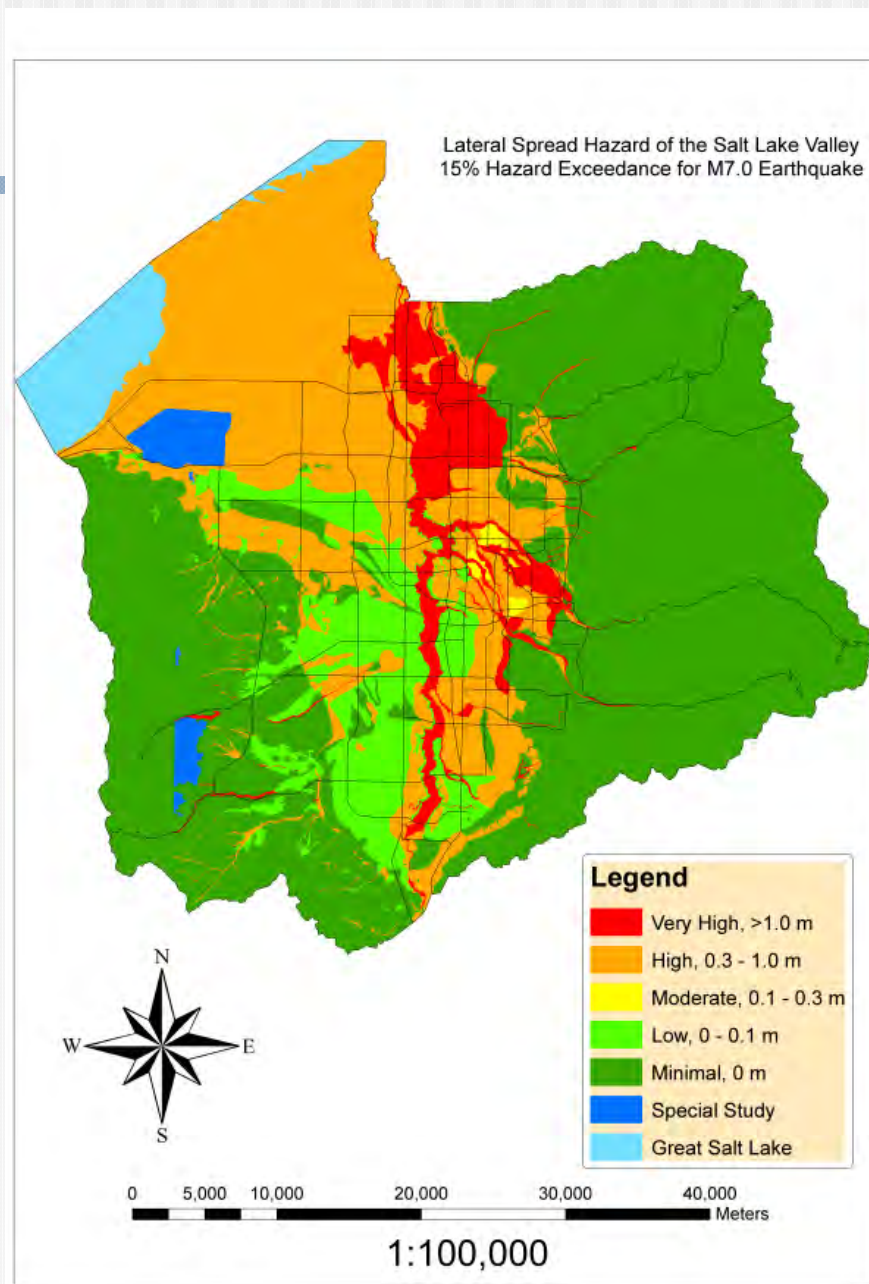


# Utah Liquefaction Advisory Group (ULAG)



## Progress Report on Liquefaction Working Group

February 15, 2011  
Salt Lake City, Utah

Steven F. Bartlett, Ph.D., P.E.  
Associate Professor  
University of Utah

# ULAG Members and Participants



**Utah State**

**BYU**

BRIGHAM YOUNG  
UNIVERSITY



## Members

**Steve Bartlett, UU CE, Facilitator**

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**Mark Petersen, USGS liaison**

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**Jim Higbee, UDOT**

**Bill Turner, Earthtec**

**Ryan Cole, Gerhart-Cole**

# **Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps**

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## **Objective 1**

**Develop Probabilistic Liquefaction Hazard Maps  
for Urban Counties in Utah**

**Salt Lake County**

**Utah County**

**Davis County**

**Weber County**

**Cache County**

# **Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps**

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## **Objective 1 (cont.)**

### **Types of Maps**

- (1) Liquefaction Triggering Maps**
- (2) Lateral Spread Displacement Hazard Maps**
- (3) Liquefaction-Induced Ground Settlement Maps**

# **Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps**

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## **Objective 2**

**Develop ARC GIS Programs for Implementing Probabilistic Mapping Procedures for Other Regions in U.S.**

- **Strong ground motion hazard estimates from PSHA and National Strong Motion Mapping Program**
- **User methods based on ArcGIS algorithms**

# **Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps**

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## **Objective 3**

### **Establish and Populate a Subsurface Geotechnical Database for Public Use**

- **Geotechnical Evaluations**
- **Land Use Planning**
- **Research**
- **Potential Partners**
  - **UDOT**
  - **Salt Lake County and Cities**

# **Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps**

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## **Objective 4**

### **Education and Public Outreach**

- **User Friendly Maps**
- **Assist Counties in Implementation and Ordinances**
- **Outreach Seminars and Website**

# Status Previous Work

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## **FY 2004**

- **Geotechnical Database (N. Salt Lake Co.)**
- **M7.0 lateral spread displacement hazard map (N. Salt Lake Co.) published in Earthquake Spectra.**

## **FY 2005**

- **Geotechnical Database (S. Salt Lake Co.)**

# Status Previous Work

## FY 2006

2.1.1 .....	7	
Task 1: Development of CPT and SPT correlations (University of Utah).....	7	<b>2.1.1 Done</b>
2.1.2 Task 2: Correlation of Subsurface Geologic and Geotechnical ArcGIS™ Database with Surficial Geologic Mapping (Utah Geological Survey) .....	8	<b>2.1.2 Done</b>
2.1.3 Task 3: Mapped mean annual probability of triggering liquefaction for southern Salt Lake County (University of Utah) .....	8	<b>2.1.3 Done</b>
2.1.4 Task 4: Mapped probability of triggering liquefaction for a scenario earthquake for Salt Lake County (University of Utah) .....	8	<b>2.1.4 Done</b>
2.1.5 Task 5: Mapped mean annual probability of lateral spread exceeding displacement thresholds of 0.1, 0.3 and 1.0 meters for northern Salt Lake County (University of Utah).....	9	<b>2.1.5 Done</b>
2.1.6 Task 6: Mapped lateral spread horizontal displacement for a scenario event for northern Salt Lake County (University of Utah) .....	9	<b>2.1.6 Done</b>
2.1.7 Task 7: Synthesis report of seismically induced ground displacement in Salt Lake County (University of Utah, Simon-Bymaster, Inc., and Utah Geological Survey ) .....	9	<b>2.1.7 Done</b>
2.1.8 Task 8: CPT subsurface investigations in downtown Salt Lake City (University of Utah and ConeTech) .....	12	<b>2.1.8 Done</b>
2.1.9 Task 9: Map production and report delivery (University of Utah and Utah Geological Survey).....	12	<b>2.1.9 Done</b>

# Status Previous Work

## FY 2007

2.1 Methods and Tasks – Phase IV, FY 2007 .....	8
2.1.1 Task 1: Collection and preliminary geologic analysis of surface and subsurface data to identify data gaps and data-collection requirements for future hazard mapping efforts in Utah Valley (Brigham Young University, University of Utah, Utah Geological Society).....	9
2.1.2 Task 2: Completion of probabilistic lateral spread hazard maps and deterministic lateral spread hazard map for a scenario earthquake for southern Salt Lake County (University of Utah).....	10
2.1.3 Task 3: Development of liquefaction-induced settlement map for Salt Lake County (Brigham Young University, University of Utah). ....	10
2.1.4 Task 4: Map production and report delivery (University of Utah, Brigham Young University and Utah Geological Survey).....	10

**2.1.1 Unfunded**

**2.1.2 Done**

**2.1.3 Done**

**2.1.4 Ongoing**

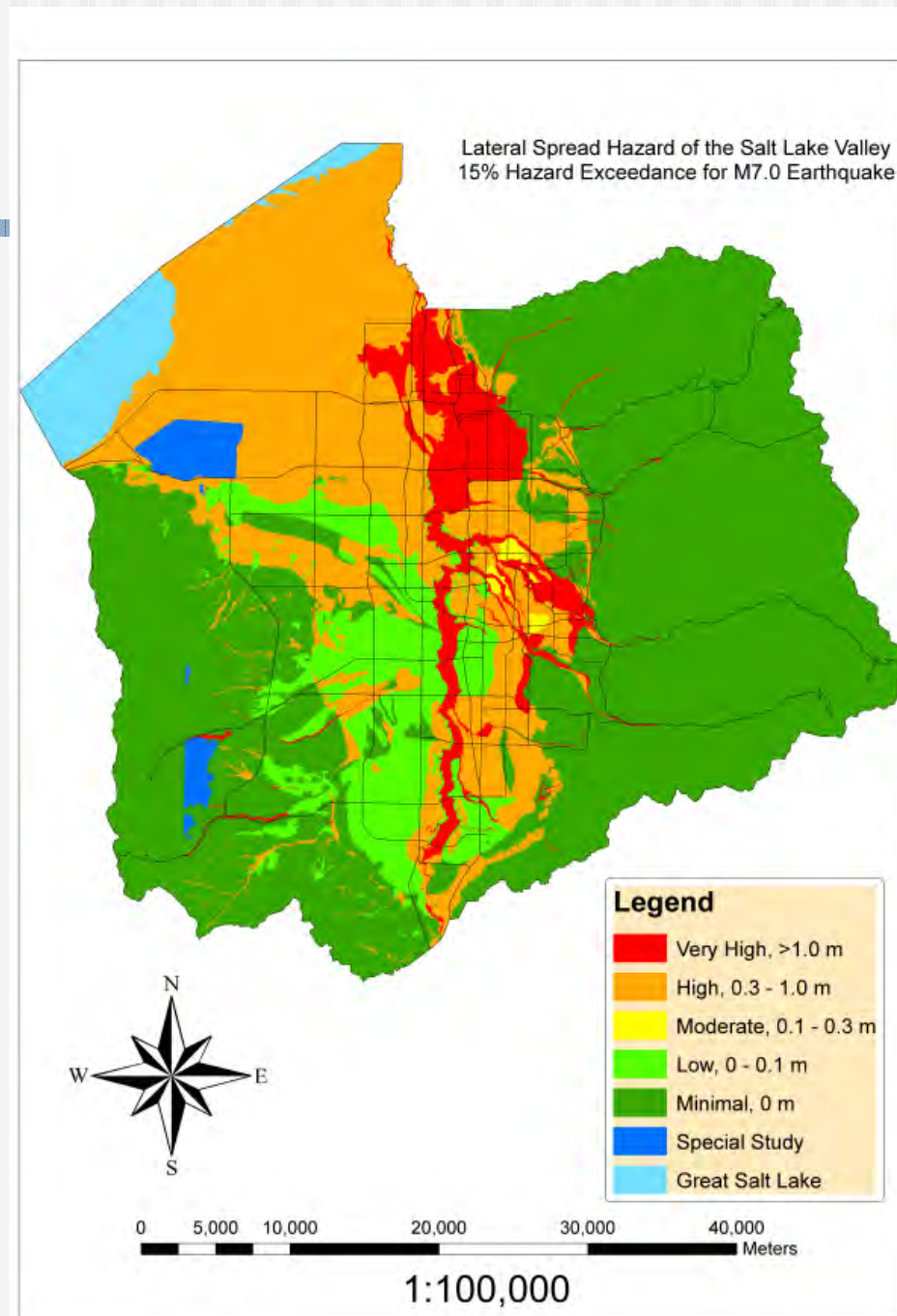
**FY 2008 (No Funding)**

**FY 2009 (No Funding)**

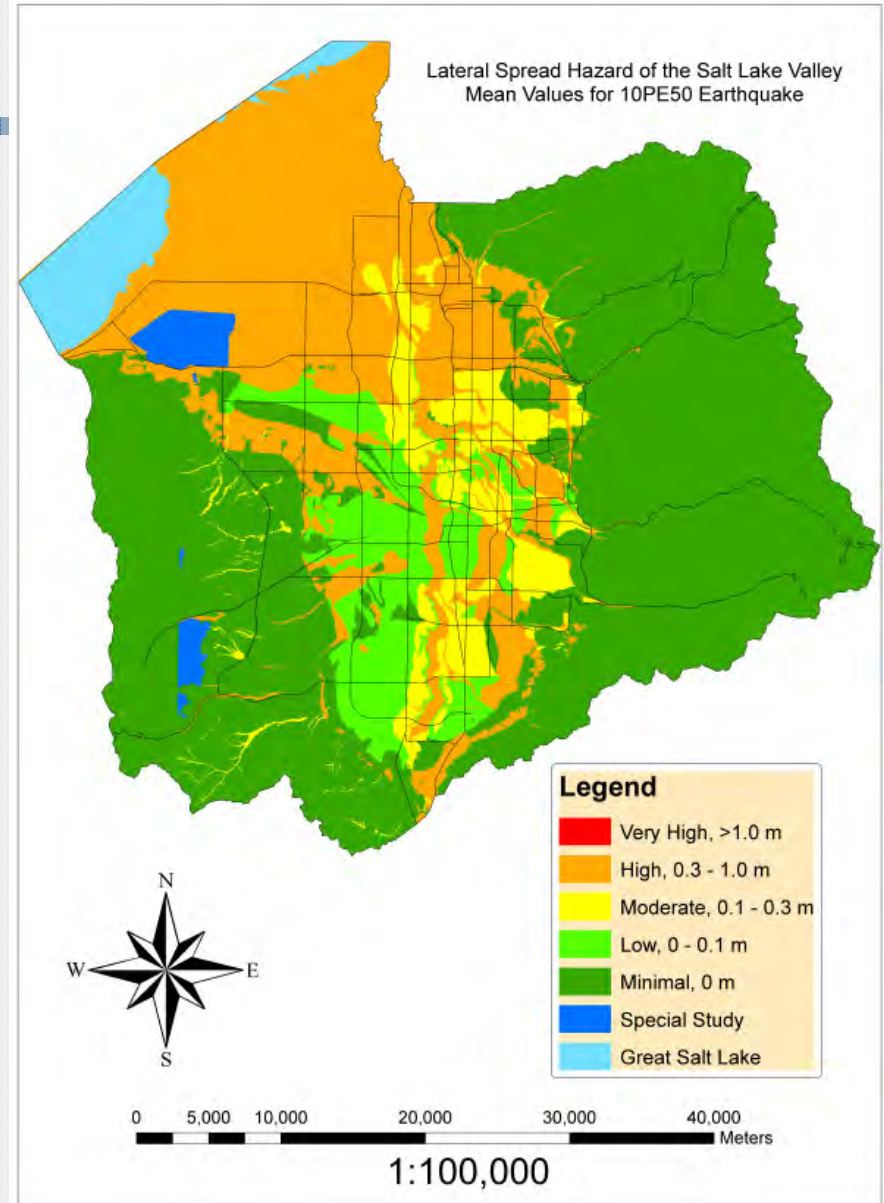
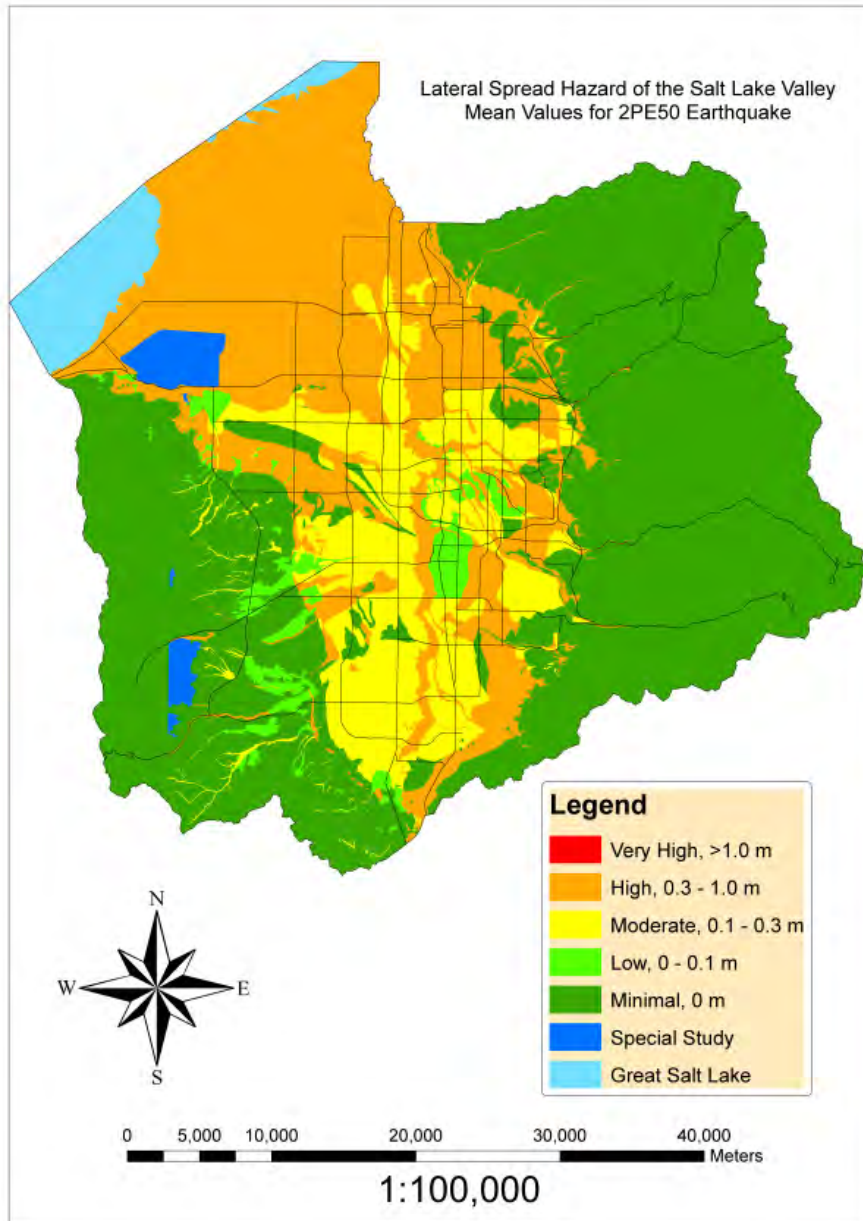
**FY 2010 (No Funding)**

**FY 2010 (Partial Funding from  
WBWCD)**

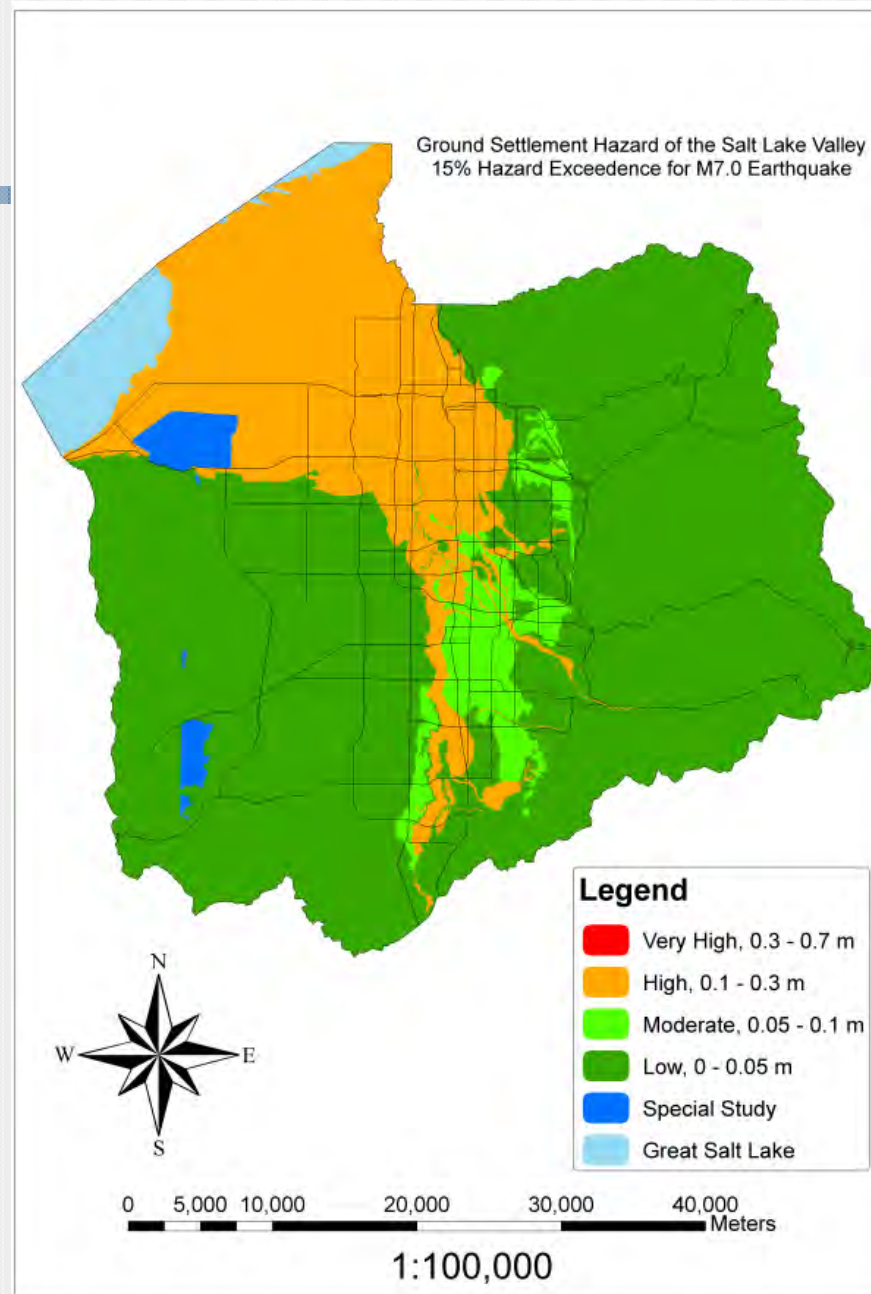
# M 7.0 Lateral spread displacement map



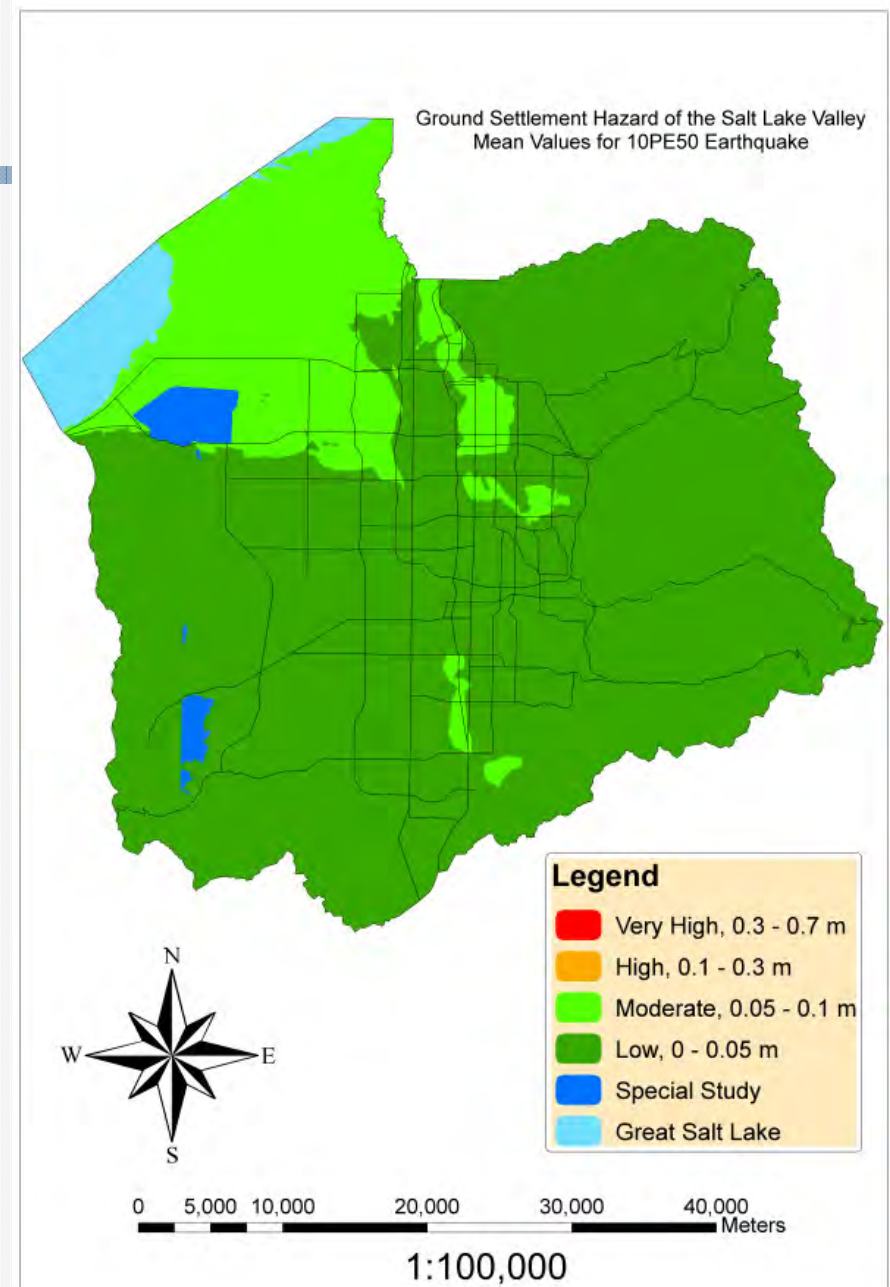
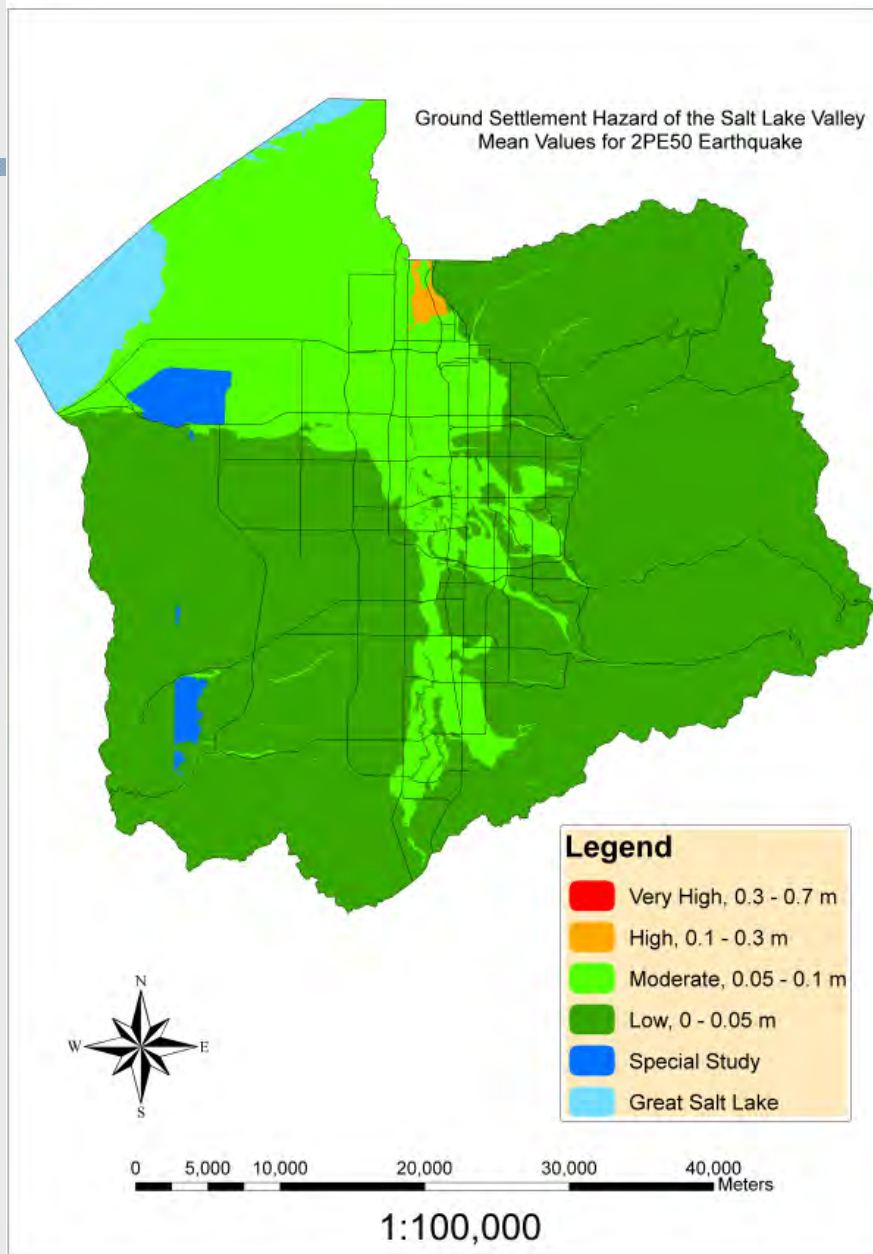
# Probabilistic liquefaction potential maps for 2500 and 500-year return periods



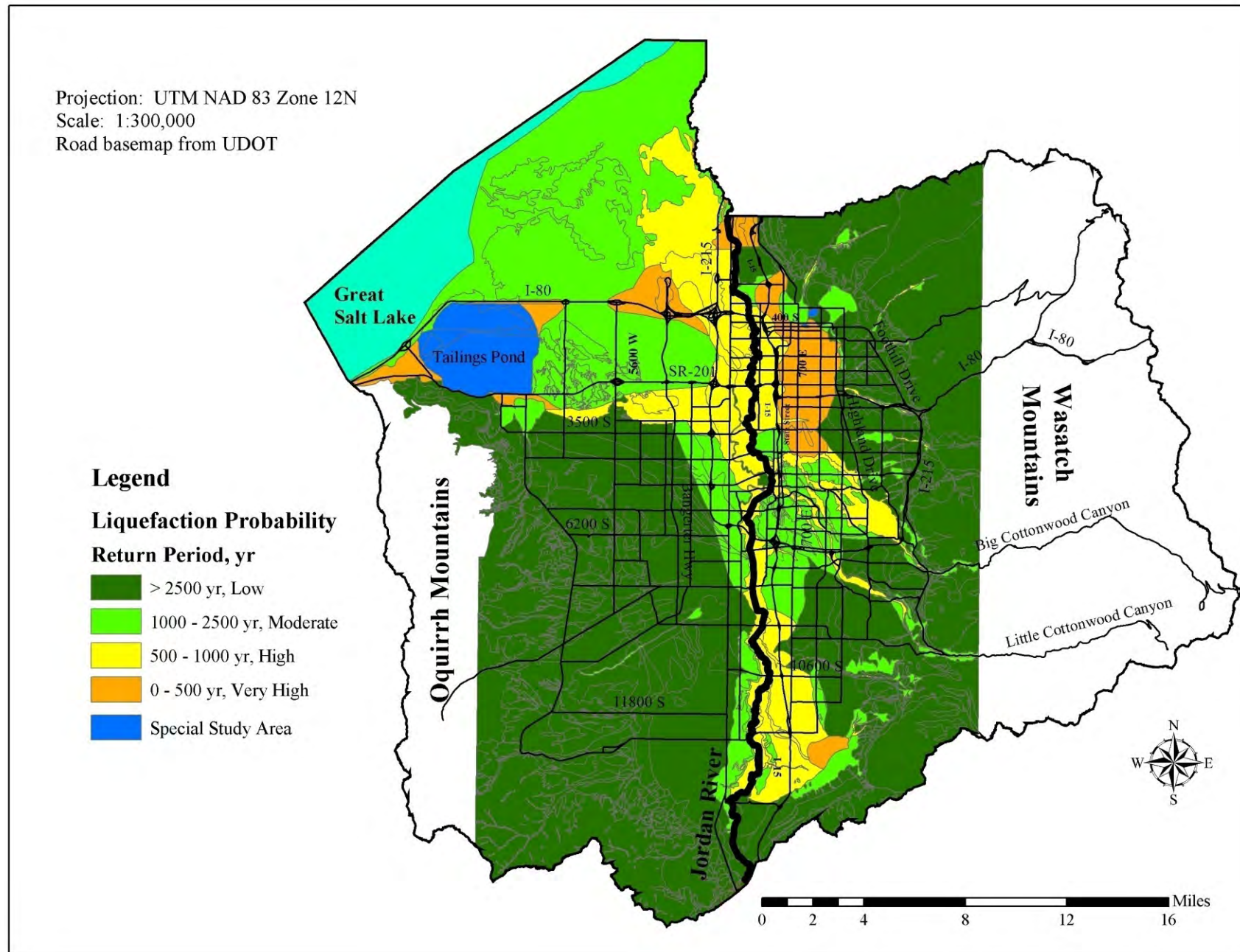
# M 7.0 ground settlement map



# Probabilistic ground settlement maps for 2500 and 500-year return periods



# Probabilistic liquefaction potential map – (2002 Input)



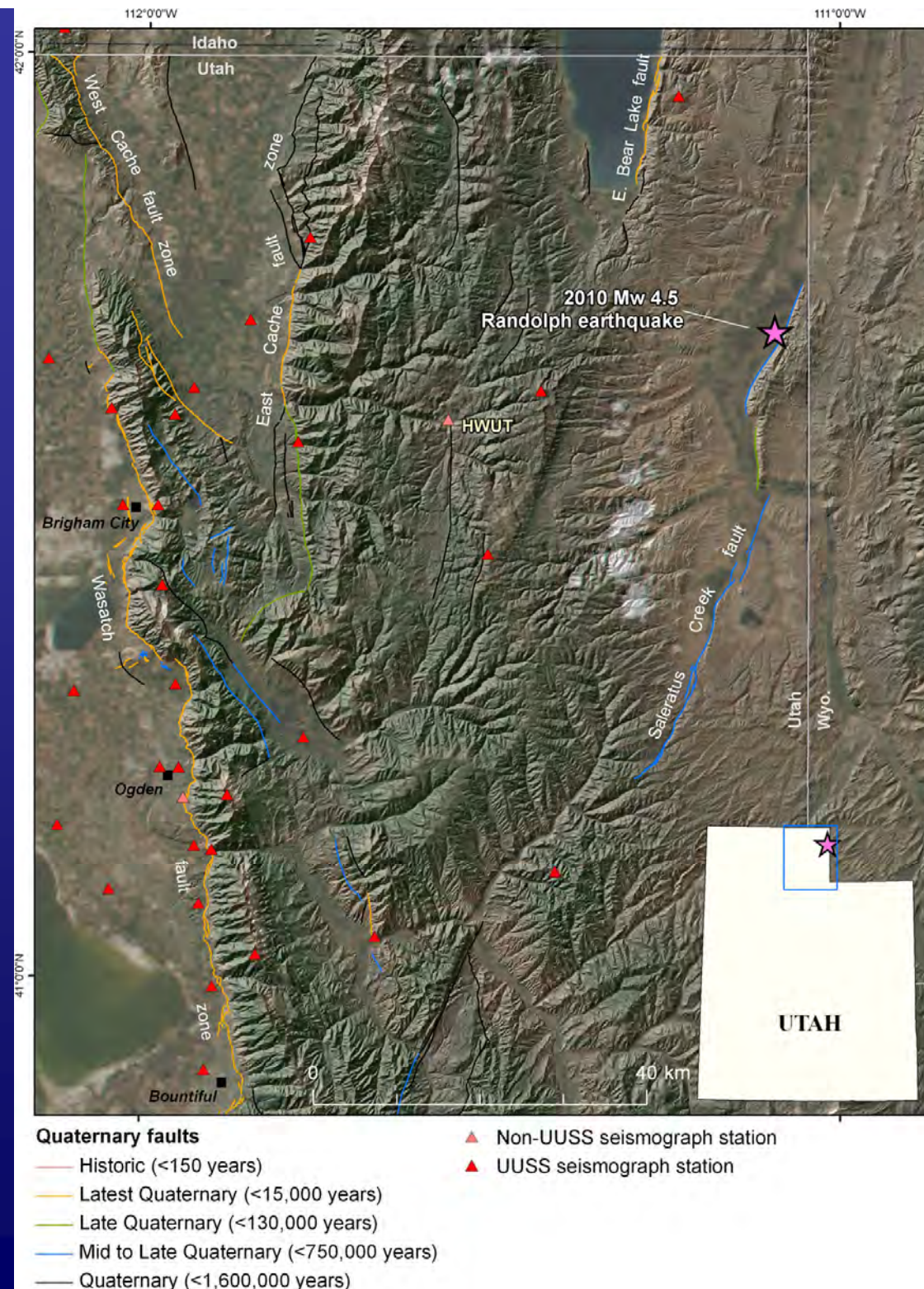
# **Liquefaction in the April 15, 2010, M 4.5 Randolph, Utah, Earthquake**

Chris DuRoss (UGS)

Kristine Pankow (UUSS)

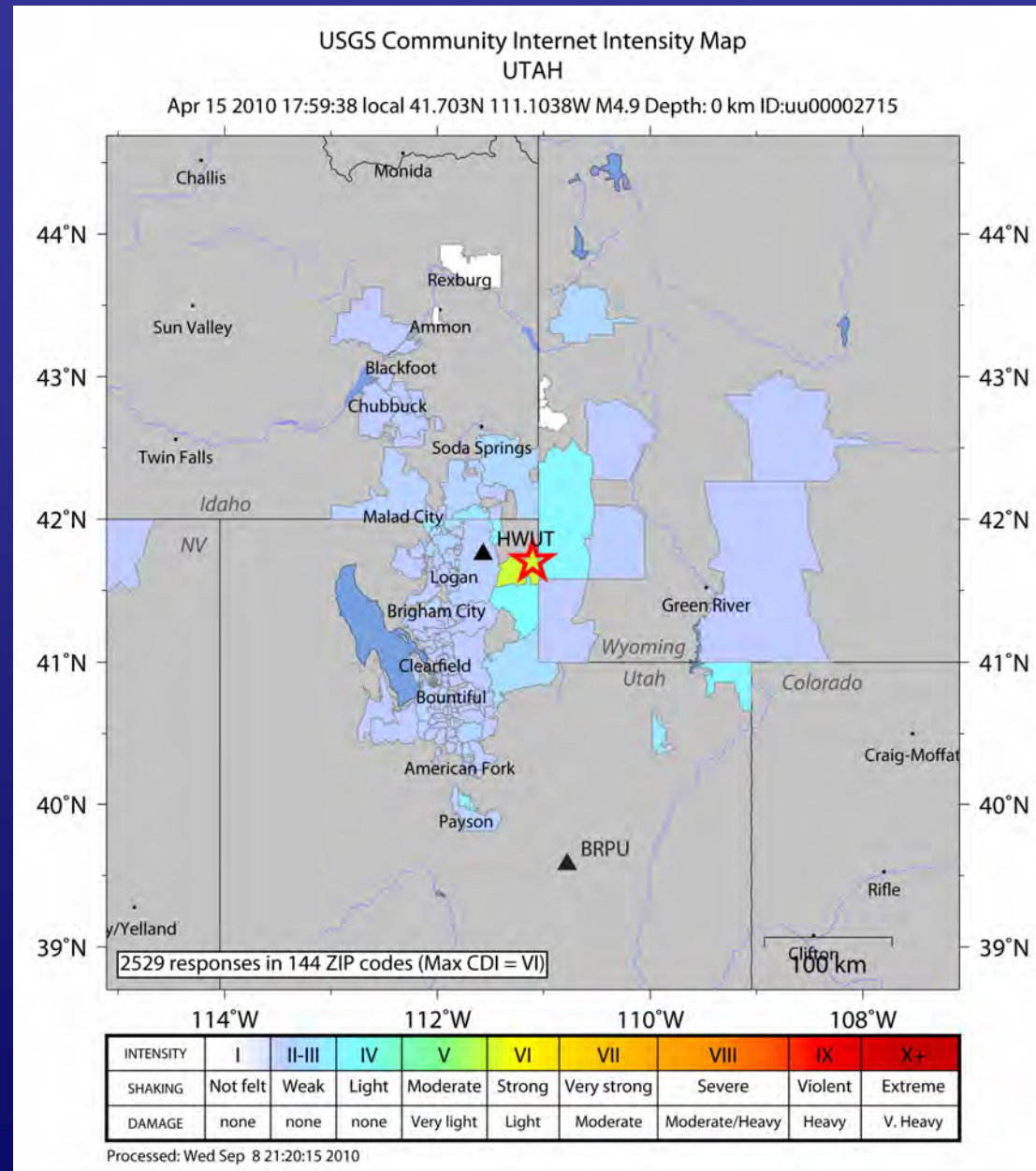
# Mw 4.5 Randolph Earthquake

- 9 km northeast of Randolph, near late-Pleistocene-active Crawford Mountains fault
- Normal-faulting earthquake
  - Local magnitude 4.9
  - Moment magnitude 4.5
  - Depth 5 km
- Well recorded by Utah Regional Seismic Network
- Generated liquefaction (sand boils), which is rare for earthquakes of  $M < 5$



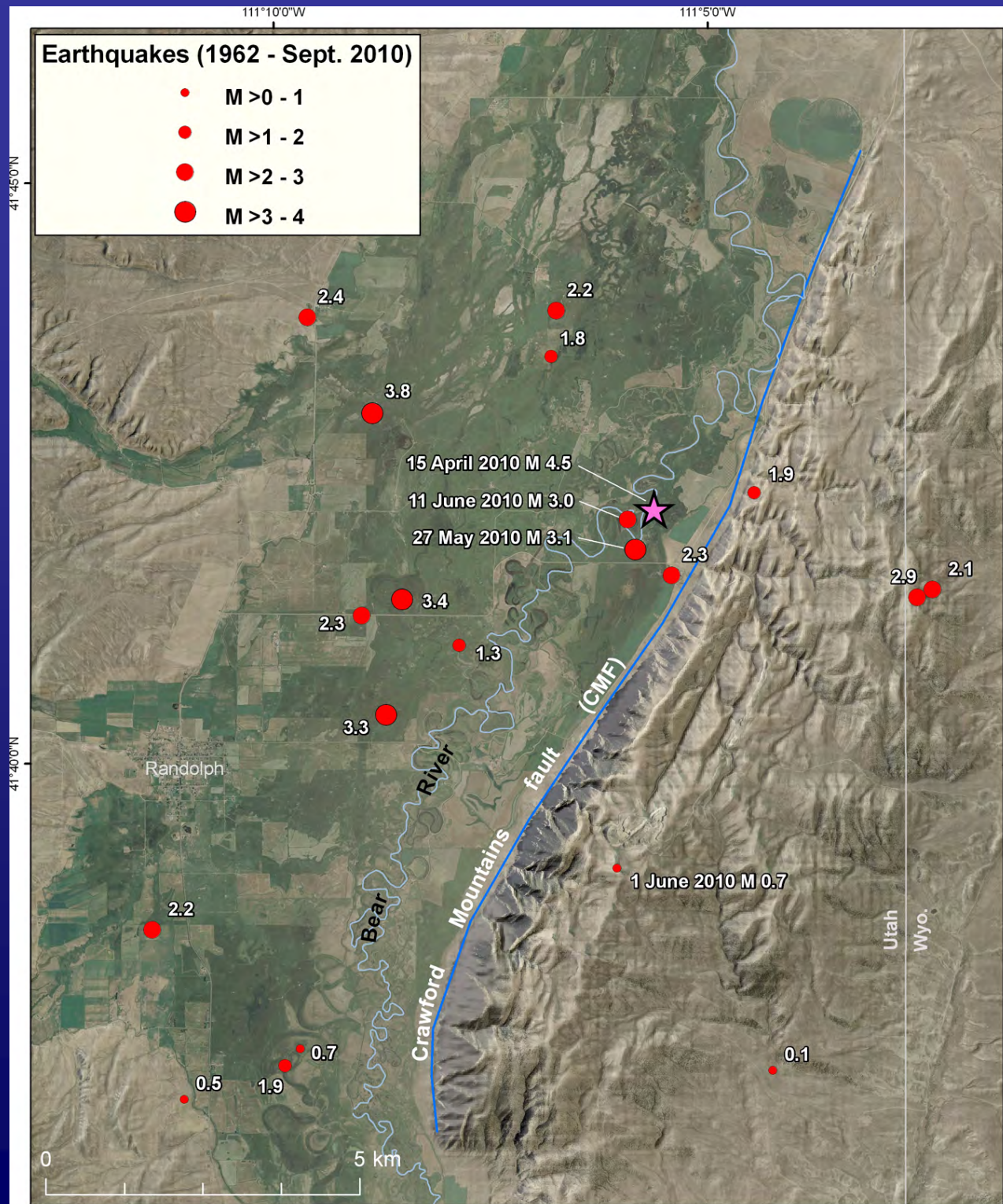
# Mw 4.5 Randolph Earthquake

- Widely felt throughout northern Utah and surrounding states
- >2500 responses in a ~200-250 km radius
- Moderate to strong shaking in the epicentral region
- Only moderate, non-structural damage reported



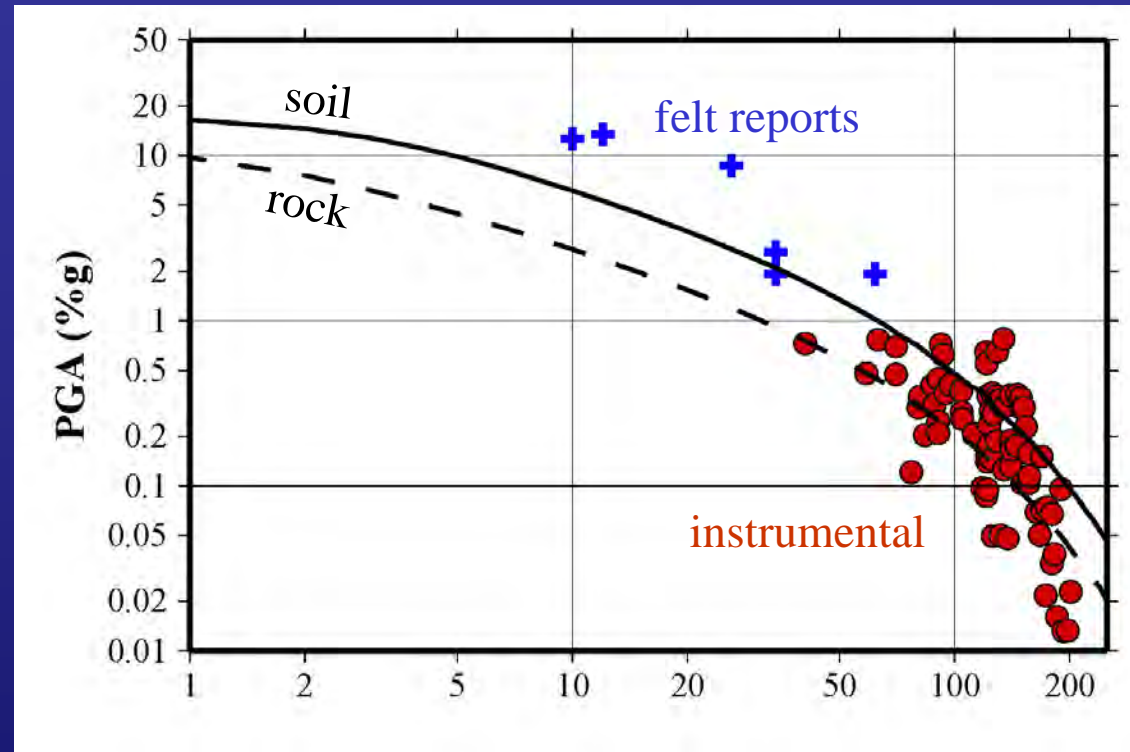
# Seismology

- Only three aftershocks (two near mainshock epicenter)
- Focal mechanism:
  - NW strike,  $66^\circ$  E dip
  - NE strike,  $35^\circ$  W dip
- Stress drop:  $\sim 50$  bars (circular rupture)



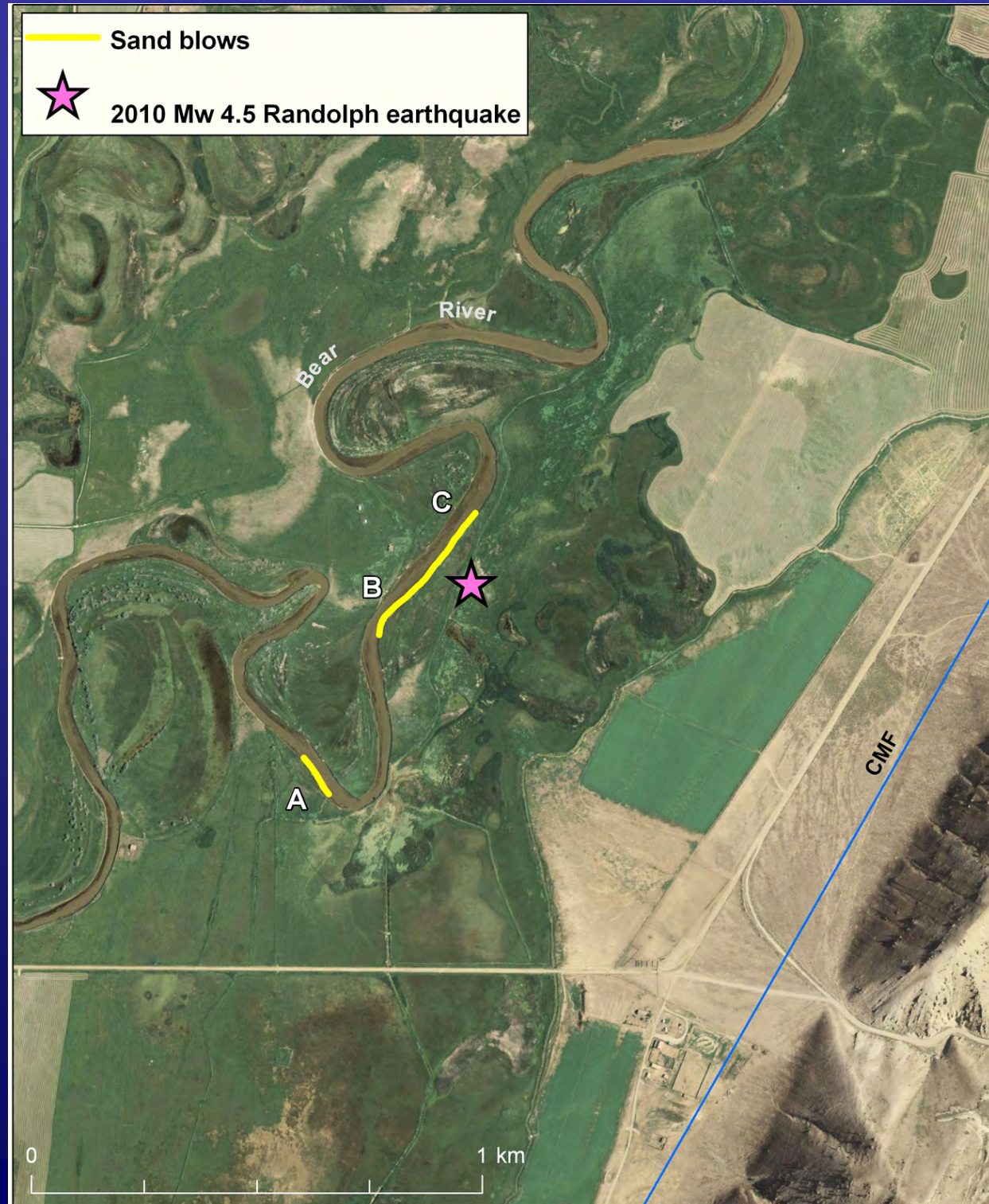
# Ground Motion

- Instrumental ground motion (red circles) follow those predicted by Boore and Atkinson (2008)
- Felt intensities (blue crosses; based on CIIM map) are also consistent with empirical ground motions
- PGA at epicenter: likely ~20% g, using Boore and Atkinson (2008) soil regression



# Liquefaction

- Sand boils in alluvial sediments
  - <1 km west of the epicenter along a 1-km stretch of the Bear River
  - <1 cm to ~1 m in diameter
  - Consisted of fine to coarse sand deposited on fine-grained, unconsolidated, and partly to fully saturated stream sediments





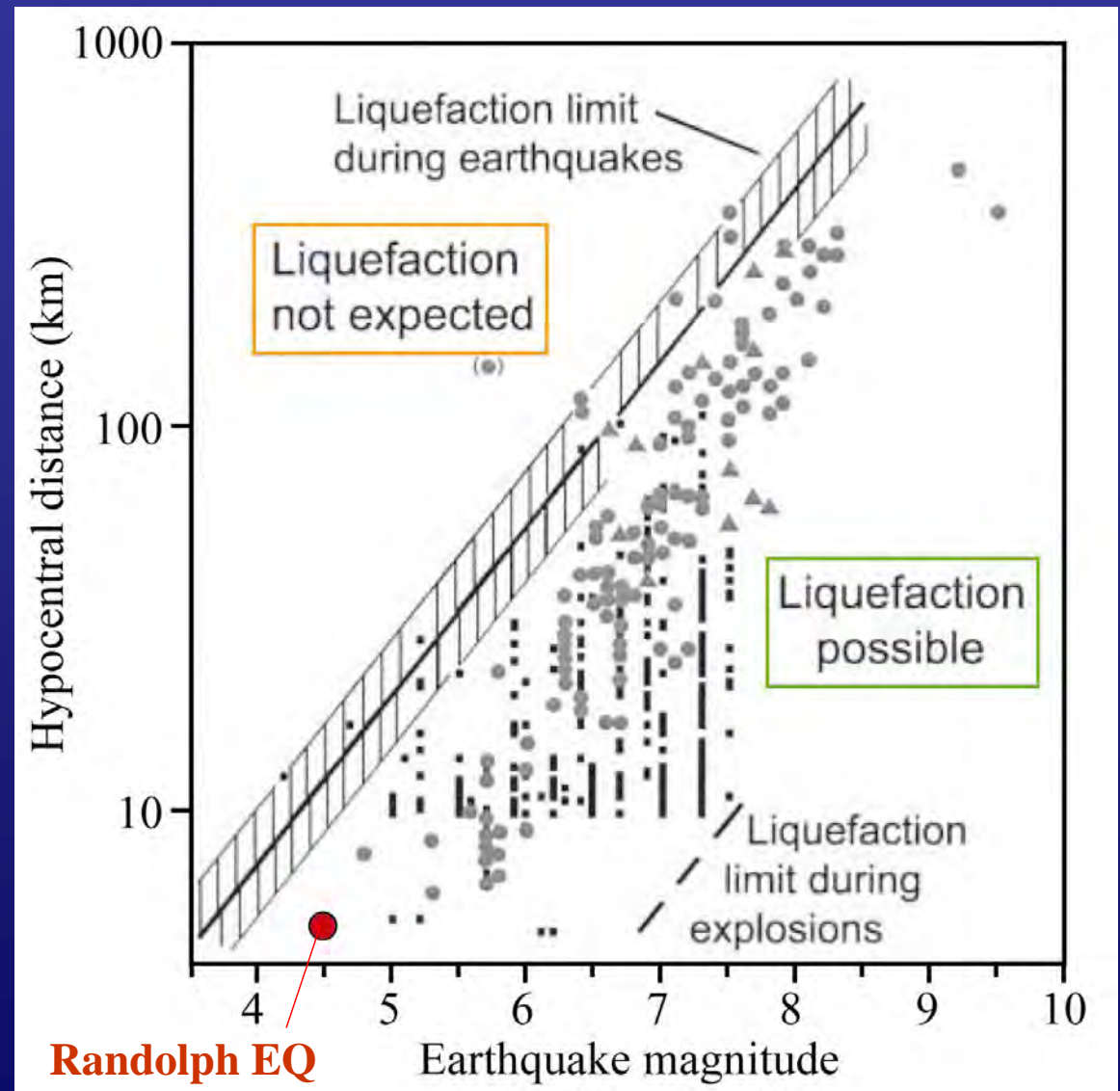
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# Liquefaction

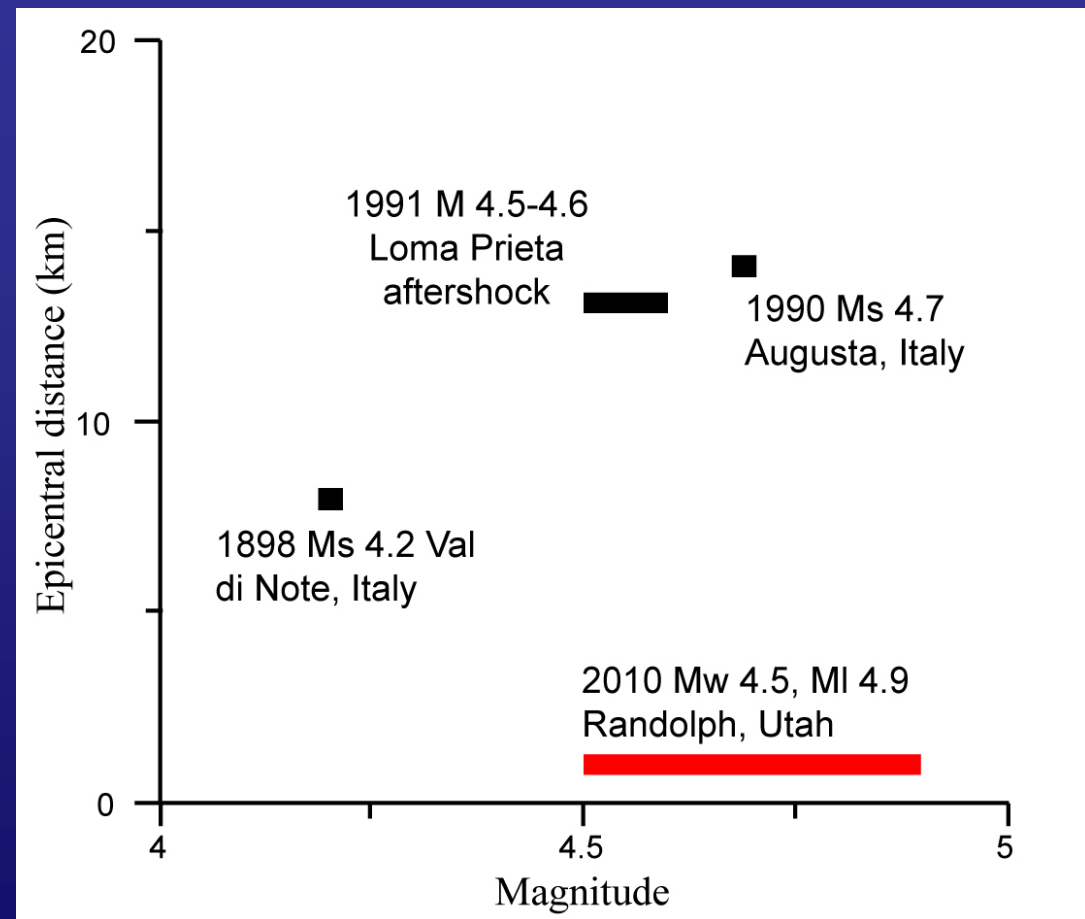
- April 15 earthquake is one of the smallest earthquakes recorded with modern instrumentation to generate liquefaction
- Helps define lower-magnitude threshold for liquefaction



Wang and others (2006)

# Liquefaction

- Earthquakes of  $M < 5$  that induced liquefaction:
  - 1898 Ms 4.2 Val di Noto, Italy (poorly documented; Galli, 2000)
  - 1990 Ms 4.7 Augusta, Italy earthquake (Galli, 2000)
  - 1991 M 4.5-4.6 aftershock to the Loma Prieta EQ (Sims and Garvin, 1995)
- In Utah?
  - 1992 M 5.8 St. George
  - 1934 M 6.6 Hansel Valley



# Conclusions

- The Mw 4.5 Randolph earthquake is possibly the smallest earthquake recorded with modern instrumentation to generate liquefaction in undisturbed sediment
- We attribute the occurrence of liquefaction to highly susceptible sediments in close proximity to the epicenter
- The shallow depth of the mainshock (5 km) probably contributed to liquefaction production and the paucity of aftershocks
- Felt information and recorded ground motions are consistent with empirical ground motion relations; the main shock stress drop was ~50 bars.
- The Randolph earthquake helps refine the lower magnitude and ground-shaking limit for liquefaction, which is important for geotechnical engineering applications in areas underlain by highly susceptible soils and for interpretation of paleoliquefaction features in regions lacking fault evidence of paleoearthquakes