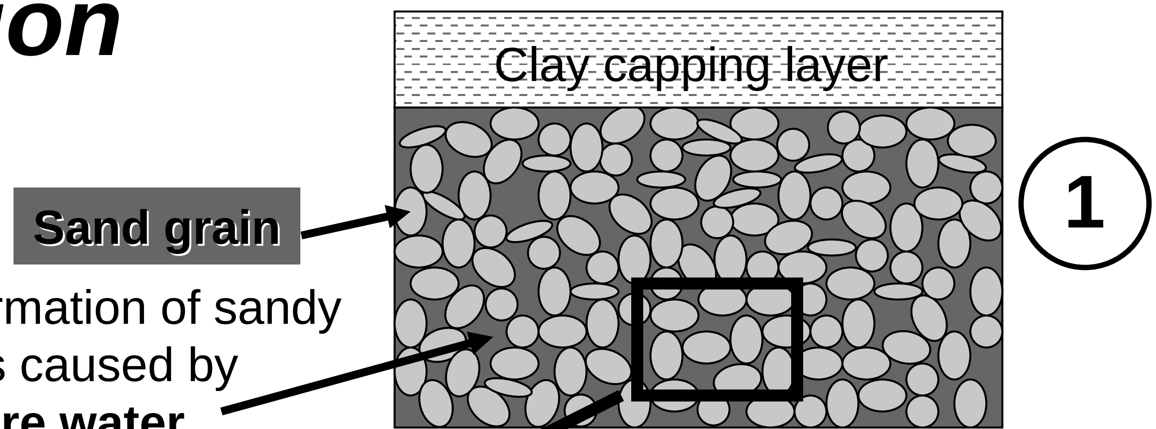
Liquefaction

Thomas L. Holzer, U.S. Geological Survey

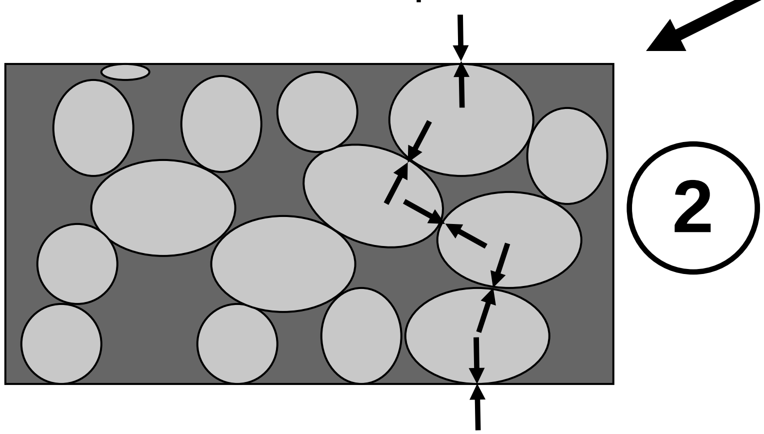
- **What is it?**
- **Effects**
- **Significance**
- **What can we do about it?**

Liquefaction



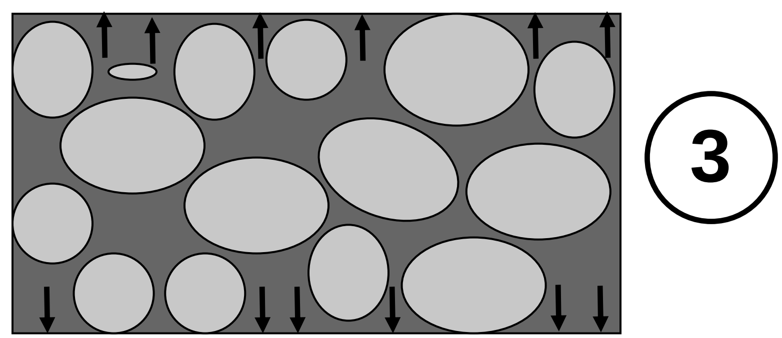
Liquefaction is the transformation of sandy soil into a liquefied state. It is caused by pressure increases in the **pore water**.

Before the earthquake

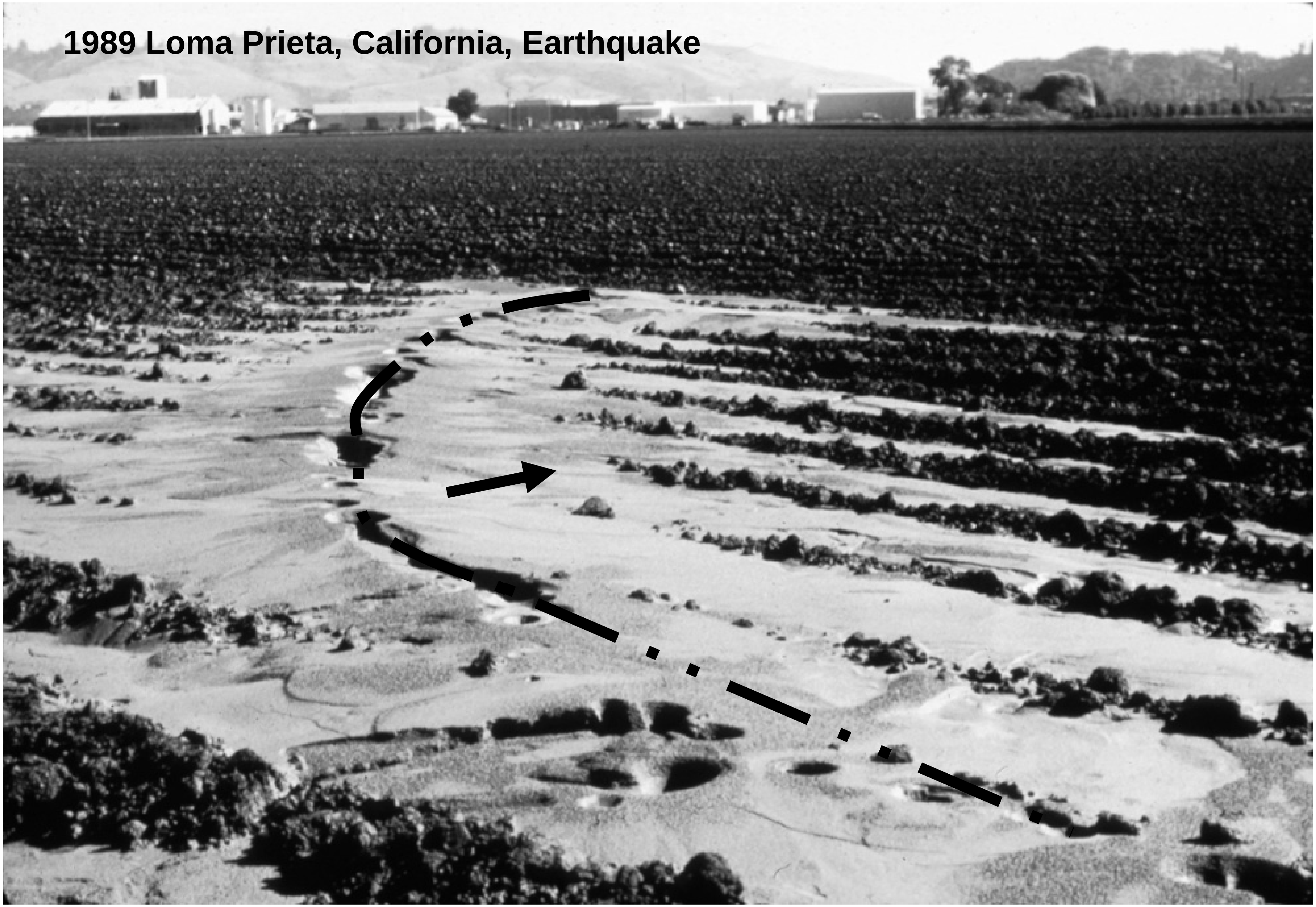


Weight of ground is supported by sand grains.

During the earthquake

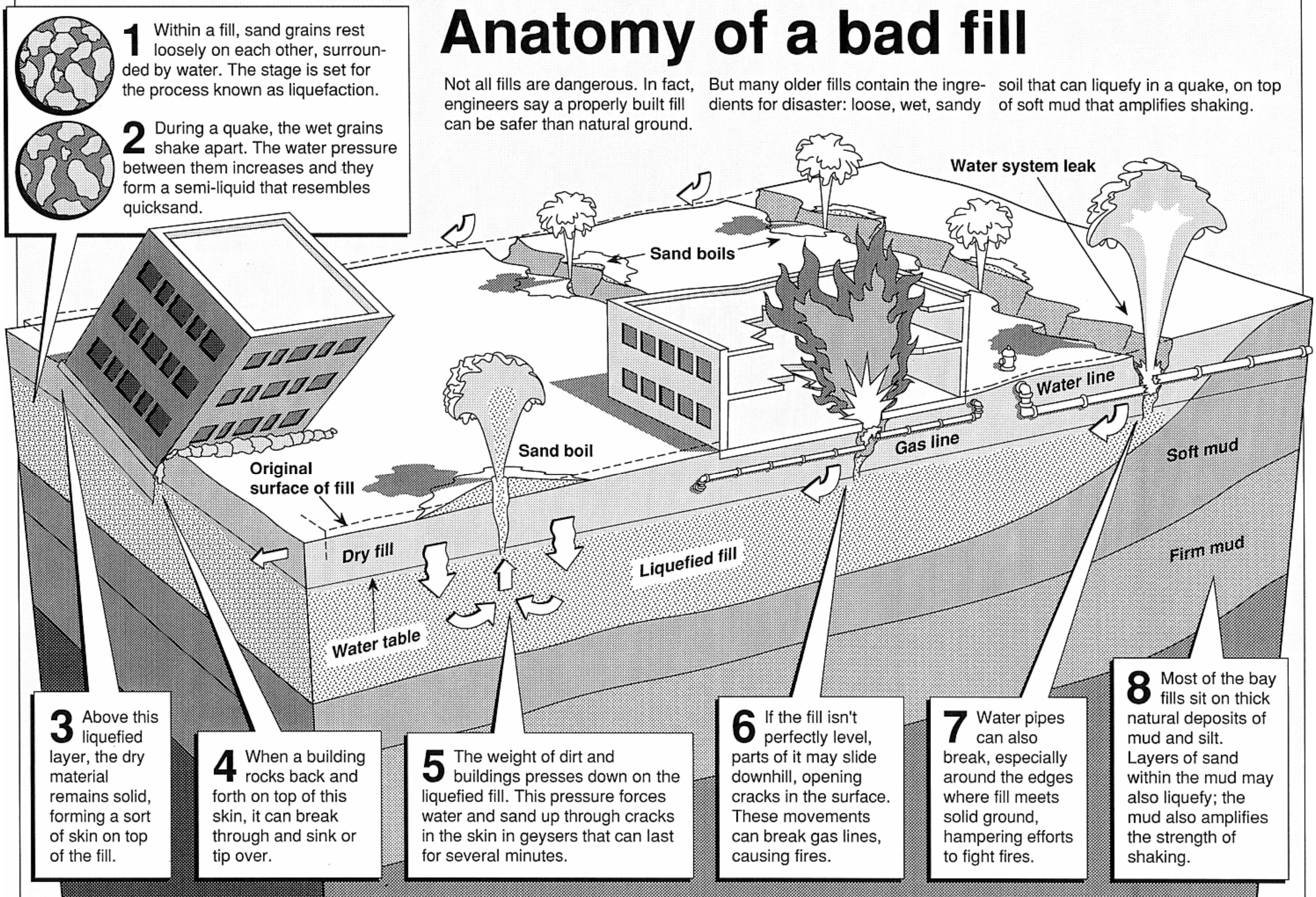


Weight of ground is supported by pore water.


1989 Loma Prieta, California, Earthquake

Anatomy of a bad fill

Not all fills are dangerous. In fact, engineers say a properly built fill can be safer than natural ground. But many older fills contain the ingredients for disaster: loose, wet, sandy soil that can liquefy in a quake, on top of soft mud that amplifies shaking.



Sources: Tom Holzer, U.S. Geological Survey; Kent Dedrick, State Lands Commission; UC-Berkeley; Gerald Dow, "Bay Fill in San Francisco: A History of Change;" and staff reports.

1906 San Francisco Earthquake

Liquefaction
↓
Pipeline damage
↓
Fire

Lateral Spreading

Broken Water & Gas Pipelines
1994 Northridge Earthquake
Balboa Boulevard, Granada Hills

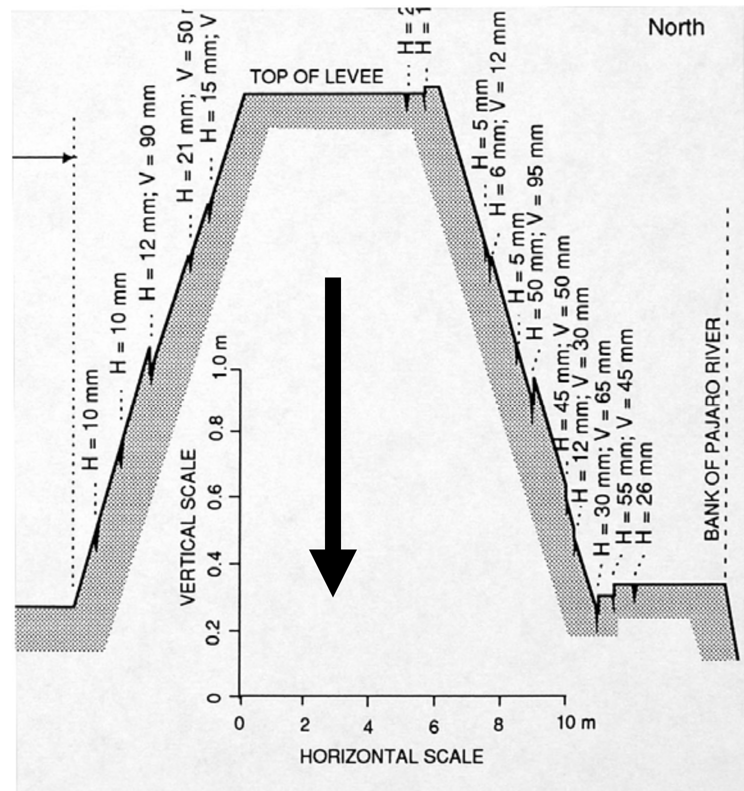
Destroyed Buildings
1989 Loma Prieta Earthquake
Moss Landing Marine Laboratory

Sinking Buildings

1964 Niigata, Japan

1999 Kocaeli EQ, Adapazari, Turkey

Levee Cracking and Failure



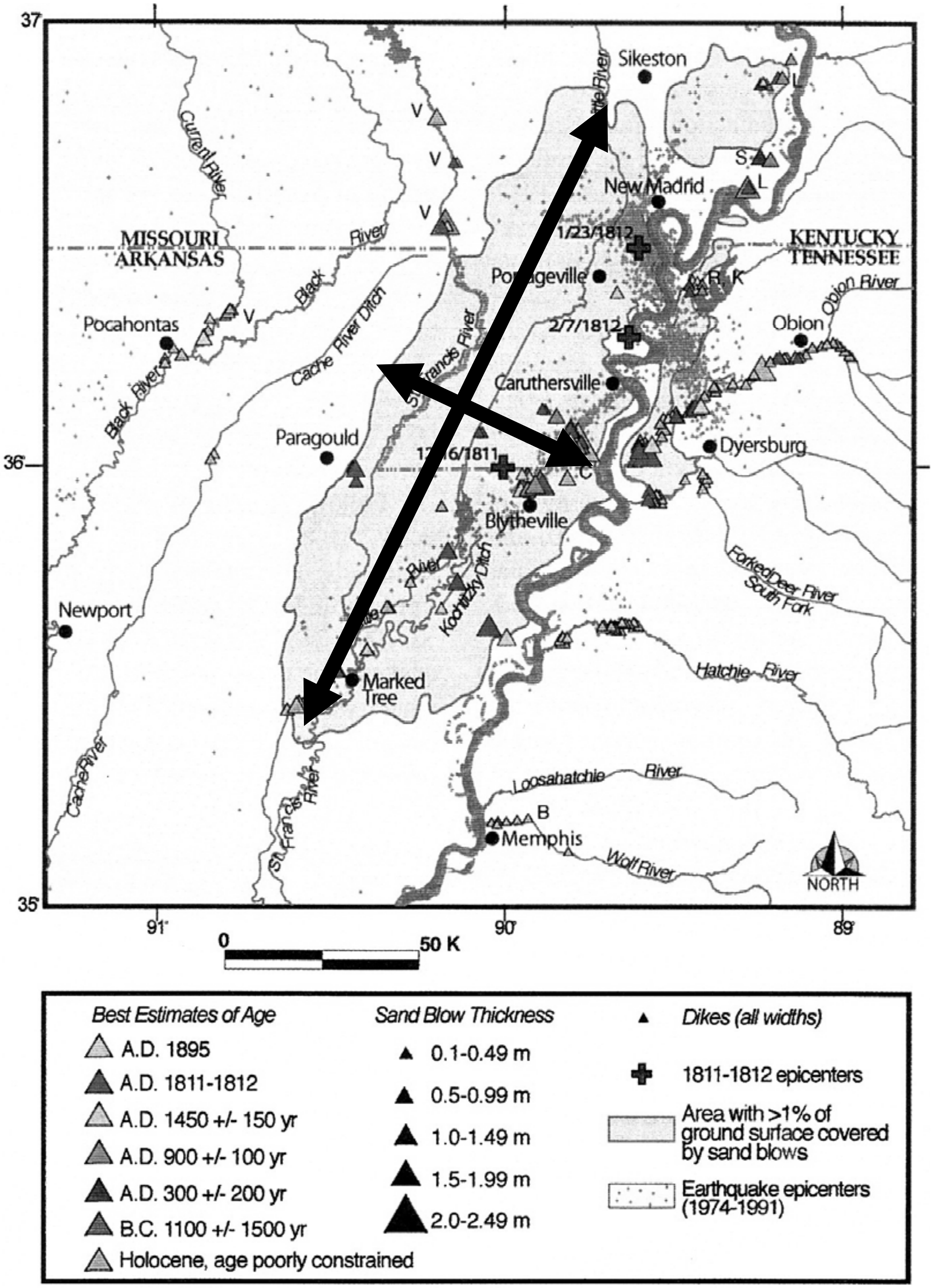
Cracked levee
Monterey Bay region
1989 Loma Prieta Earthquake

Losses (in % of total loss) by Hazard
1989 Loma Prieta Earthquake

Earthquake Hazard	%
Shaking	
Normal	28
Enhanced	70
Liquefaction	2
Fault rupture	0
Total	100

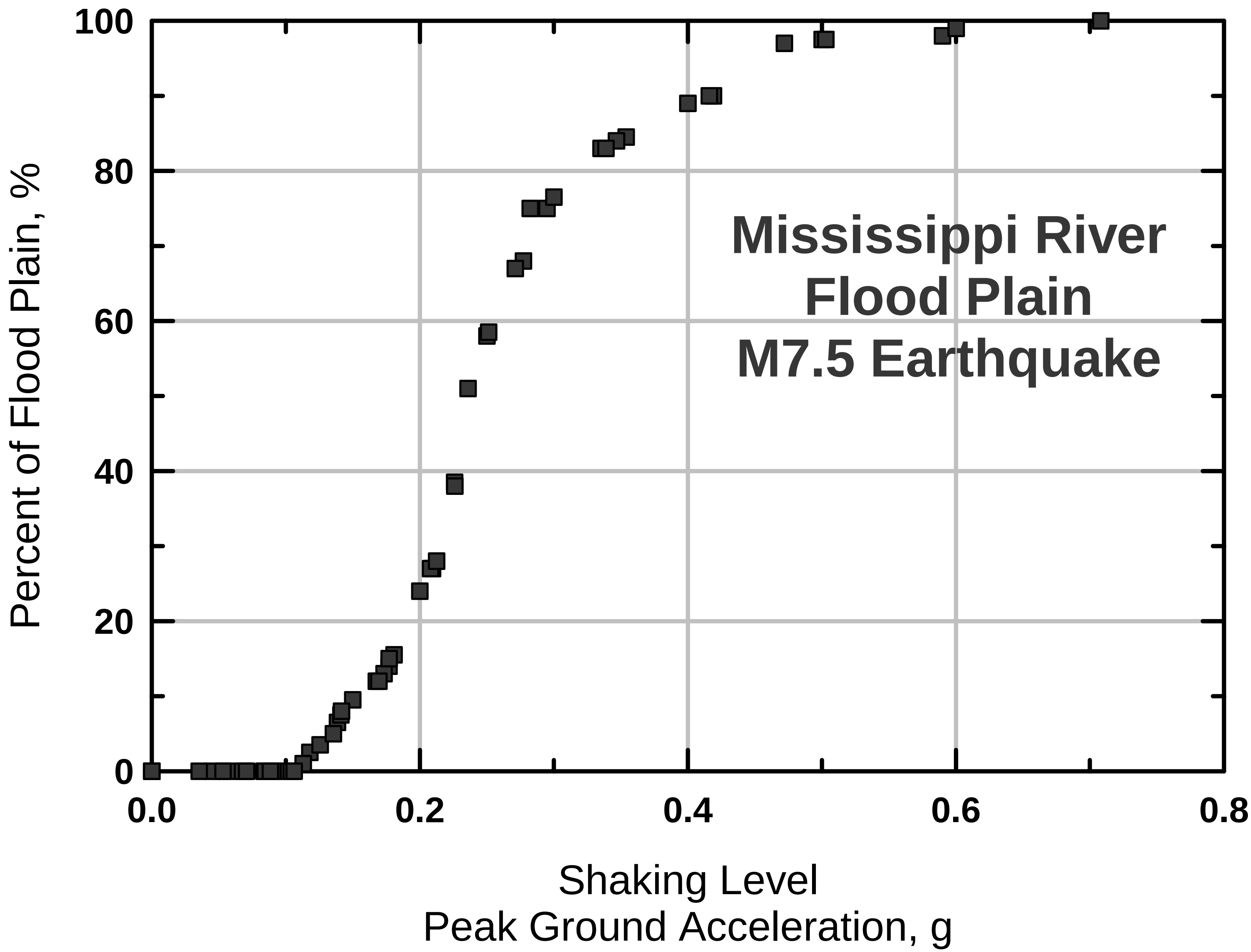
Damaged Levee

Total Dollar Loss (2005 dollars) = $10 -$16B

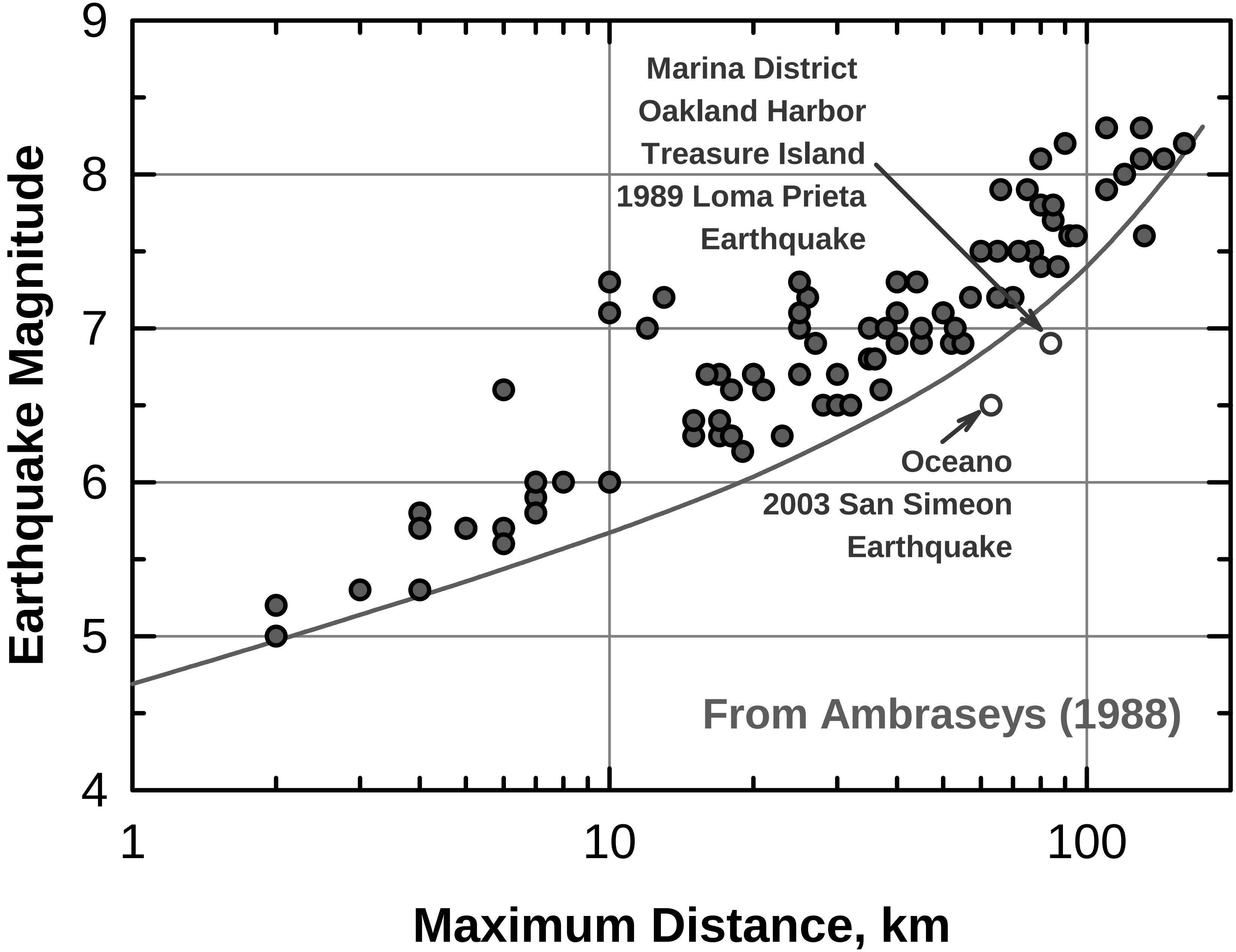


~6000 mi^2 Sand Blow Area 1811/1812 New Madrid Earthquakes

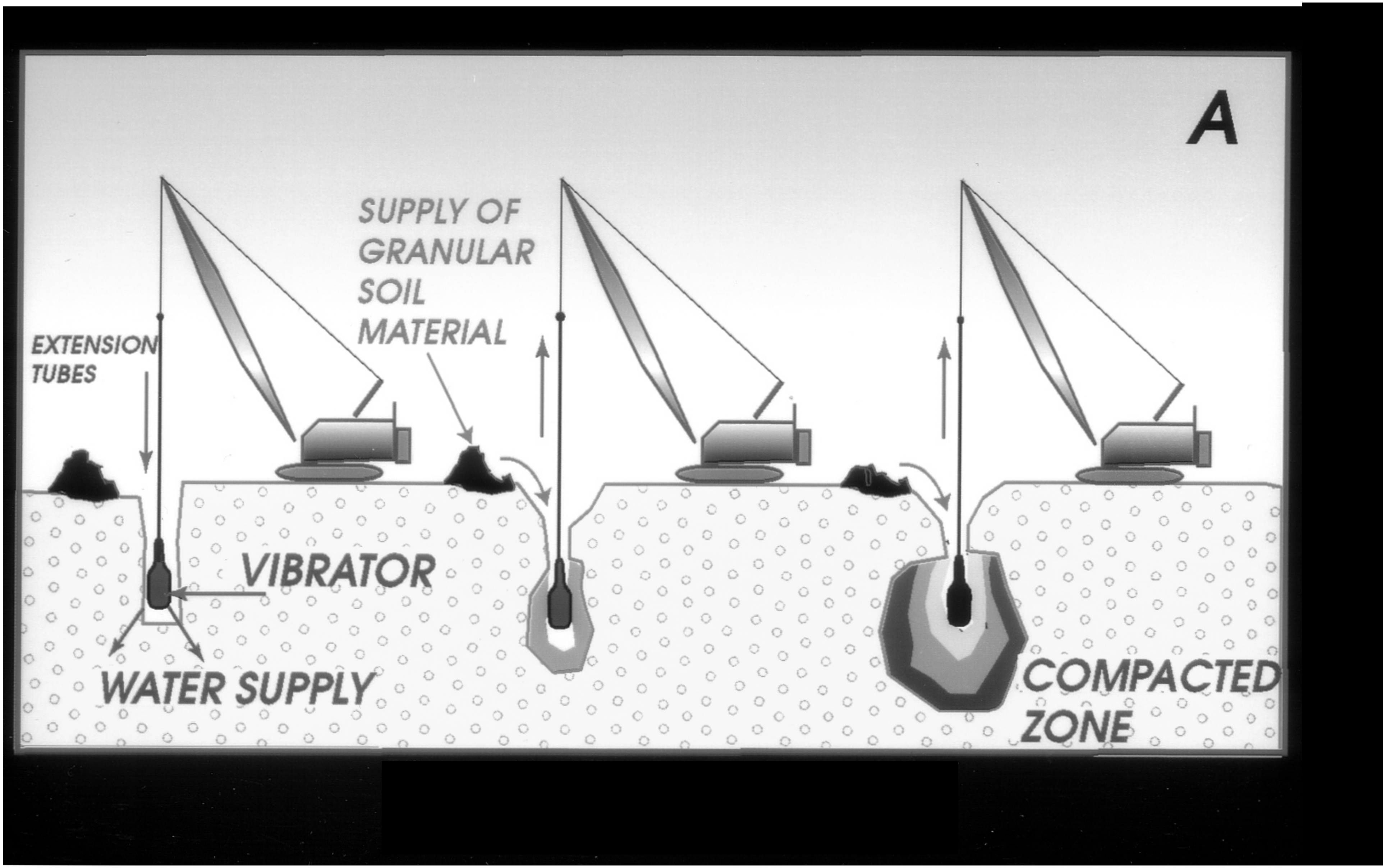
Predicted Size of Liquefaction Area



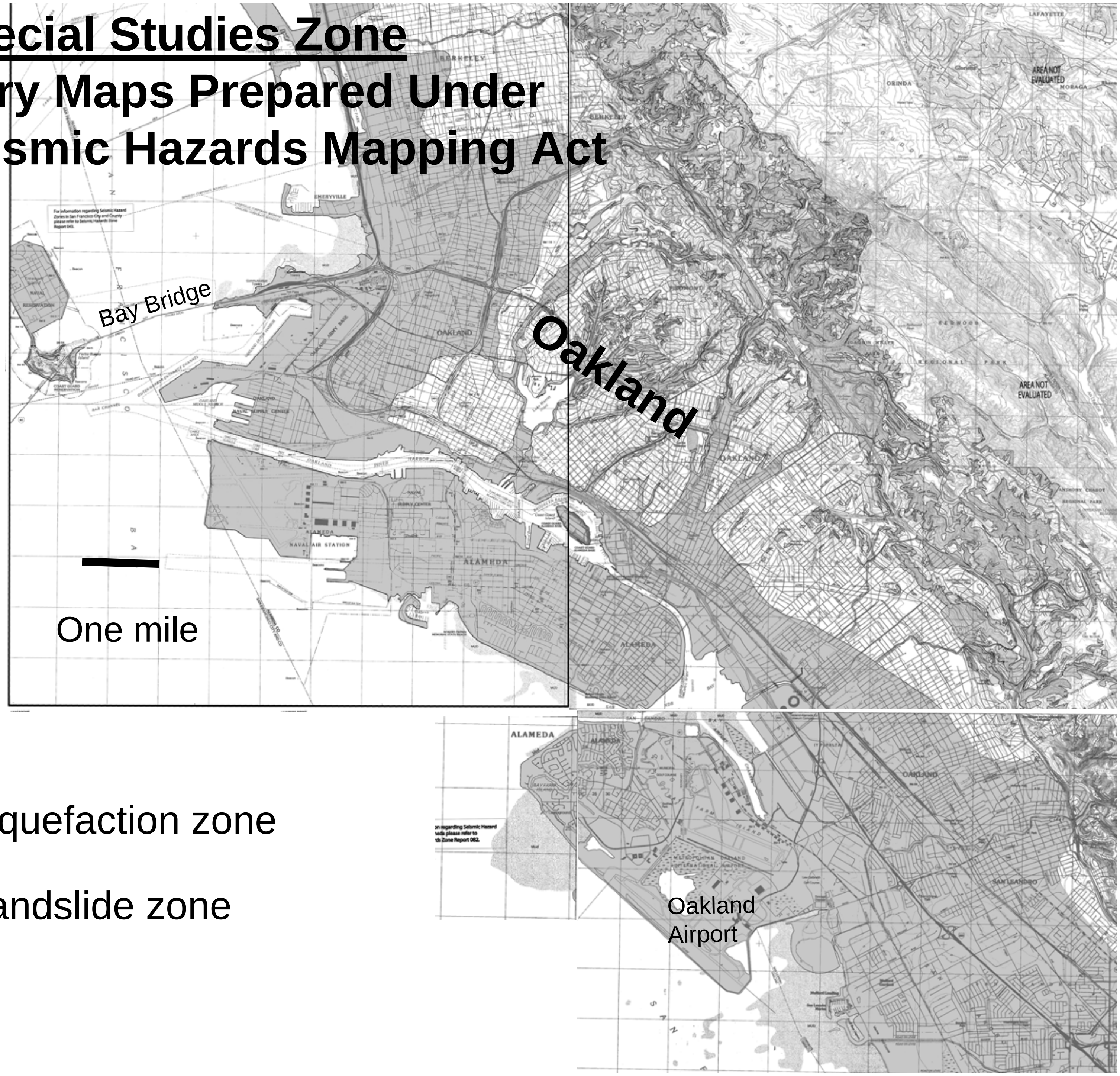
Maximum Distance from EQ to Liquefaction



Soil Improvement



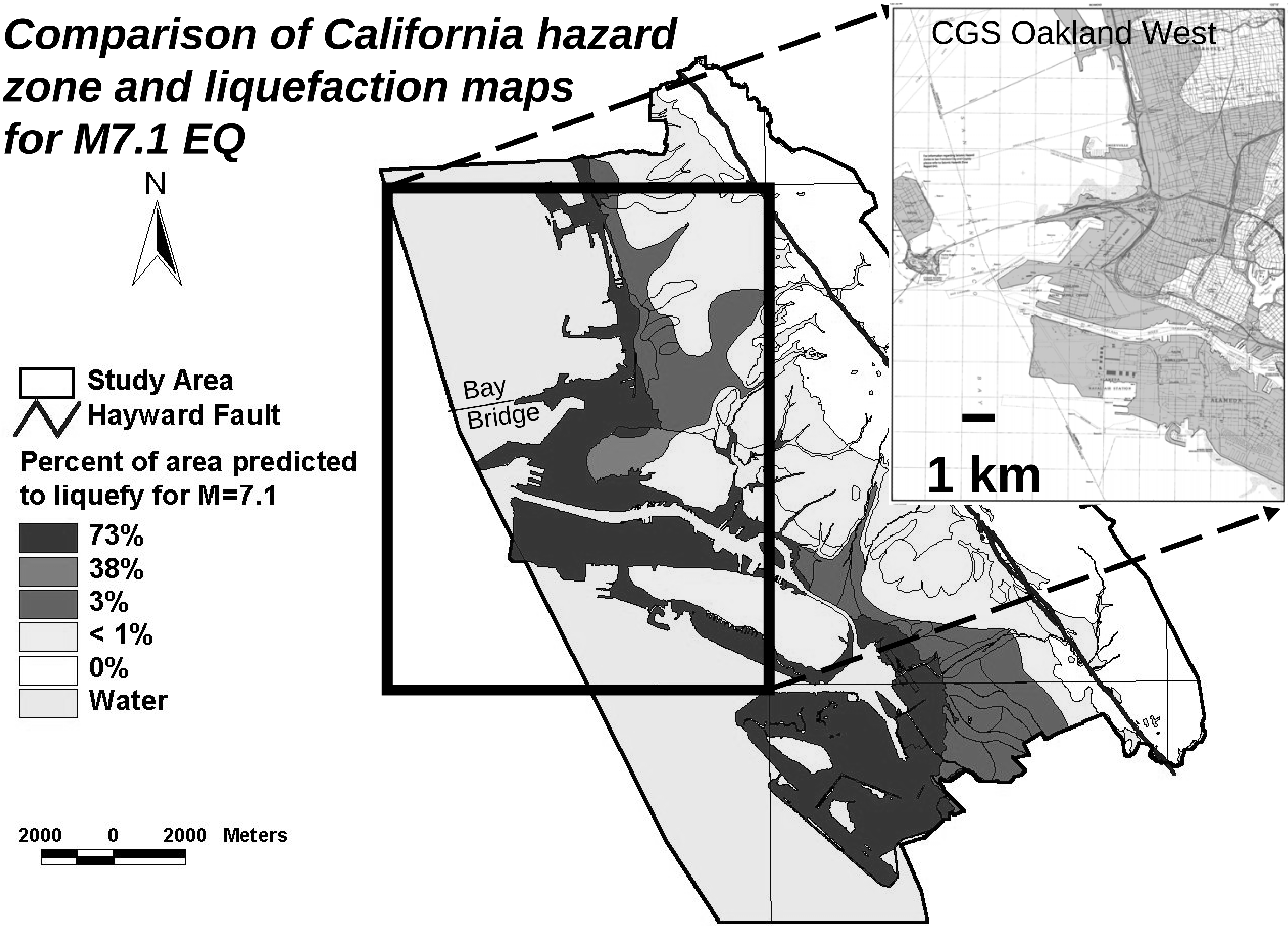
Special Studies Zone
Regulatory Maps Prepared Under 1990 CA Seismic Hazards Mapping Act



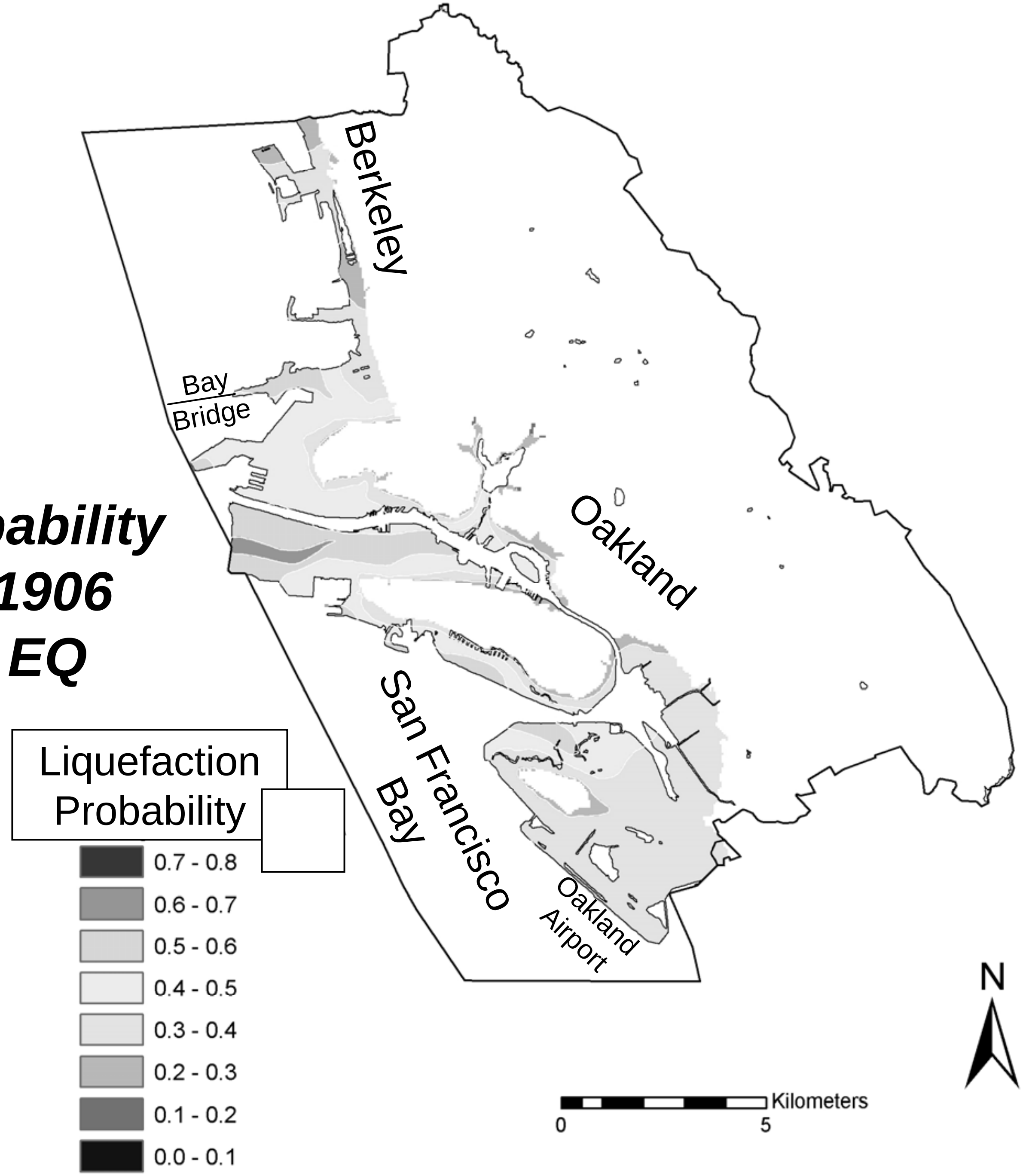
Liquefaction zone

Landslide zone

Comparison of California hazard zone and liquefaction maps for M7.1 EQ

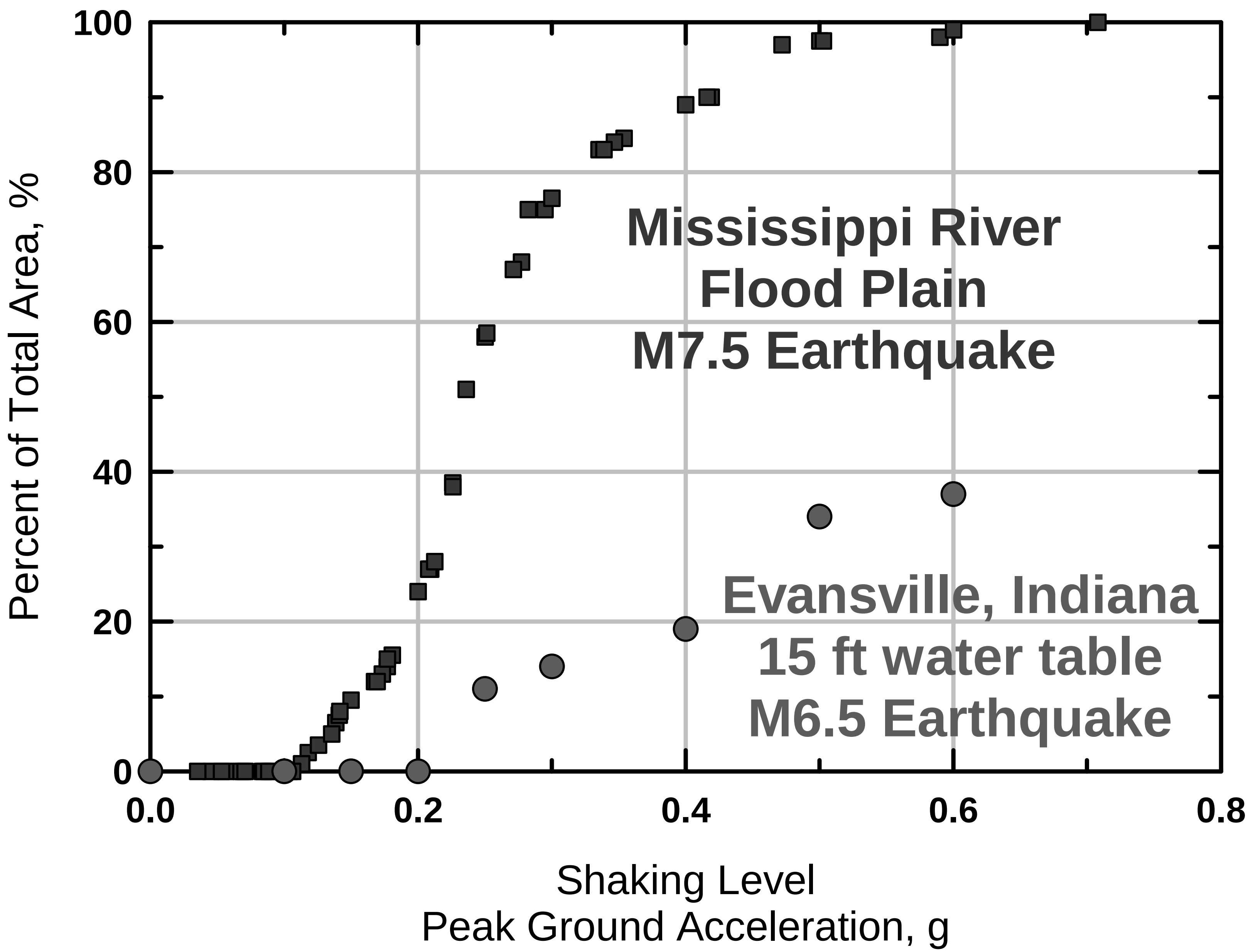


Liquefaction Probability for a Repeat of 1906 San Francisco EQ



Liquefaction Summary

- **Typical damage**
  - **Buried pipelines**
  - **Bridges**
  - **River levees**
  - **Port facilities**
- **Losses are <10% of total loss**
- **Areas can be mapped**


100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
Percent of Total Area, %
Shaking Level
Peak Ground Acceleration, g
Mississippi River
Flood Plain
M7.5 Earthquake
Evansville, Indiana
15 ft water table
M6.5 Earthquake

Liquefaction Susceptibility Geologic Units

Type of deposit (1)	General distribution of cohesionless sediments in deposits (2)	Likelihood that Cohesionless Sediments, When Saturated, Would Be Susceptible to Liquefaction (by Age of Deposit): <500 yr (3)	Holocene (4)	Pleistocene (5)	Pre-pleistocene (6)
(a) Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	—	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable	High	Moderate	Low	Very low
Colluvium	Variable	High	Moderate	Low	Very low
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very low	Very low
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low
(b) Coastal Zone					
Delta	Widespread	Very high	High	Low	Very low
Esturine	Locally variable	High	Moderate	Low	Very low
Beach					
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low
(c) Artificial					
Uncompacted fill	Variable	Very high	—	—	—
Compacted fill	Variable	Low	—	—	—

Youd, T.L., and Perkins, D.M., 1978, Jour. Geo. Eng'g., 104(4), p. 433-446.

Liquefaction Map for M7.1