Characterization of Earthquake Ground Shaking Hazard for Input Into the Delta Risk Analysis

Ivan Wong and Patricia Thomas
Seismic Hazards Group,
URS Corporation, Oakland, CA

Jeff Unruh
William Lettis & Associates,
Walnut Creek, CA

Kathryn Hanson and Robert Youngs
Geomatrix Consultants, Inc.,
Oakland, CA

Delta Vision Stakeholder Coordination Group Meeting
3 April 2007

Introduction

- The effects of earthquakes may be the most significant natural hazard that can impact the Delta levees.
- As part of the Delta Risk Management Strategy Project, a probabilistic seismic hazard analysis (PSHA) was performed to define plausible earthquake ground shaking events that will contribute to the risk of levee failure in the Delta.
- These events are being used to develop estimates of risk (defined as the annual probability of seismically-induced levee failure) at selected times over the next 200 years, e.g., 2005, 2050, 2100, and 2200. (Yes, I said 200 years!)

Products

- Plausible scenario events for input into the risk analysis
- Site-specific hazard at six selected sites to illustrate the hazard
- Ground shaking hazard maps of the Delta

What is a PSHA?

- The objective of performing a PSHA is to answer the question: Given some annual probability, what is the level of ground shaking that will be exceeded?
- An example is the building code, which uses an annual probability of 1/2500 or a return period of 2500 years.
- Ground motions are often characterized by the parameter called peak horizontal ground acceleration (PGA).

Question 1

- What do we know and don't know and what is the scientific basis?

Approach

- A working group developed the seismic source model and selected ground motion predictive relationships for input into the PSHA.
- The PSHA was performed in accordance with a set of industry guidelines.
- The inputs are intended to be a composite representation of the informed technical community.
- The PSHA methodology allows for the explicit consideration of epistemic uncertainties and inclusion of the range of possible interpretations of the PSHA inputs.

Approach (cont.)

- Given that selected times are of interest, the PSHA calculations will incorporate the time-dependent behavior of the major faults characterized by the Working Group on California Earthquake Probabilities (2003).
- Typically, probabilistic hazard is calculated assuming time-independent behavior of seismic sources because we almost always lack time-dependent information.
- PSHA results were reviewed by DWR Senior Review Panel and U.S. Geological Survey and California Geological Survey experts.

Steps in a PSHA

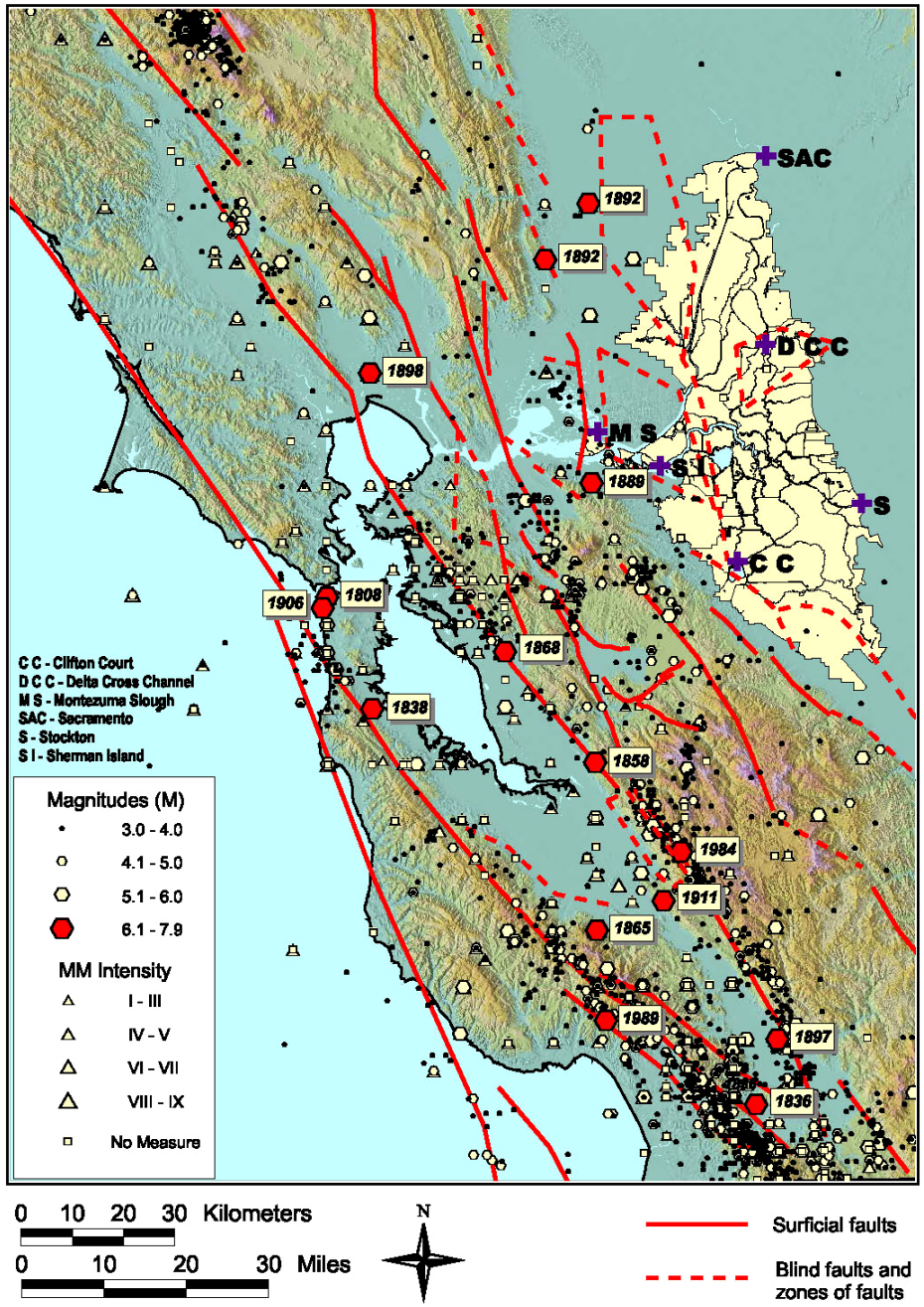
1) Identify all seismic sources that can generate strong ground shaking at the site.

2) Characterize each seismic source in terms of location, geometry, sense of slip, maximum magnitude, and earthquake occurrence rates for all magnitudes of significance to the site hazard (typically moment magnitude [**M**] $\geq$ 5).

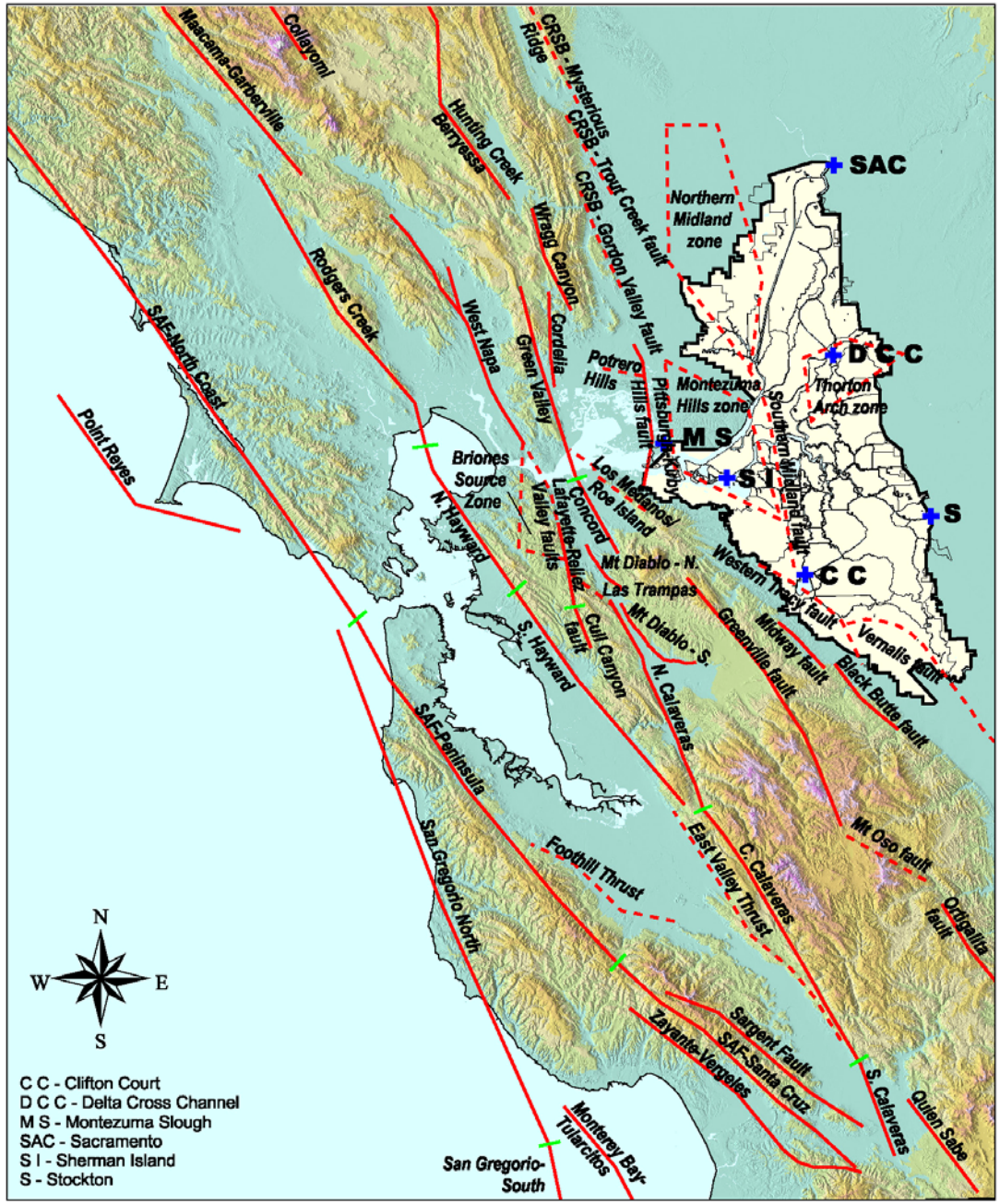
3) Select ground motion attenuation relationships appropriate for the seismic sources, seismotectonic setting, and site conditions.

4) Calculate the probabilistic hazard using a qualified computer program. The hazard can be expressed in terms of seismic hazard curves.

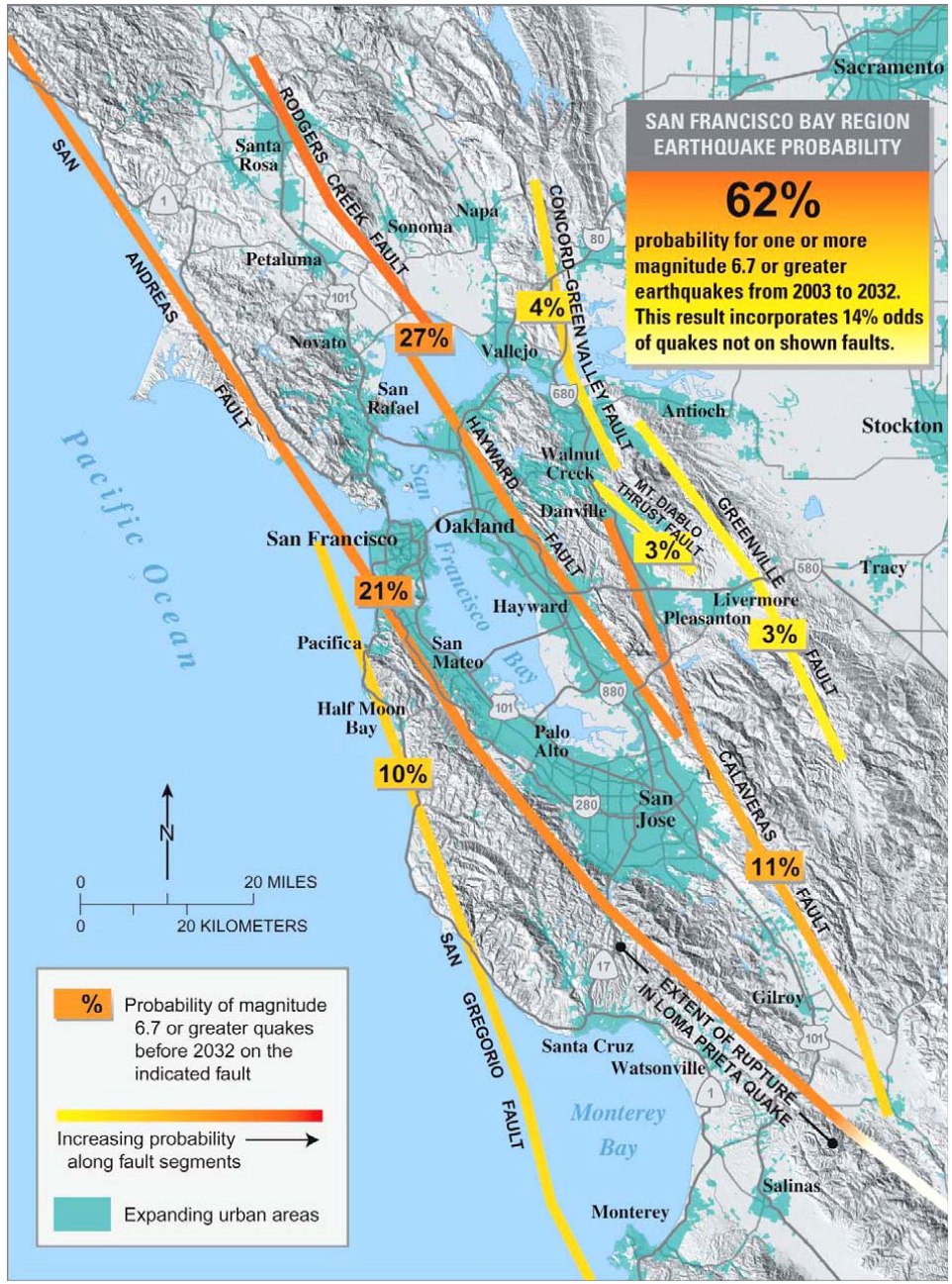
Historical Seismicity of the San Francisco Bay Region (M ≥ 3.0) 1800 – 2006



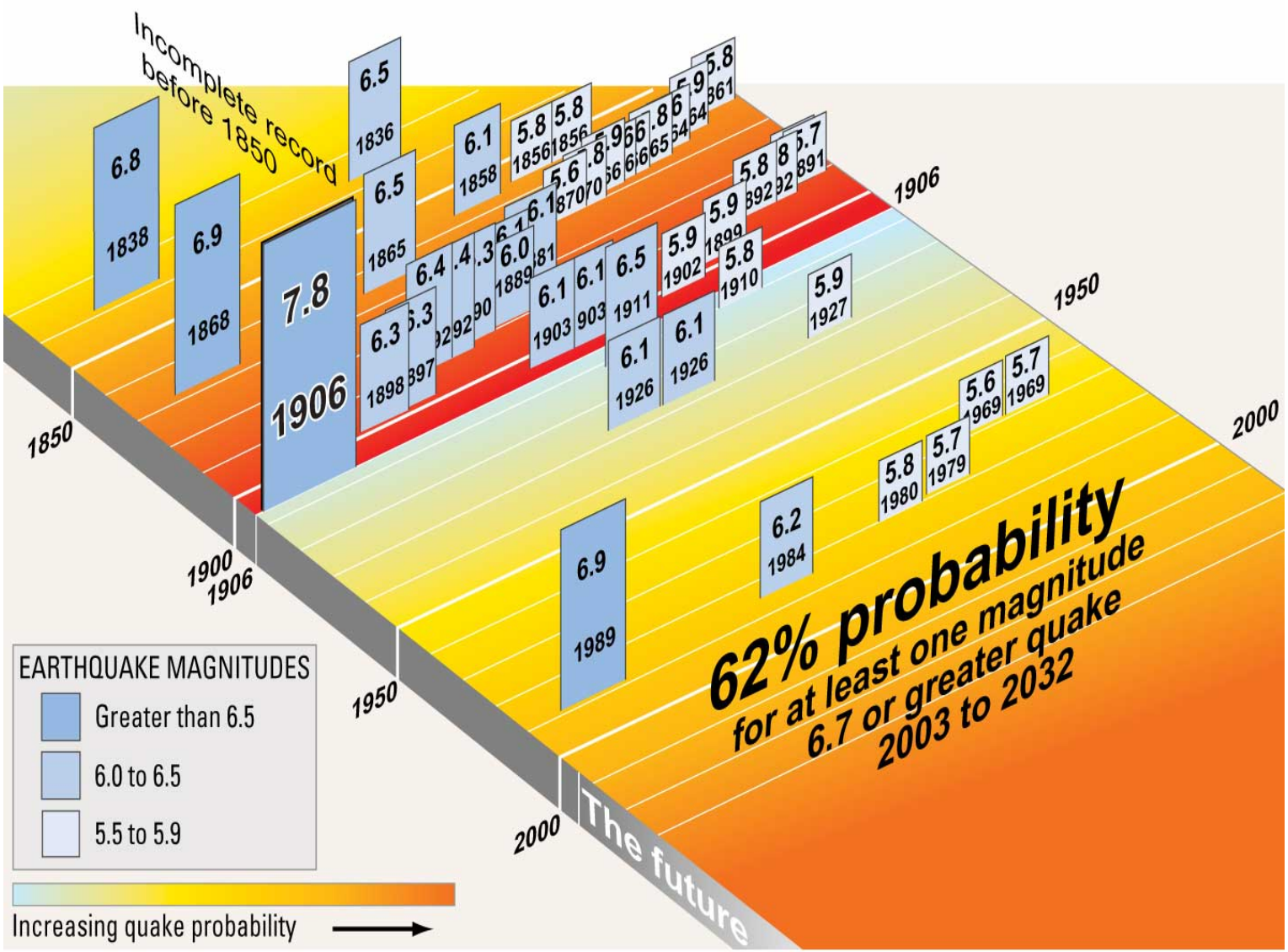
Seismic Sources in the San Francisco Bay Region



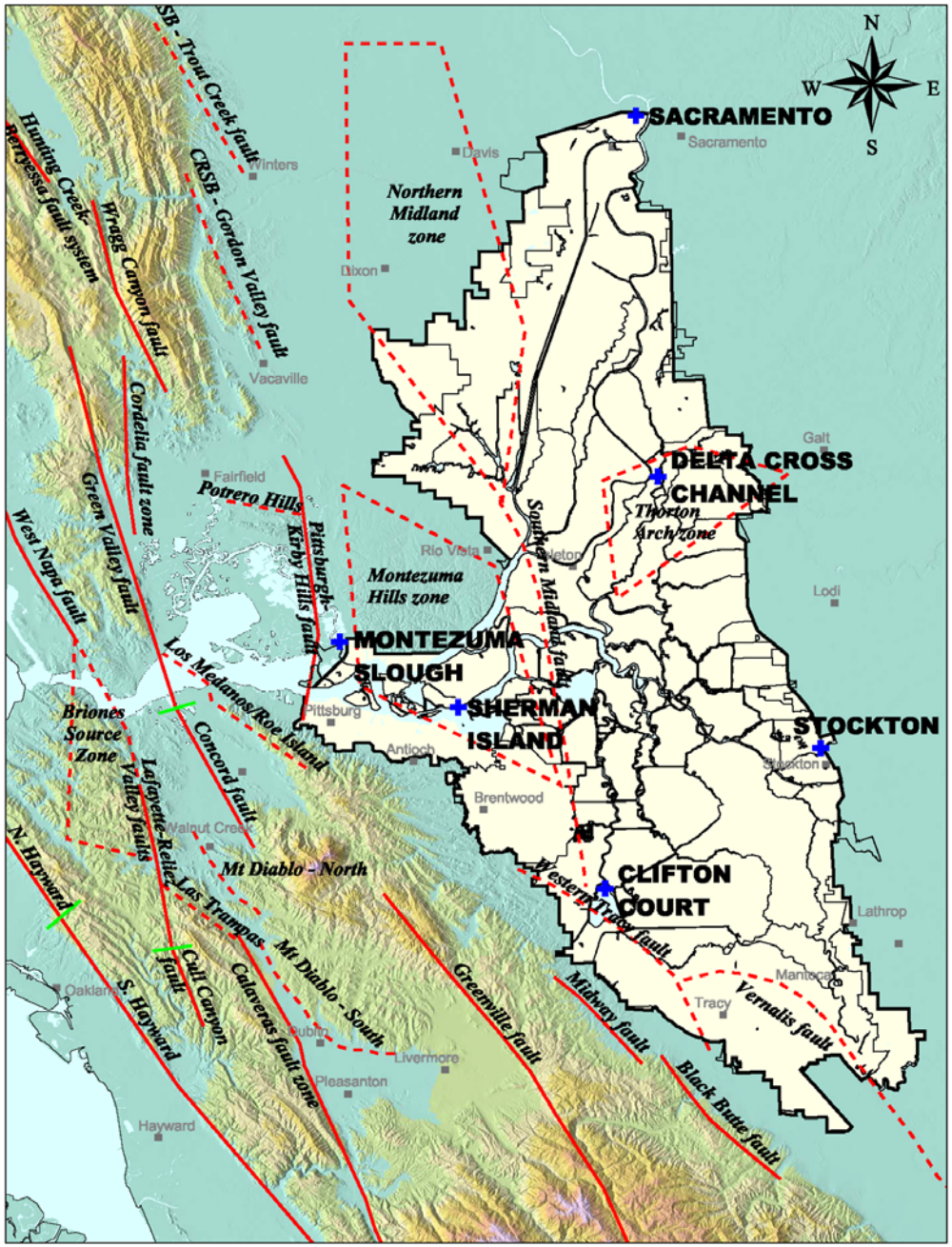
Probabilities of One or More Major ($M \geq 6.7$) Earthquakes on Faults in the San Francisco Bay Region During the Period 2003 to 2032



Bay Area Historical Seismicity



Seismic Sources In and Near the Delta

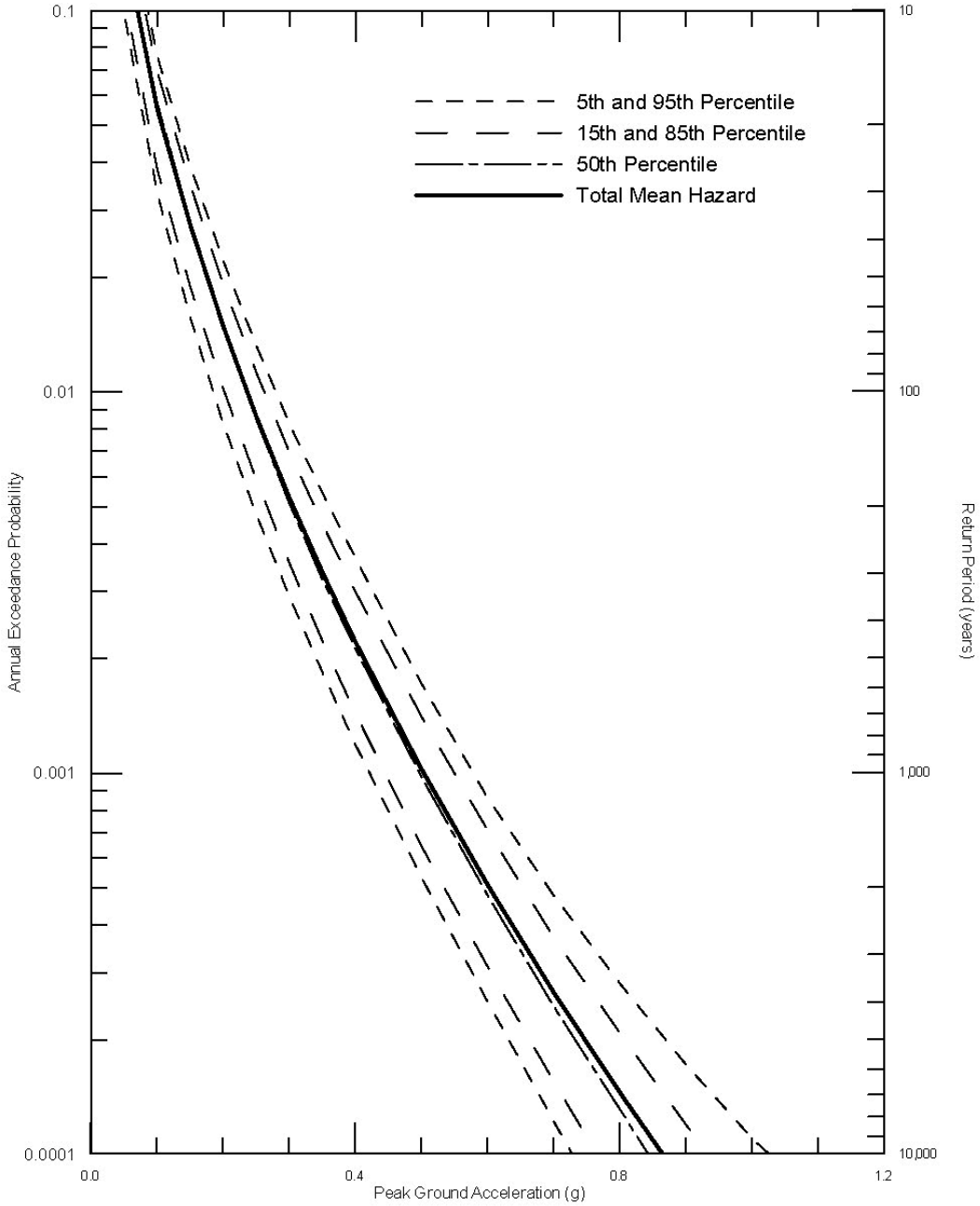


Seismic Source Issues in the Delta

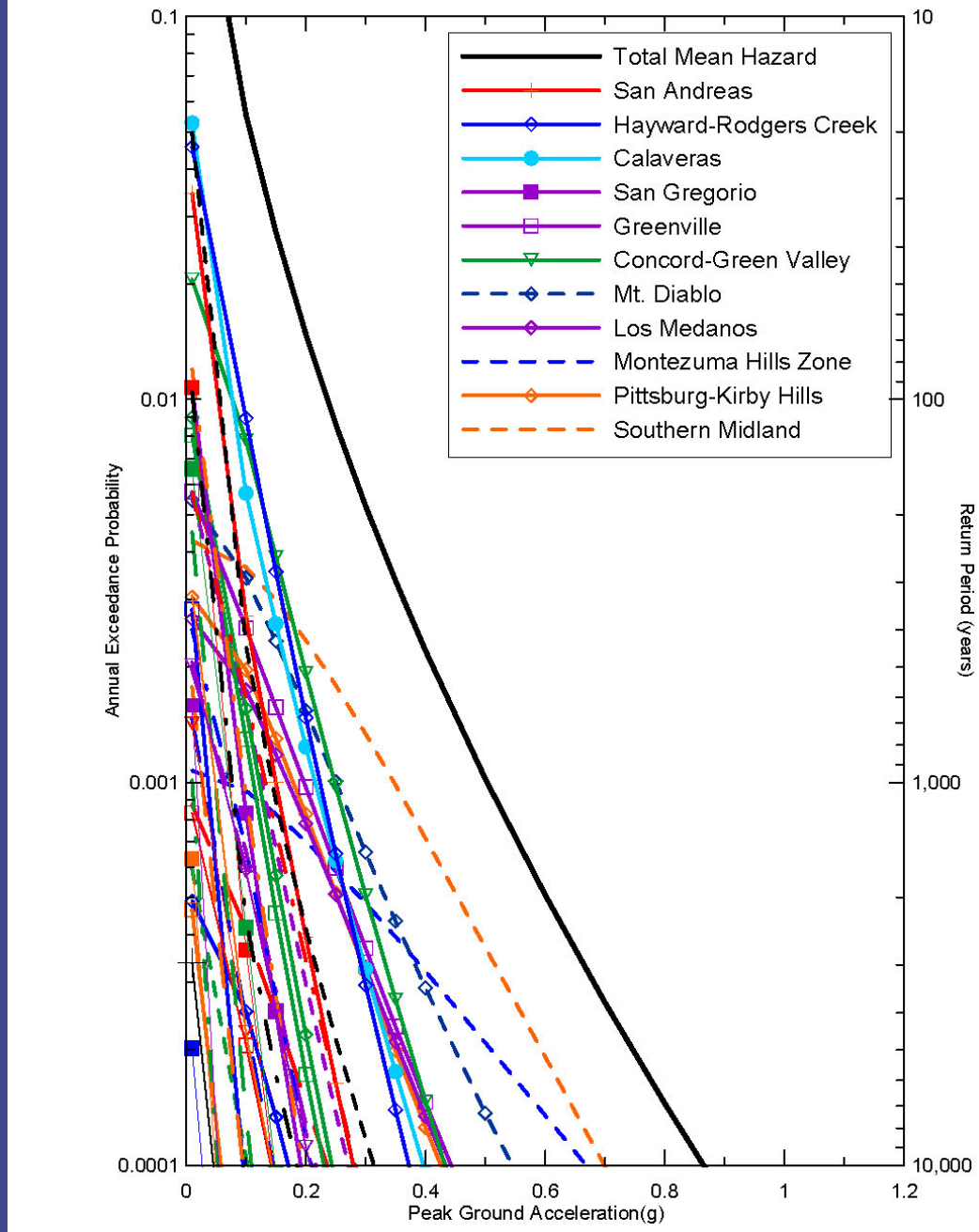
- How is crustal deformation accounted for in the Delta?
- Are there blind faults?
- What is the role of the Midland fault?
- No time-dependent information.

PSHA RESULTS

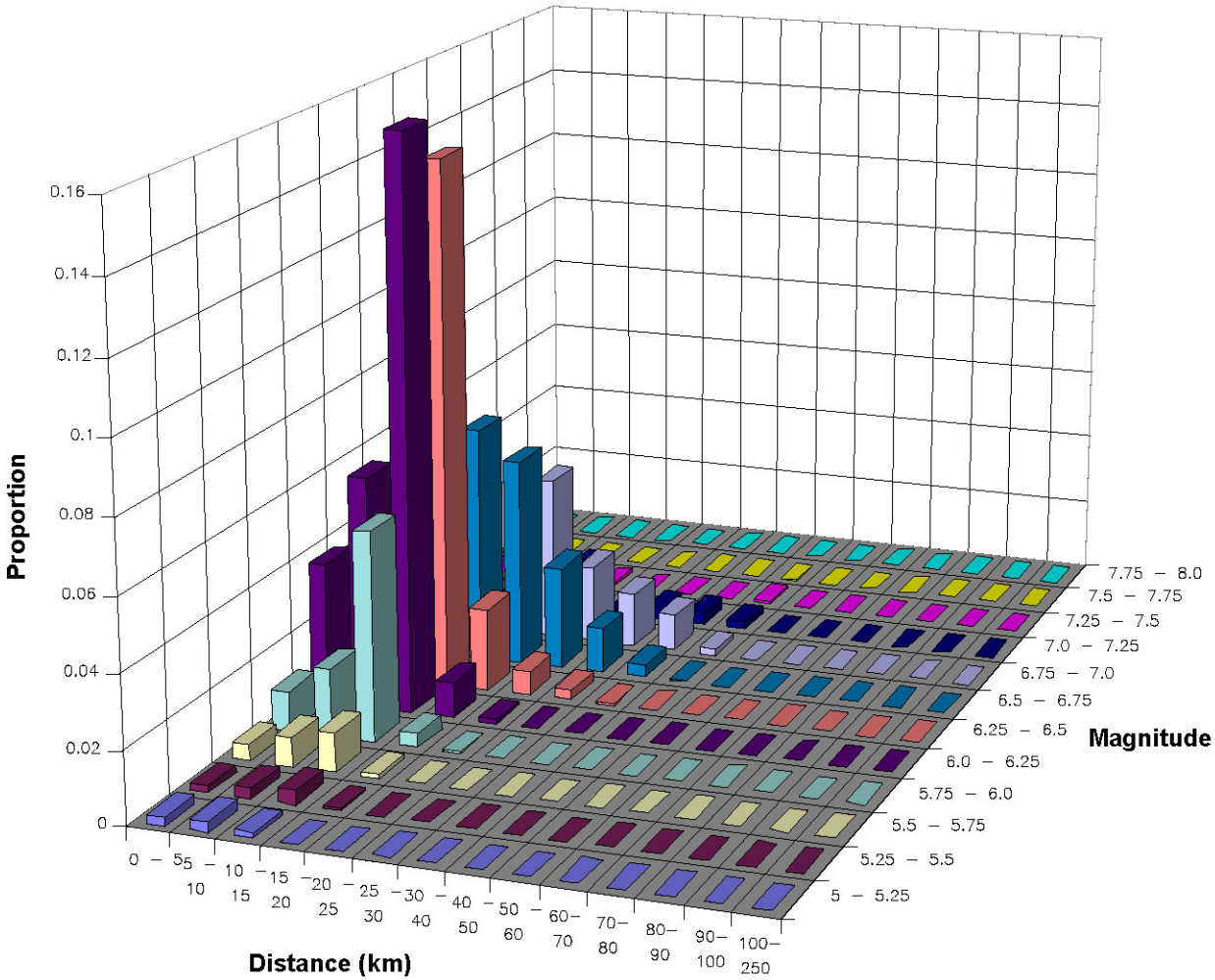
Time-Dependent Seismic Hazard Curves for Mean Peak Horizontal Acceleration for Sherman Island for 2005



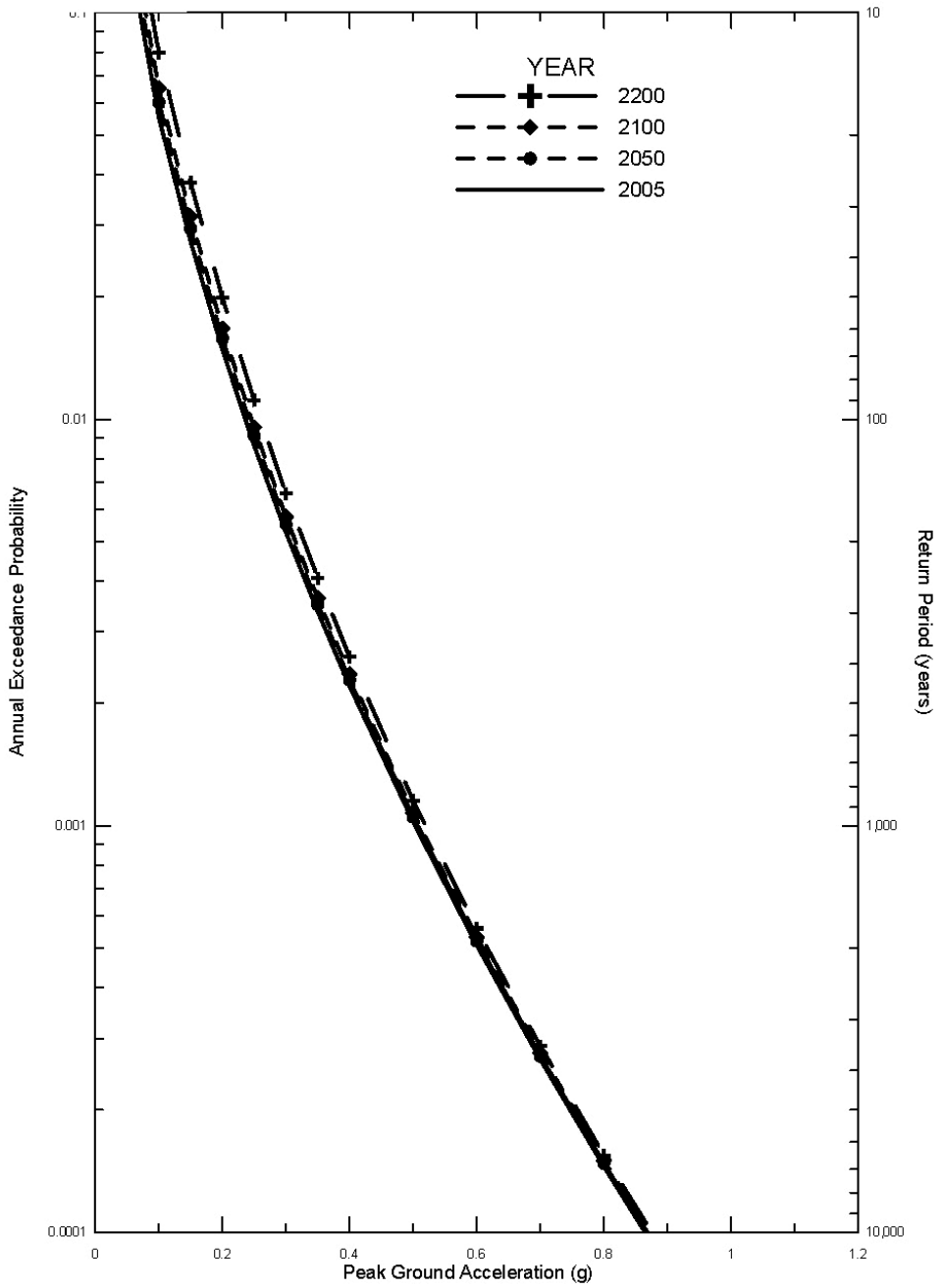
Seismic Source Contributions to Mean Peak Horizontal Acceleration Time-Dependent Hazard for Sherman Island for 2005



Magnitude and Distance Contributions to the Mean Peak Horizontal Acceleration Time-Dependent Hazard at 2,500-Year Return Period for Sherman Island for 2005



Time-Dependent Mean Peak Horizontal Acceleration Hazard for Sherman Island



Controlling Seismic Sources at a Return Period of 100 Years in 2005

Location	PGA	1.0 Sec SA
Clifton Court	Southern Midland Mt. Diablo	Mt. Diablo Hayward-Rodgers Creek
Delta Cross Channel	Southern Midland Northern Midland Zone	Mt. Diablo
Montezuma Slough	Concord-Green Valley	Concord-Green Valley
Sacramento	Northern Midland Zone	Mt. Diablo San Andreas
Sherman Island	Southern Midland	Southern Midland Hayward-Rodgers Creek San Andreas
Stockton	Southern Midland Hayward-Rodgers Creek Calaveras	Hayward-Rodgers Creek San Andreas

Note: Seismic sources are ordered by contribution.

Controlling Seismic Sources at a Return Period of 2,500 Years in 2005

Location	PGA	1.0 Sec SA
Clifton Court	Southern Midland	Southern Midland
Delta Cross Channel	Southern Midland Northern Midland Zone	Cascadia Subduction Zone Southern Midland
Montezuma Slough	Pittsburg-Kirby Hills	Pittsburg-Kirby Hills
Sacramento	Northern Midland Zone	Cascadia Subduction Zone
Sherman Island	Southern Midland Montezuma Hills Zone	Southern Midland
Stockton	Southern Midland	Cascadia Subduction Zone

Note: Seismic sources are ordered by contribution.

Question 2

- What would it take to address what we don't know and can it be available within a year?

Answers: Some basic geologic studies of the Delta Faults such as collecting information from gas exploration studies, compile and evaluate borehole data, evaluate drainage systems and geomorphic development of some of the structures in the Delta.

Yes.

Ground Motions for Return Periods of 100 to 2,500 Years in 2005

Site	PGA (g's)			
	100 years	200 years	500 years	2,500 years
Clifton Court	0.22	0.29	0.40	0.66
Delta Cross Channel	0.15	0.19	0.25	0.37
Montezuma Slough	0.27	0.35	0.47	0.74
Sacramento	0.12	0.15	0.20	0.30
Sherman Island	0.24	0.31	0.41	0.64
Stockton	0.13	0.17	0.22	0.32

Deterministic Scenario Earthquake PGAs

Site	Median PGA (g's)			
	Hayward Fault M 7	Greenville Fault M 7	San Andreas M 7	San Andreas M 8
Clifton Court	0.10	0.20	0.06	0.11
Delta Cross Channel	0.05	0.07	0.04	0.08
Montezuma Slough	0.11	0.15	0.07	0.12
Sacramento	0.05	0.05	0.04	0.07
Sherman Island	0.10	0.18	0.06	0.11
Stockton	0.06	0.10	0.04	0.08

Question 3

- How might each driver impact the planning for the Delta?

Answer: To be determined by the DRMS study, but it doesn't look pretty!

Summary

- Based on the hazard results, a number of seismic sources contribute to the hazard in the Delta. One of the most important seismic sources is the Southern Midland fault, a buried structure we know little about.
- Time-dependent probabilistic ground motions for the six specific sites in the Delta had PGAs that range from more than 0.75 g on the west side to about 0.3 g on the east side in the Central Valley.
- In a deterministic sense, a large earthquake (**M** > 7) anywhere in the San Francisco Bay region may still damage the levees.

Summary (cont.)

- The effects on the peat and softer soils have not been incorporated into the ground motions, however, at the reference site condition of a stiff soil, the hazard is moderate to high. No surprise!