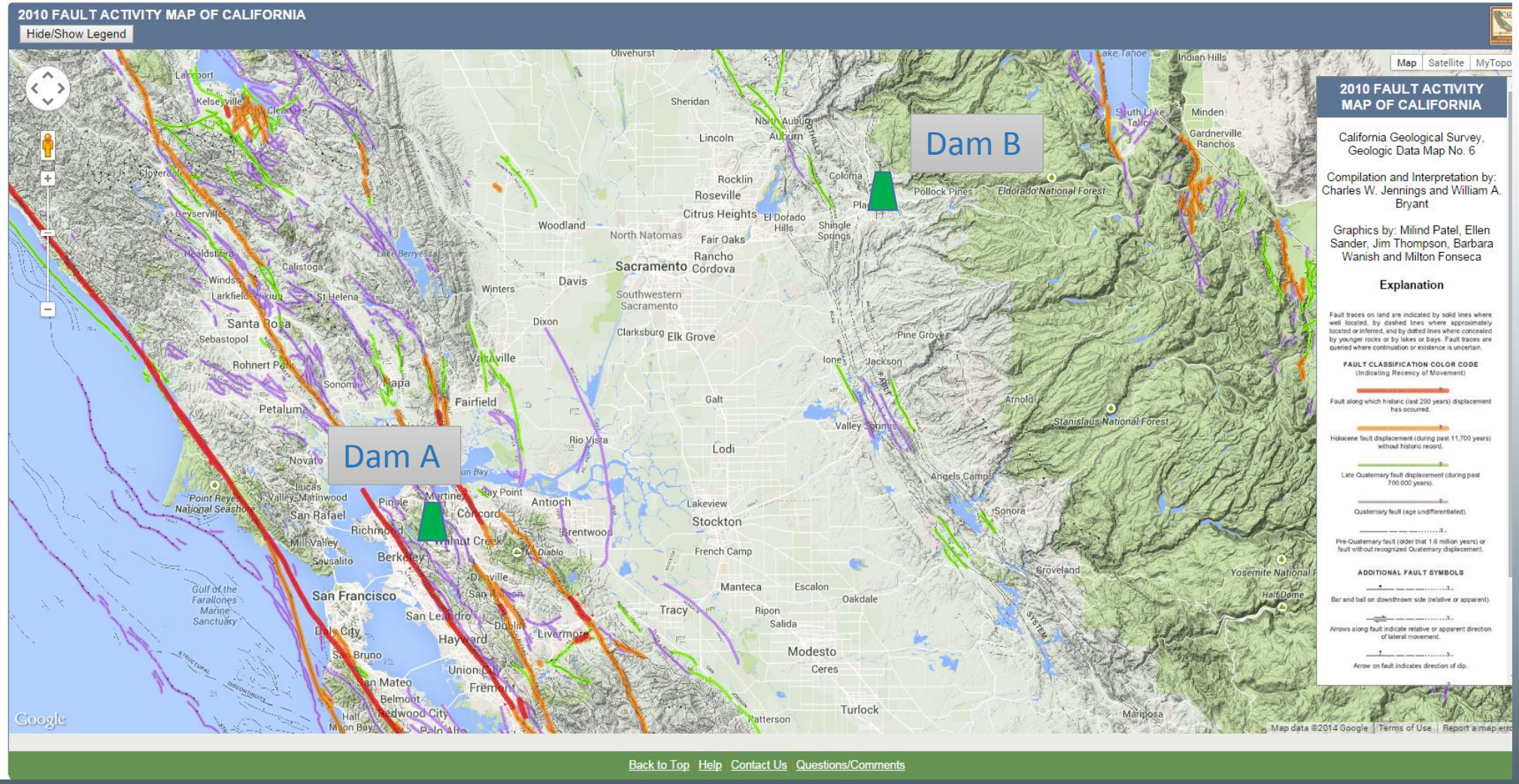
No time for evacuation

FERC Category IV

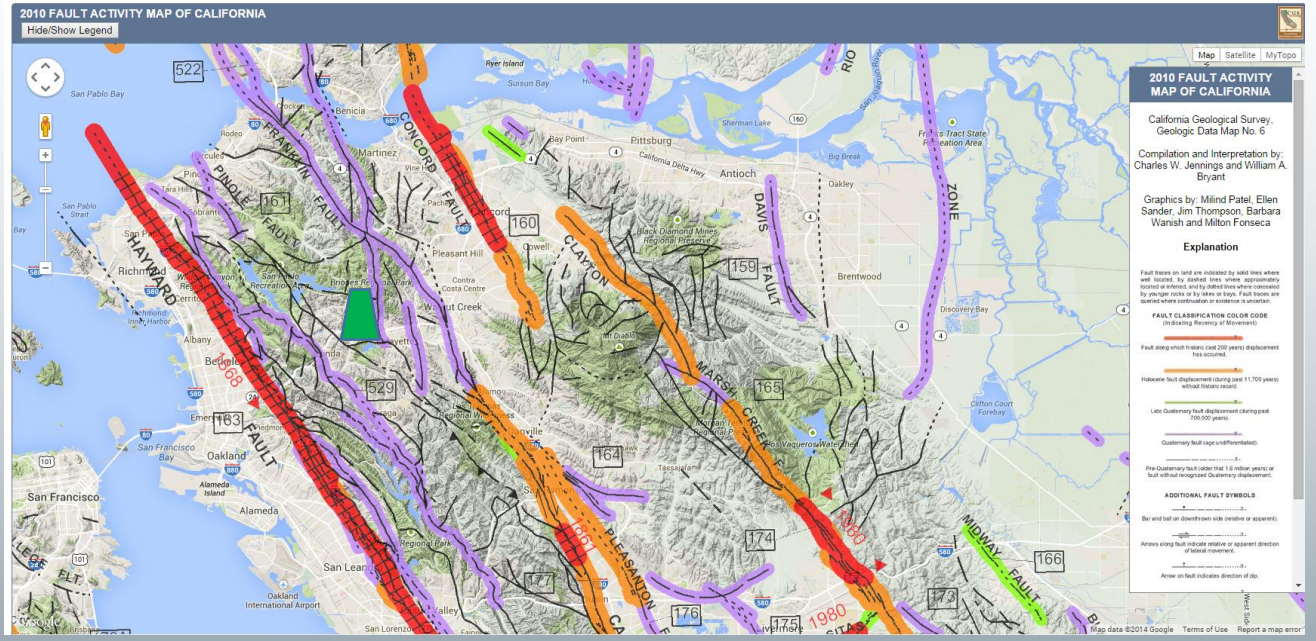
F-N Plot of Risk



Consistent Risk



Dam A



Ground Motions for Design

M7.5 at 5 km, Hayward Fault

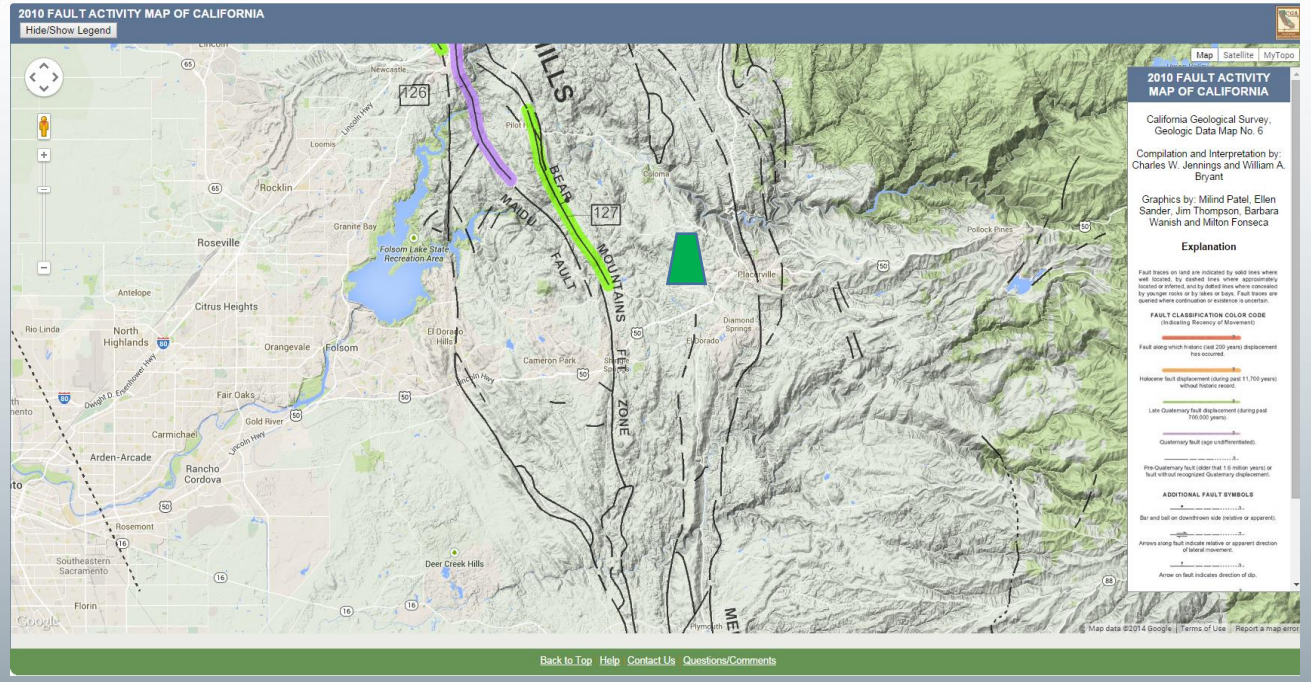
PGA = 0.73g (84th% deterministic)

High slip rate fault

Hazard Curve (USGS, 2008)

PGA: 0.73g – 885 yr return period

Dam B



Ground Motions for Design

M6.5 at 10 km, Foothills Fault system

PGA = 0.40g (84th% deterministic)

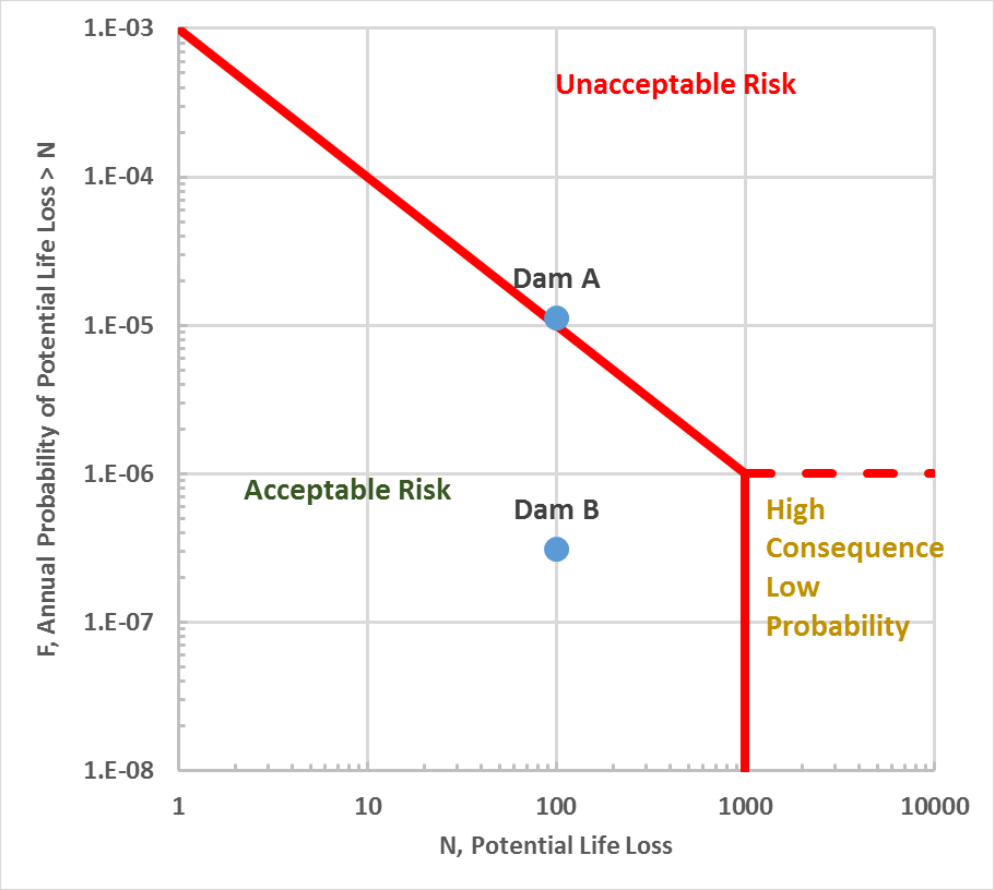
Low slip rate fault

Hazard Curve (USGS, 2008)

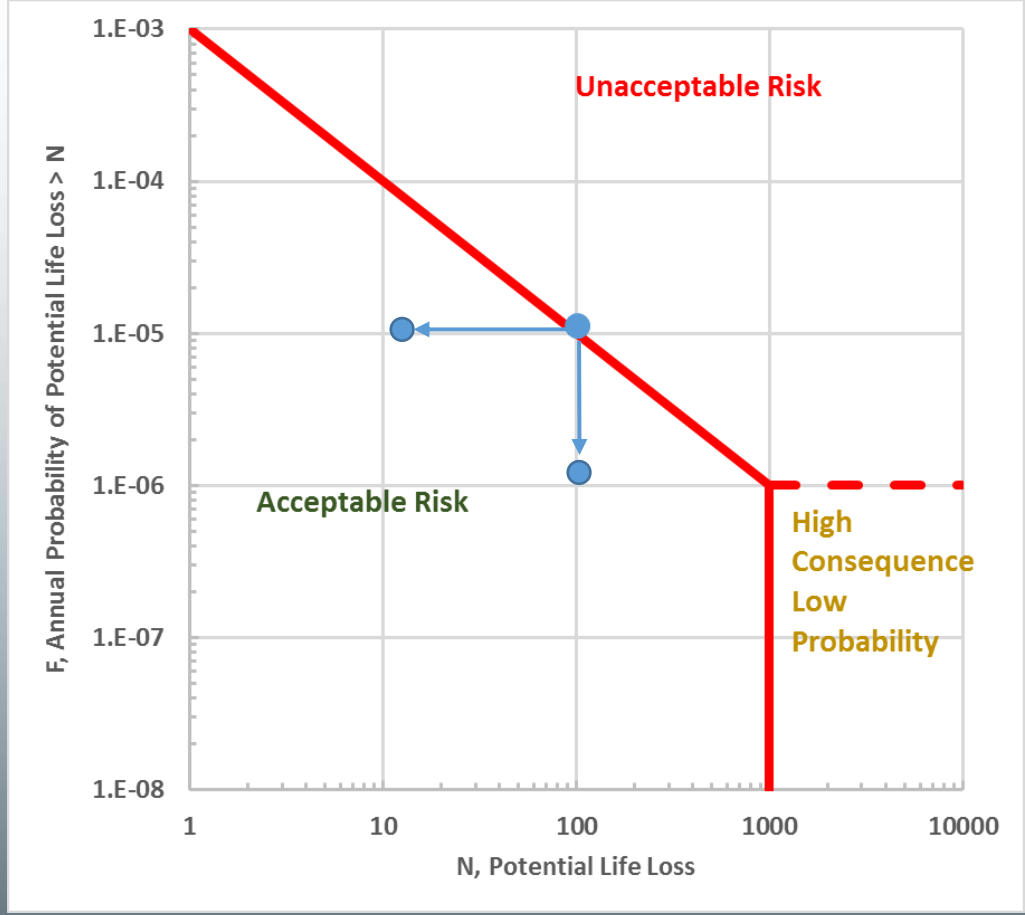
PGA: 0.40g – 32,000 yr return period

885 yr RP: ~0.10g

Consistent Risk??



Risk Reduction



- Reduce probability of failure
  - Retrofit
- Reduce consequences
  - Improved evacuation plan
  - Improved instrumentation
  - Downstream floodwalls/levees

Benefits of Risk Analysis

- Can start simple and grow in complexity
- Allows for consistent regulatory oversight across large portfolios
- Allows for more rational decision making and CIP prioritization
- Helps communication with policy makers and public
- Demonstrates benefit of both reducing the probability of failure (retrofit), and reducing losses (downstream modifications, updated EAP, cooperation with downstream emergency responders)

Innovative Technologies in Water Management

- How is dam safety an innovative technology?
  - FERC has adopted risk based approaches
  - Many states have adopted risk based approaches
  - DSOD is slowly moving towards risk
- Why is dam safety relevant in the current drought?
  - Risk based approach could benefit MCWRA members
  - Reduced seismic and hydrologic demands
  - Level playing field with rest of state
  - Return existing storage capacity

Innovative Technologies in Water Management

- Policy makers need to understand risk
- Policy makers need to encourage regulators to adopt risk
- Technical staff need to communicate the concepts of risk to non-technical policy makers

Thank you.

Contact me with your questions:

Marc Ryan
SAGE Engineers
mryan@SAGEengineers.com
916.677.4790