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Determining Background Seismicity for Dams

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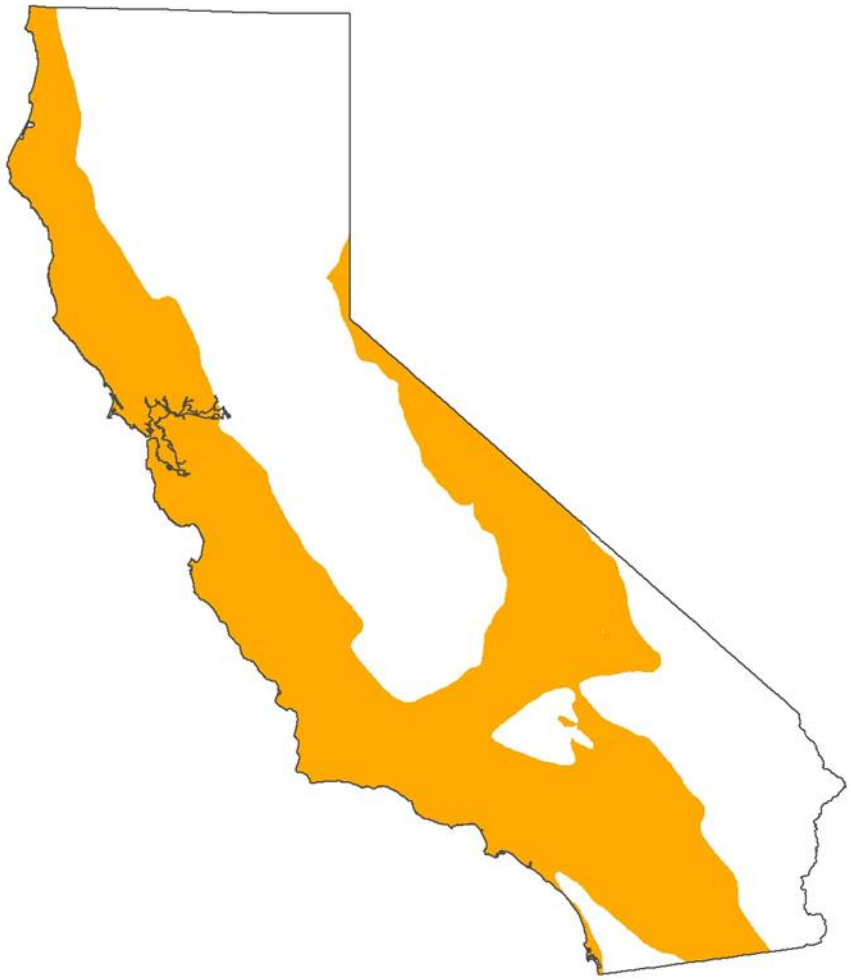
Background Seismicity

- Loading parameters from “unrecognized” seismic sources
- Known fault sources dominate the seismic hazard in many areas of California

Areas of California where known fault sources dominate a seismic hazard assessment



Background Seismicity

- Especially important for deterministic hazard analyses which rely exclusively on known sources
- Areas with historic earthquakes without known or well-defined faulting
  - Sierras
  - Central Valley
  - Southeastern California
  - Small area east of San Diego

Areas of California in which background seismicity may be important consideration

Background Seismicity Characteristics

Most active faults can be recognized in the geology

- *juxtaposition of geologic materials*
- *geomorphic expression*

Lack of geologic expression suggests:

Moderate magnitude events

- Maximum magnitudes of M6-1/4 to M6-1/2

Long recurrence intervals between events

- slip rates of less than 0.1 mm/year

Three approaches for considering background seismicity

Floating Earthquake Scenario

Minimum Loading Specification

Probabilistic Seismic Hazard Analysis

Floating Earthquake Scenario Pros & Cons

- Early approach
  - Circa late 1970's, probably earlier
- Fully deterministic
  - A hypothetical scenario is developed
- Somewhat arbitrary
  - Defined by various magnitude and distance scenarios judged appropriately conservative
    - *M6 at 0 km*
    - *M6-1/2 at 15 km*
- Little regard for event likelihood

Minimum Loading Specification Pros & Cons

- Expressed directly as loading parameter
  - PGA
  - Arias Intensity
  - Target response spectra
- Code approach
  - Simple
  - Consistent
- Variable conservatism
  - Does not consider the rate or character of background earthquake occurrence

DSOD Minimum Earthquake

- No formal consideration of unrecognized seismic sources prior to 1996
- Minimum Earthquake Policy first developed in 1996
  - PGA of 0.20g specified
    - Used only if known faults result in loading below 0.2g
  - Applied only to new dams and major rehabilitations
  - Accompanying scenario defined so other parameters could be developed as needed

DSOD Minimum Earthquake

- Modified in 2002
  - Now applies to all dams
  - Judgment allowed in selecting level of minimum earthquake
  - PGA between 0.15g, 0.20g, 0.25g based on:
    1. Dam is new or existing
    2. Consequence of dam failure
       - Total Class Weight
         - Capacity
         - Height
         - Evacuation
         - Economic loss
    3. Likelihood of loading
       - Return period associated with the selected value

DSOD Minimum Earthquake

- Accompanying scenario:
  - Magnitude fixed at M6-1/4
  - Vary the distance to obtain the specified PGA
  - Select other target parameters:
    - 0.15g ----- 50th percentile parameters
    - 0.20g ----- 67th percentile parameters
    - 0.25g ----- 84th percentile parameters

PSHA Approach
Pros & Cons

- Routinely used in regions outside of California, which are typically characterized by unrecognized seismic sources

- Conservatism well-constrained
  - Uses actual patterns and rates of historic earthquakes which have occurred in that region
  - Specify return period of loading

- More difficult to perform and review
  - Need to work with the historic earthquake record
  - Need to interpret of the appropriate scenario through deaggregation analysis

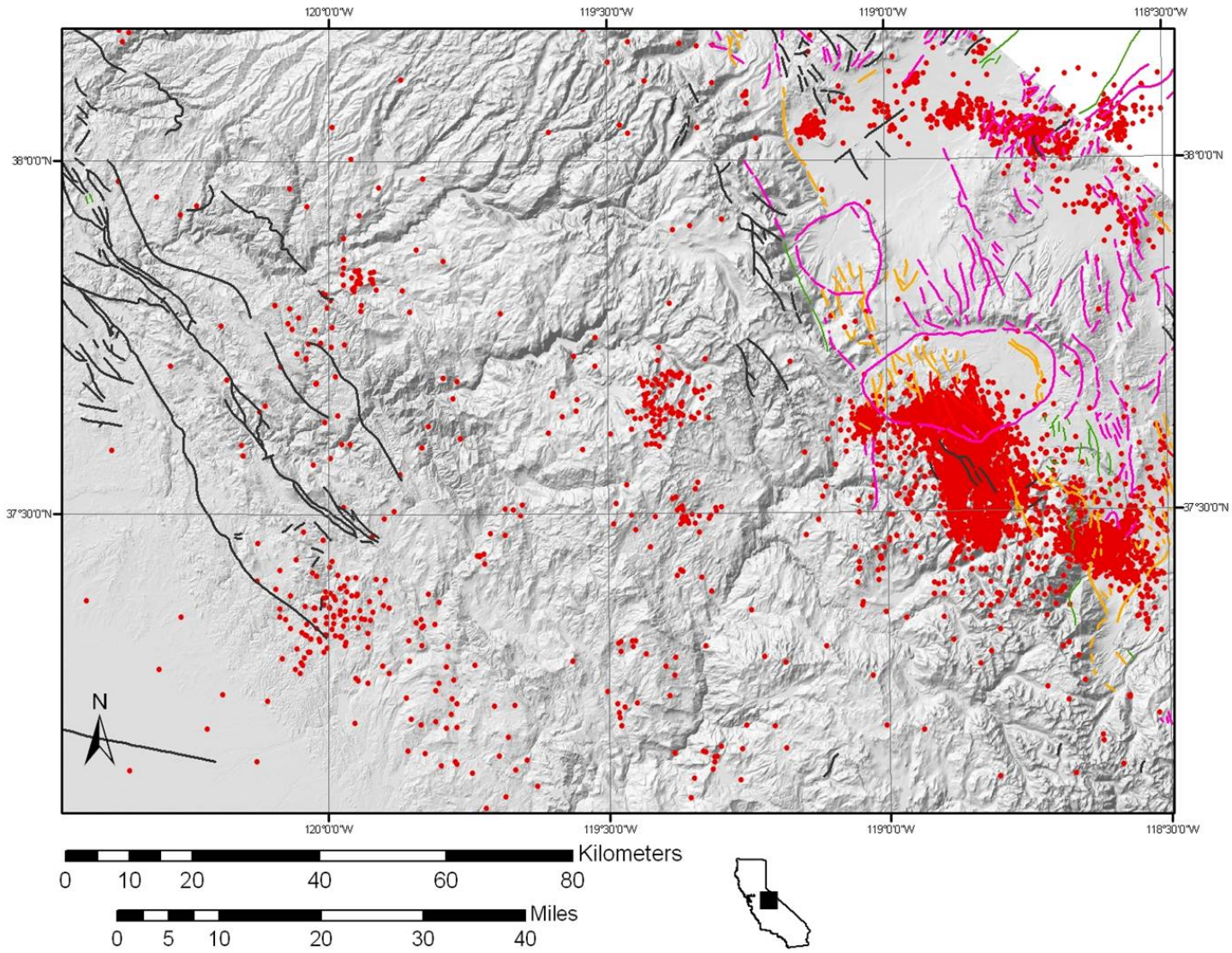
Working with the Earthquake Record

- Challenges of using the *historic earthquake record* to forward predict hazard
  - Incomplete
    - 100 years of instrumental record
      - many faults have recurrence intervals 10 times that
  - Uneven quality
    - Pre-1900 events estimated from newspaper accounts
    - Instrumental record improved in the 1930's and 1970's
      - Older events more and more approximate
      - 25 years of well-located earthquake history

Working with the Earthquake Record

- Problem Statement:
  - Historic earthquakes have occurred in the region
  - Region is believed to have active faults
  - Fault patterns are unknown

- To forward predict the seismic hazard:
  - characterize the rate, locations and size of future earthquakes
    - Number of earthquakes/year/kilometer^2
    - B-value magnitude-frequency distribution



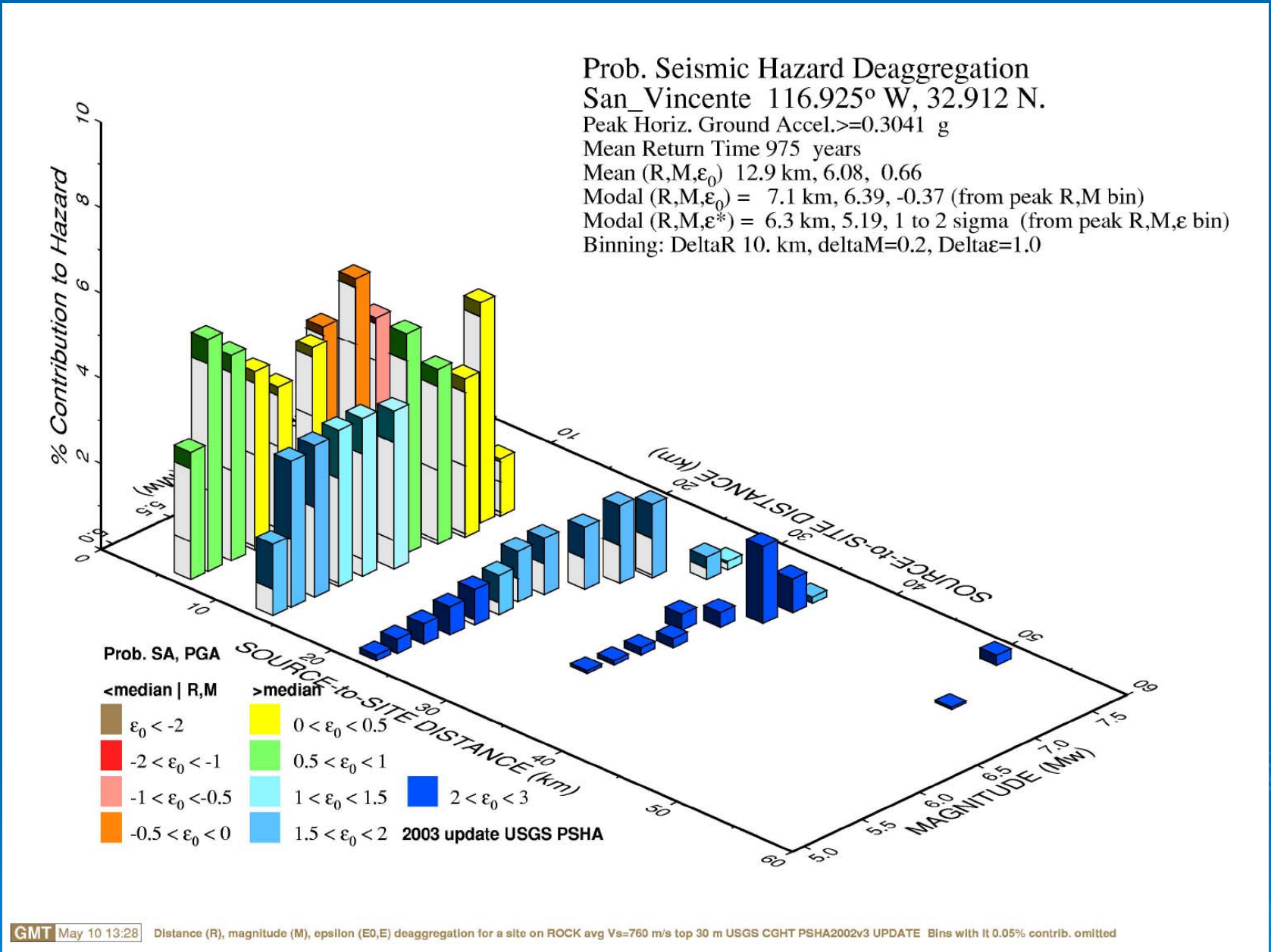
Earthquake epicenters M5 or less since 1980

Working with the Earthquake Record

- *Some* distribution the historic seismicity across the larger region is needed
- How to do it is a recurring issue in PSHA:
  - Need to account for earthquake occurring in places where they have not historically occurred
    - Smooth observed earthquake rates over the region
  - Need to recognize places where earthquakes will not occur
    - Identify sub-areas with lower earthquake rate

Deaggregating the Hazard

- Given:
  - Deformation analysis of earth dams and non-linear stress analyses of concrete dams are common
    - Event-specific time histories are needed
- Problem:
  - PSHA provides a design parameter at a specified return period that results from a number of different magnitude-distance scenarios.
  - A single scenario is usually used to develop time histories for a given seismic source
- Solution:
  - Deaggregate:
    - However---the magnitude to associate with a probabilistic parameter is not always clear cut



Which magnitude-distance scenario is indicated by the deaggregation?

Deaggregating the Hazard

- Several magnitudes seem plausible…
  - Modal magnitude
  - Mean magnitude
  - Maximum magnitude at some distance

Summary

- Three ways to evaluate the hazard associated with background seismic sources
  - Floating earthquake scenario
  - Minimum loading parameter
  - PSHA
- Each approach has precedent, is valid, and has strengths and problems
- DSOD uses the minimum loading parameter approach for developing Safety Evaluation Earthquakes in low seismic areas of the State

Looking Forward

- As part of our ongoing studies of the NGA formulas
  - Perform an internal review of Minimum Earthquake policies
    - Is the Minimum Earthquake adequate?
    - Is another approach better?
  - Early Indication:
    - Use of NGA formulas will increase the areas of the State where the Minimum Earthquake is important.

Thank you