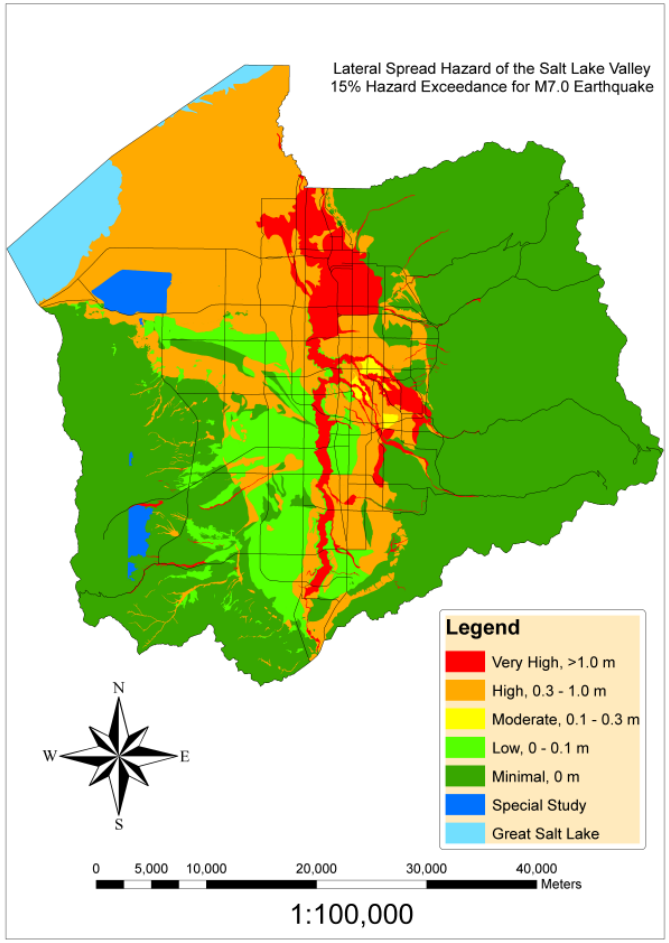
Utah Liquefaction Advisory Group (ULAG)



Probabilistic Liquefaction Hazard Mapping for Davis, Weber and Salt Lake Counties

February 12, 2018
Salt Lake City, Utah

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

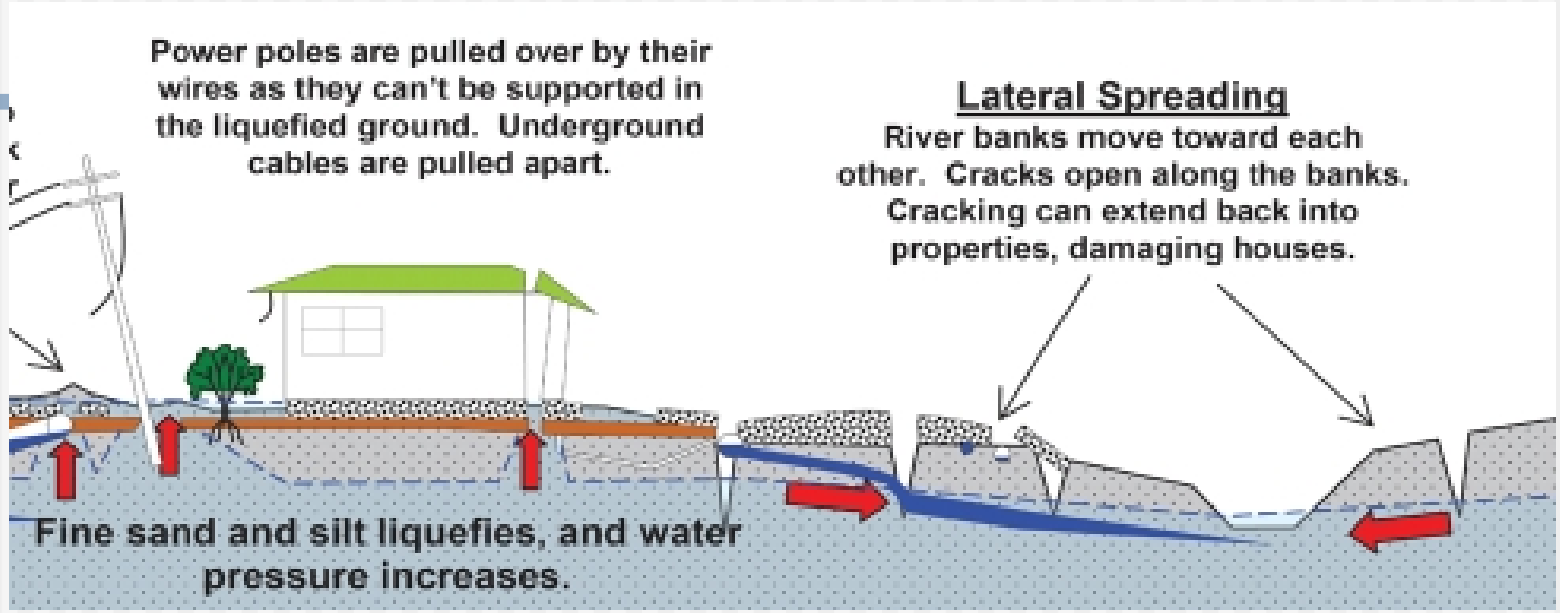
Types of Liquefaction Displacement

Port of Kobe, 1995 Kobe, Japan Earthquake

Ground Settlement

2010 Christchurch Earthquake

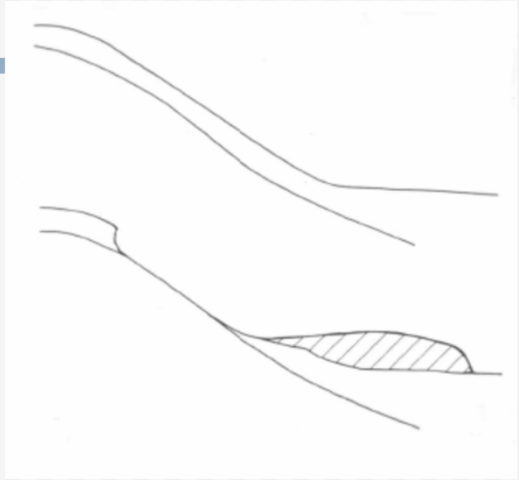
Types of Liquefaction Displacement



Lateral Spread

1964 Niigata, Japan Earthquake

Types of Liquefaction Displacement



Valdez, 1964
Alaska
Earthquake

Flow Failure

Seward,
1964
Alaska
Earthquake

Types of Liquefaction Hazard Maps

- Liquefaction Susceptibility Maps
- Liquefaction Potential Maps
  - Scenario Maps
  - Probabilistic-Based Maps
- Ground Failure Maps
  - Lateral Spread
  - Ground Settlement

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

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

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

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

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

Objective 4

Education and Public Outreach

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

Previous Work

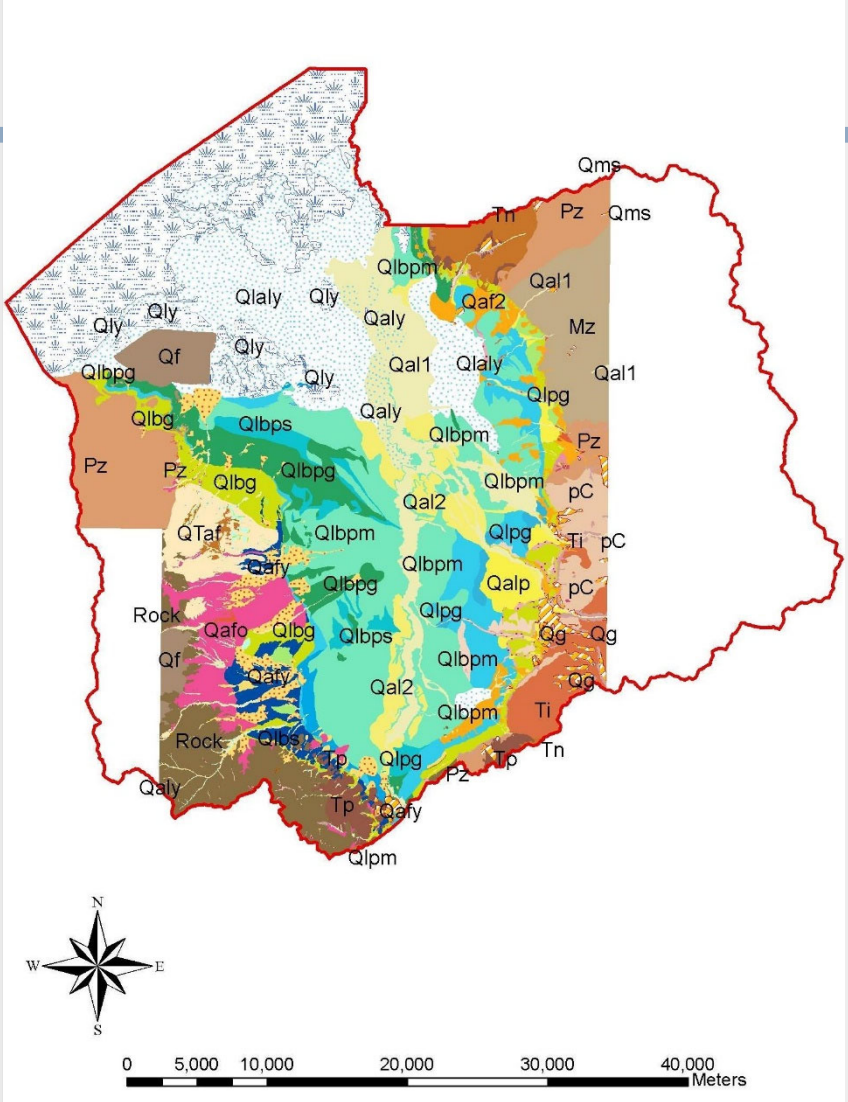
FY 2004

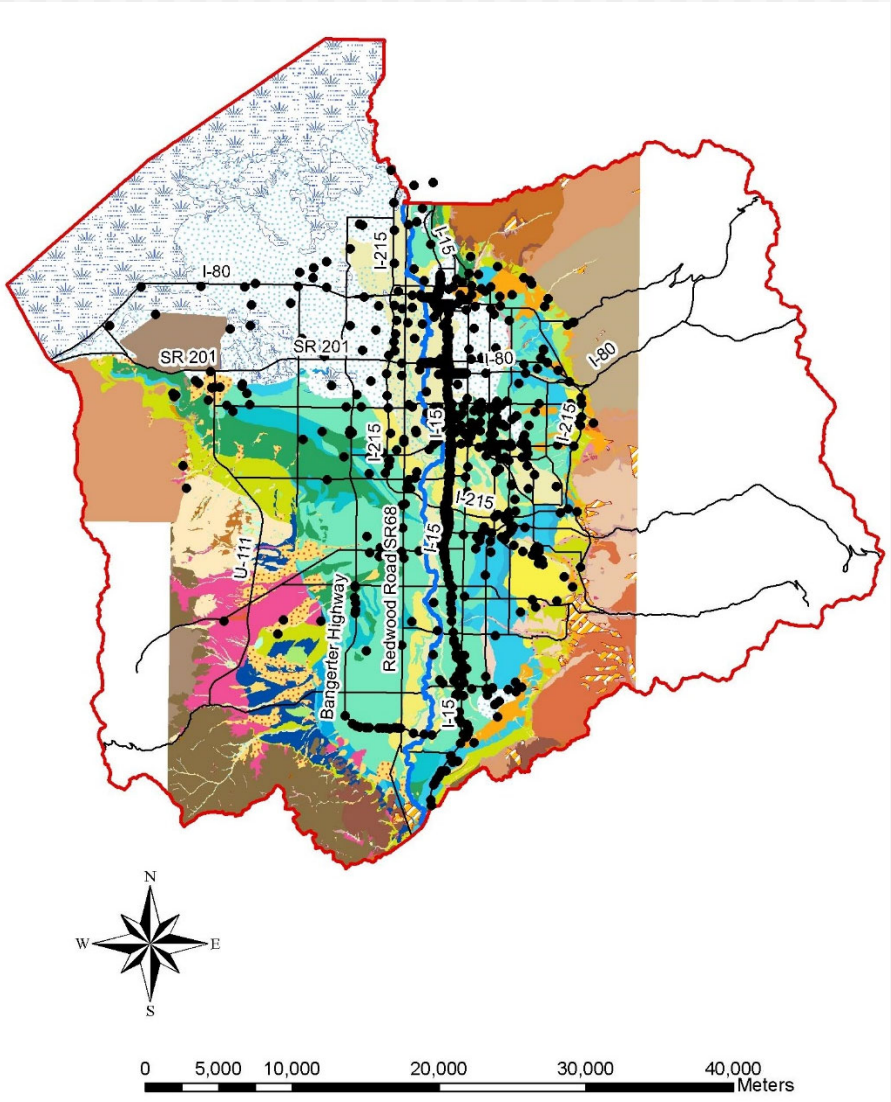
- **Geotechnical Database (N. Salt Lake Co.)**
- **M7.0 lateral spread displacement hazard map (N. Salt Lake Co.) published in *Earthquake Spectra.***

FY 2005

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

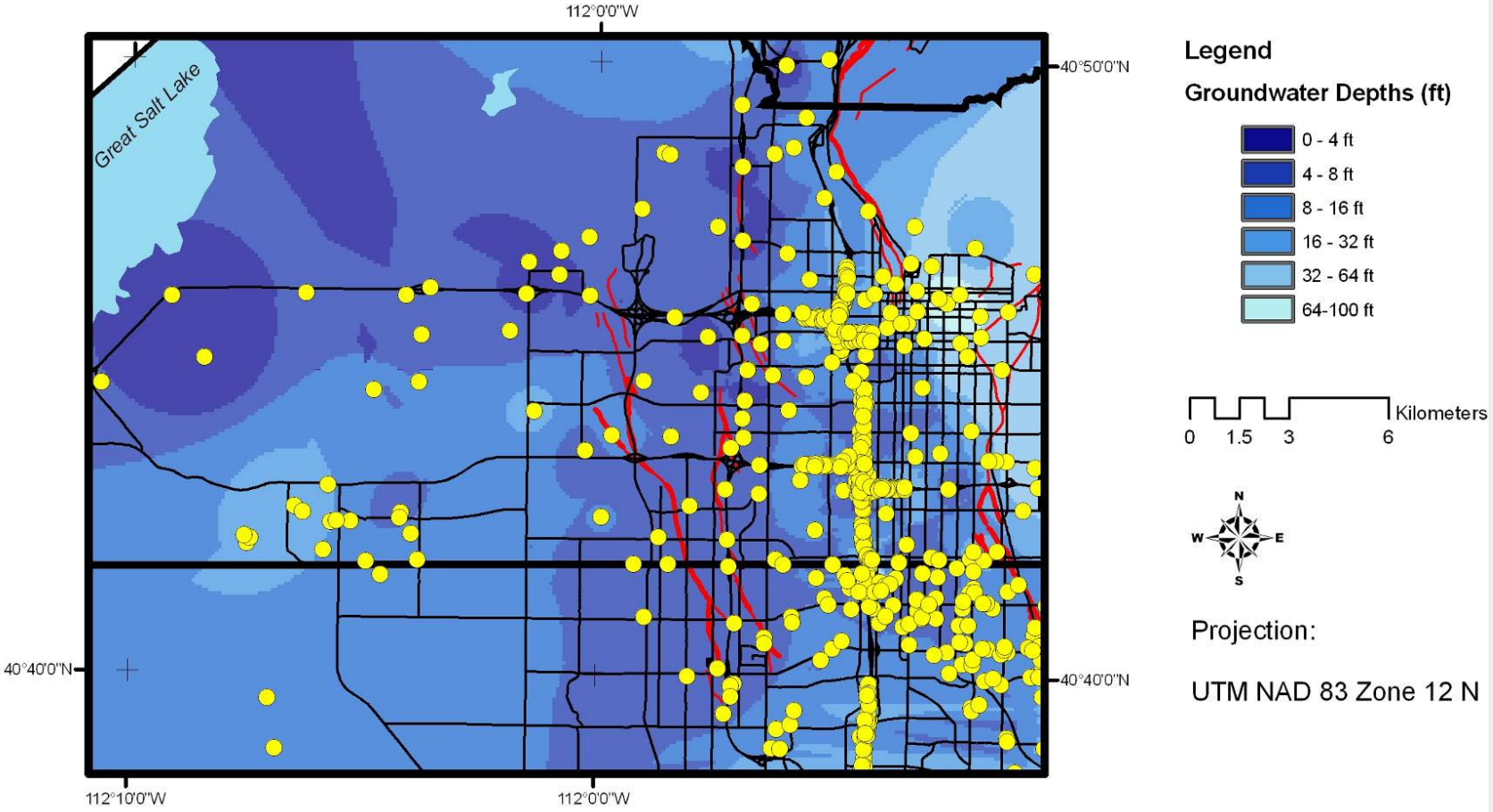
Mapping Inputs





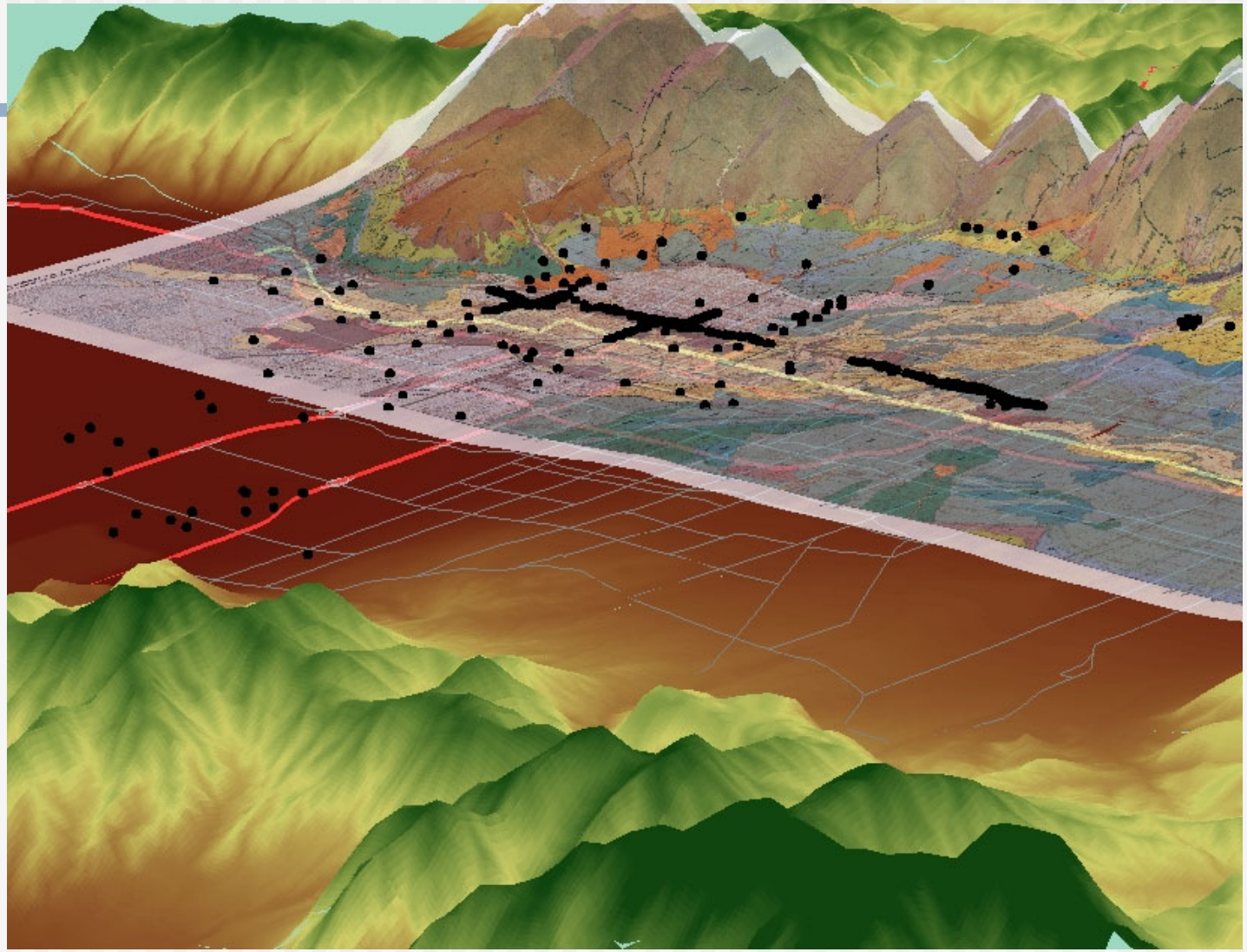
Geologic Map

Mapping Inputs



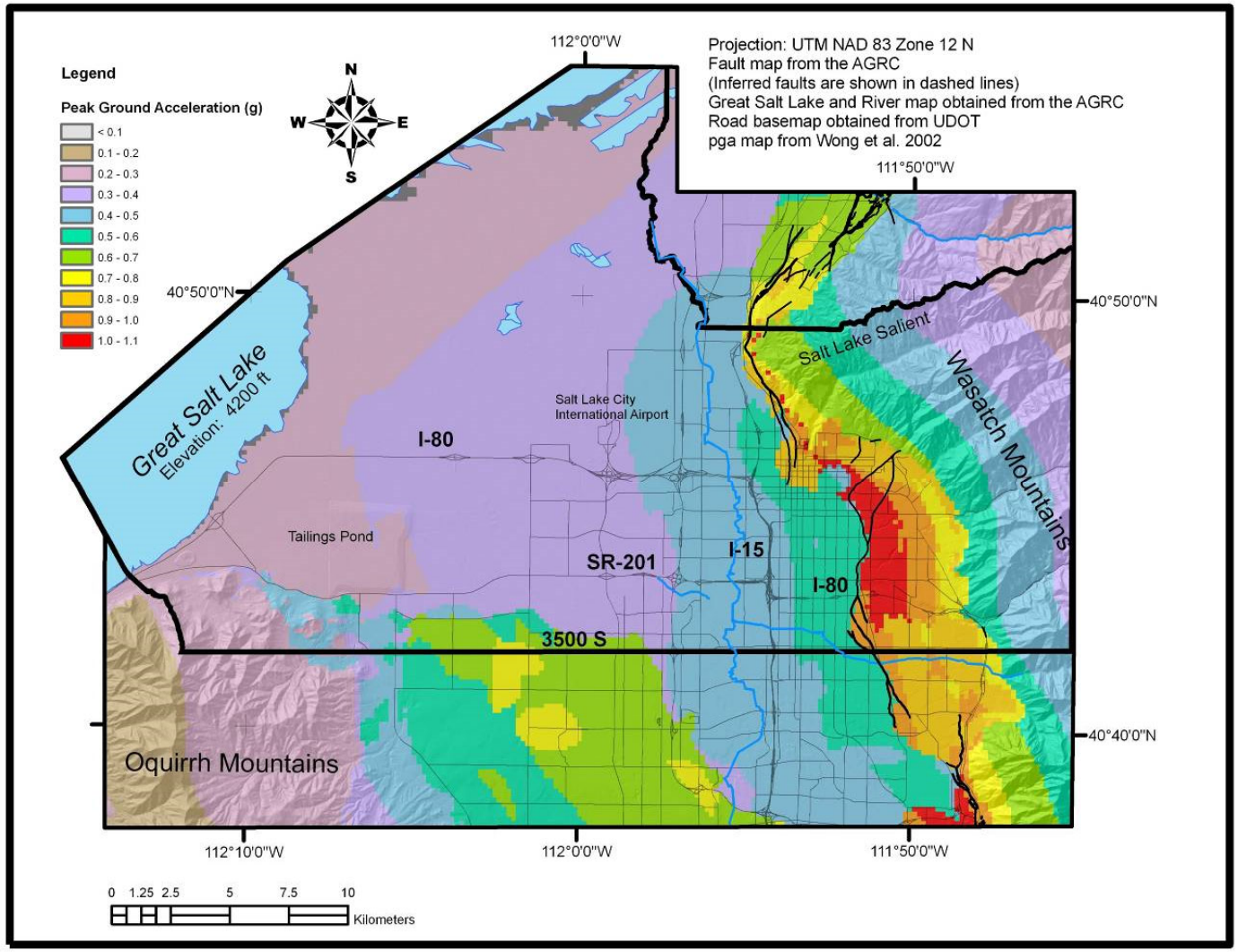
Groundwater Depth Map

Mapping Inputs



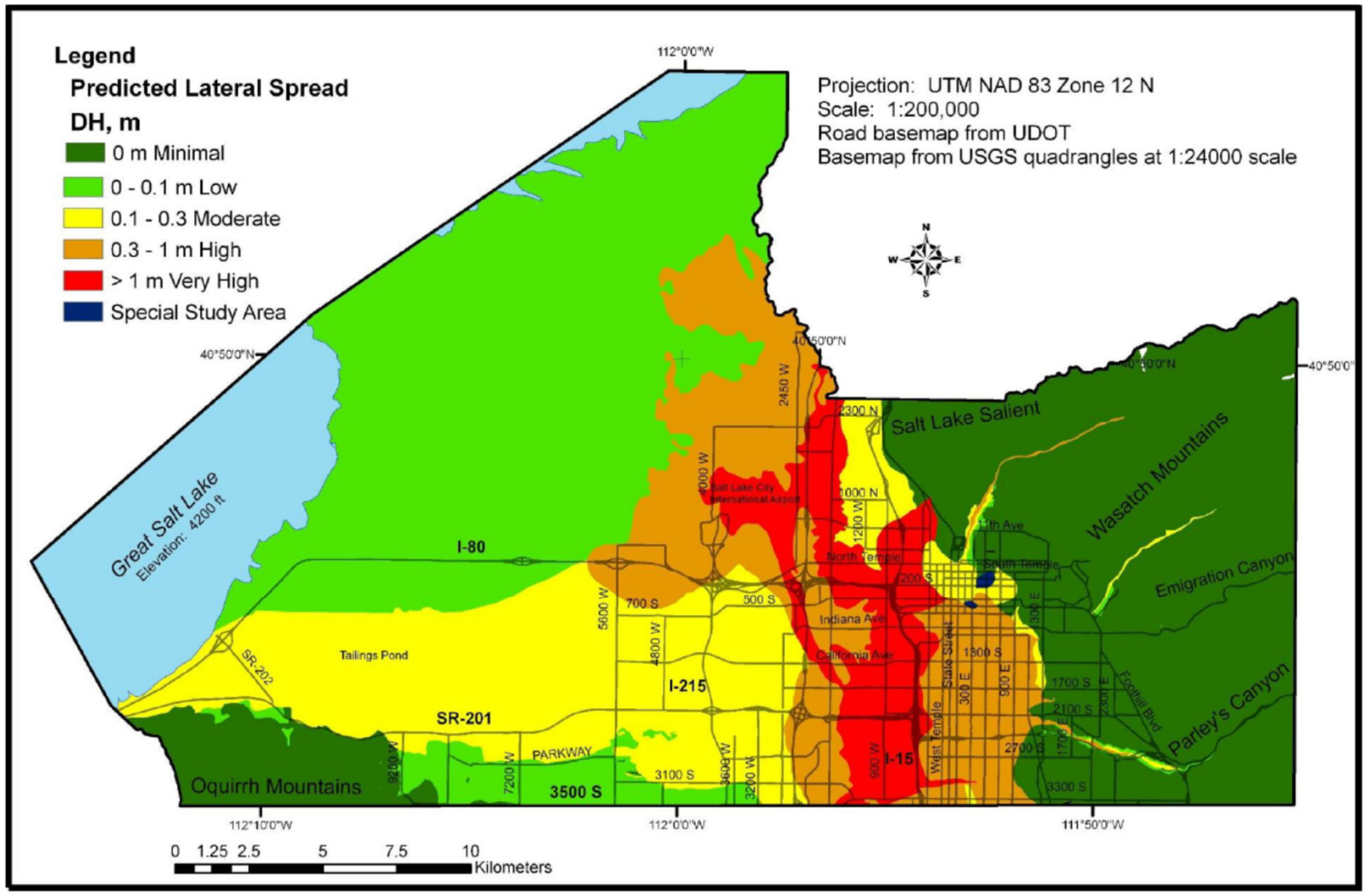
Digital Elevation Model

Mapping Inputs

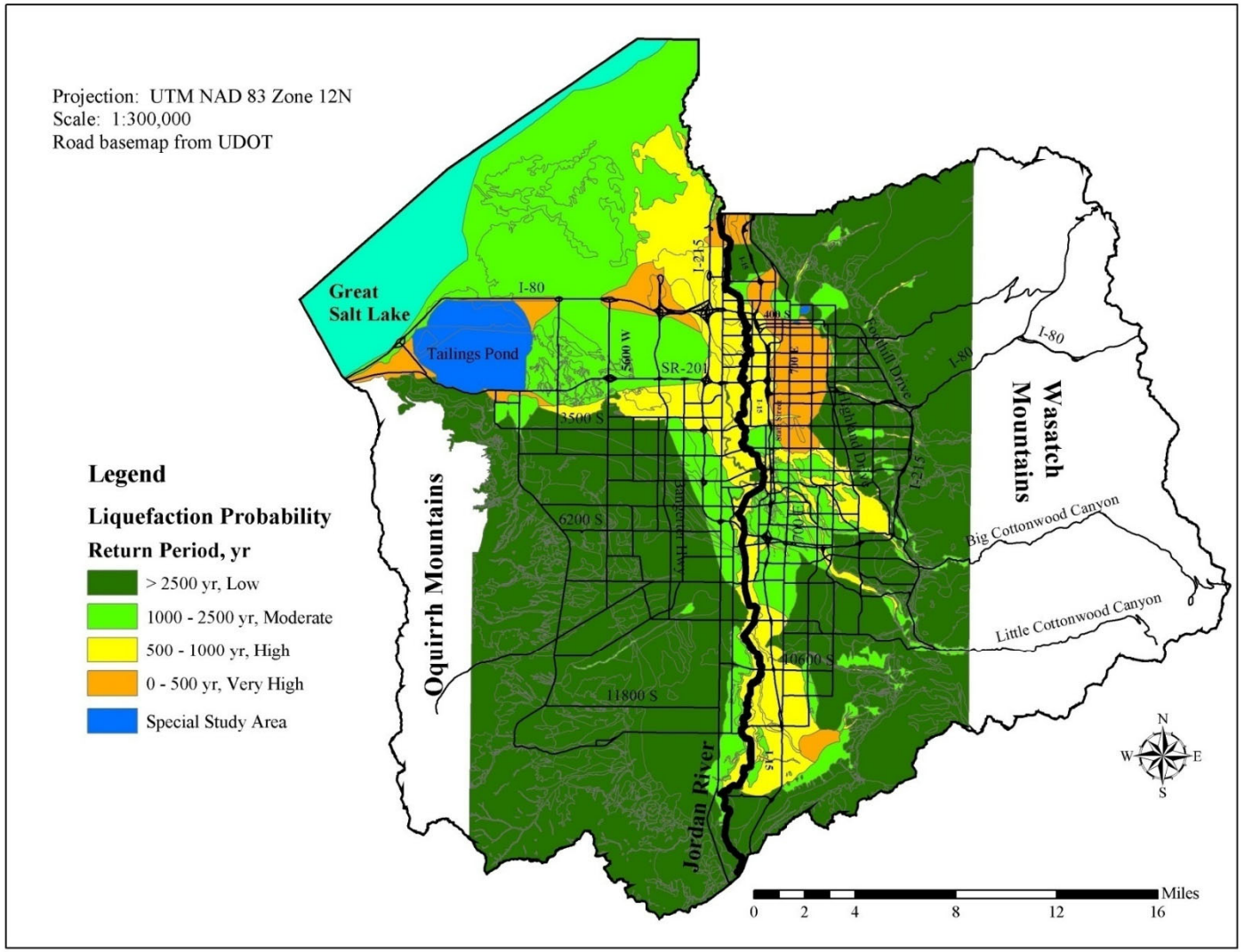


Estimates of peak ground acceleration (Wong et al., 2002)

Lateral Spread Displacement Hazard – N. Salt Lake Co.



Probabilistic liquefaction potential map Salt Lake Co. – (2002 USGS Input)



Previous Work

FY 2006 & 2007

Previous Work

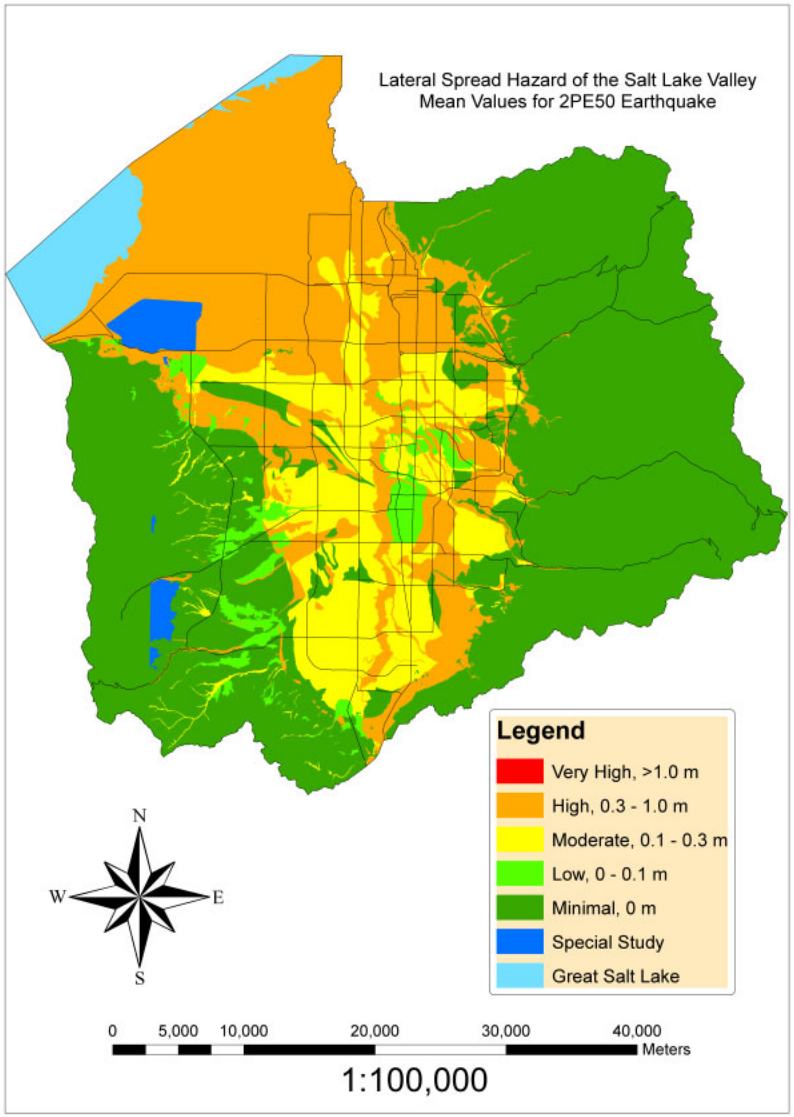
FY 2006 – 2007 (cont.)

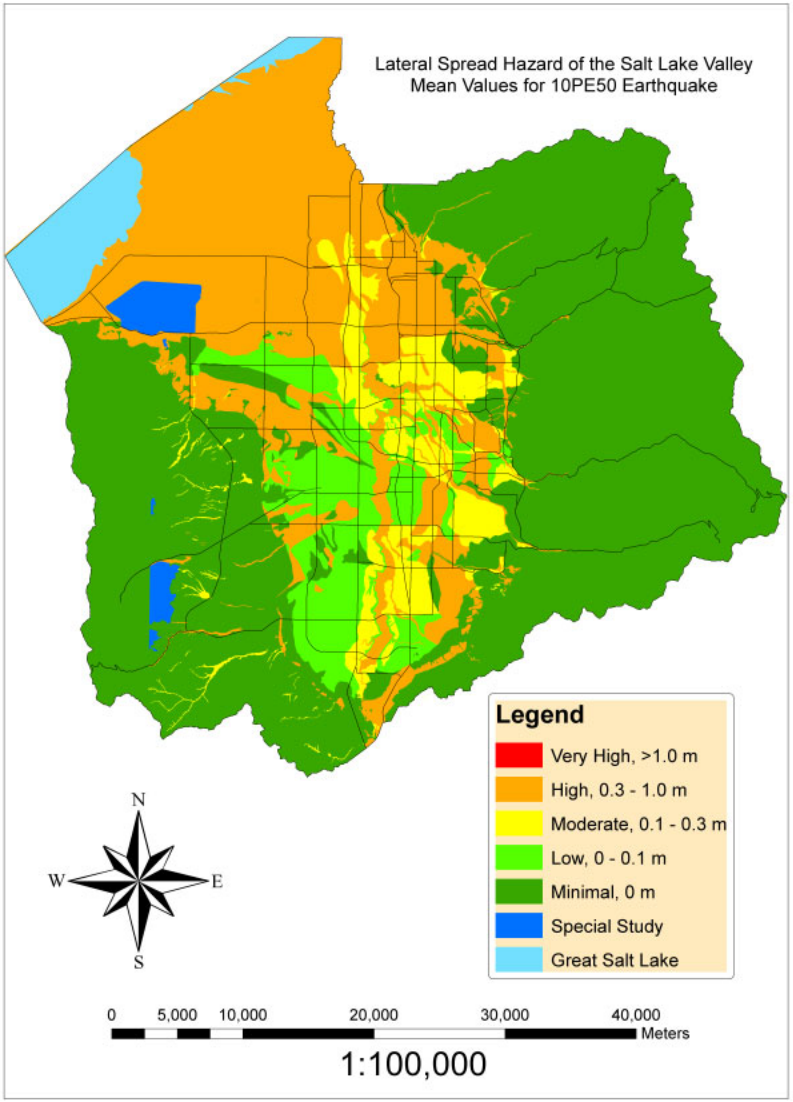
FY 2008 (No Funding)

FY 2009 (No Funding)

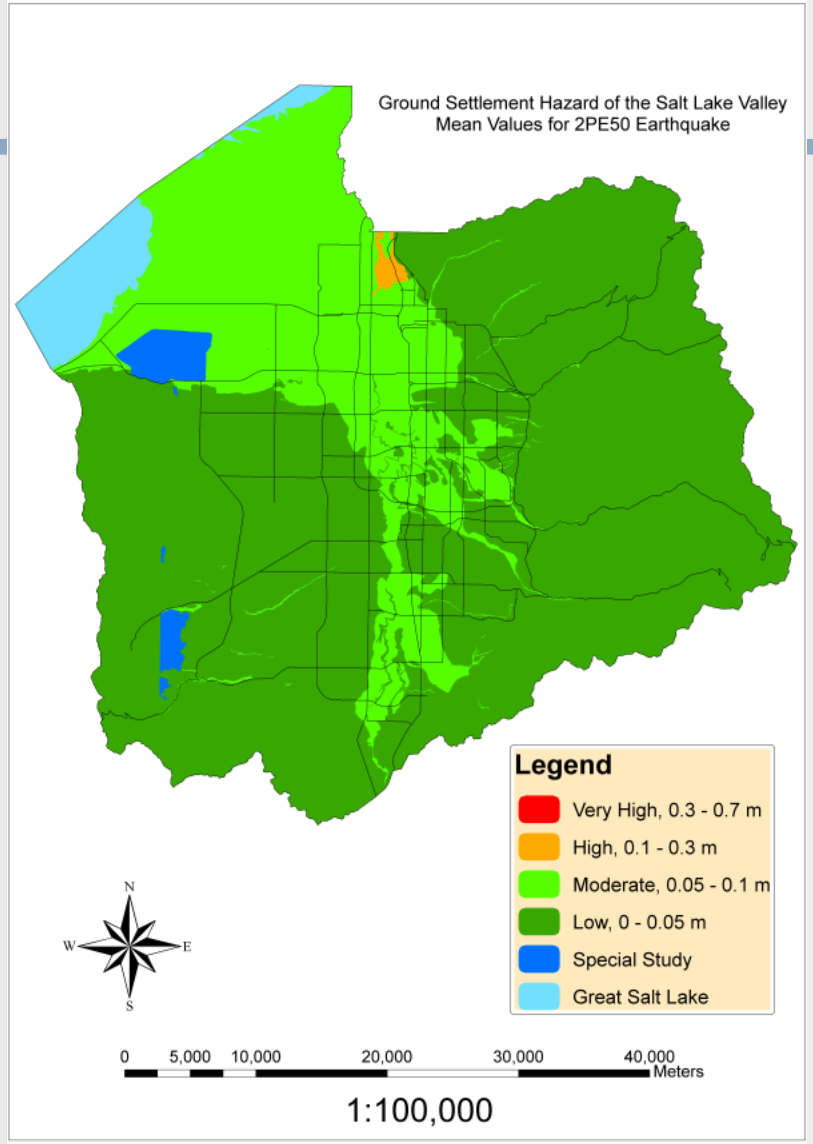
FY 2010 (No Funding)

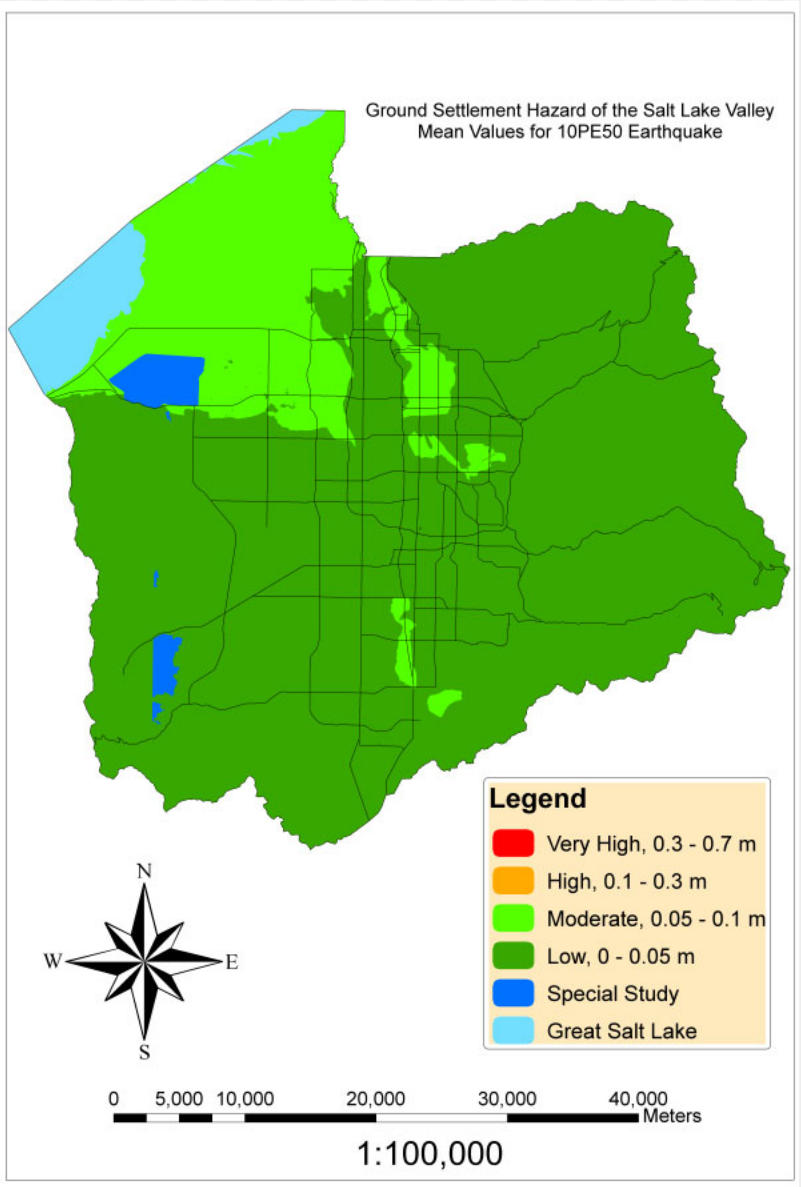
Probabilistic liquefaction potential maps for 2500 and 500-year return periods



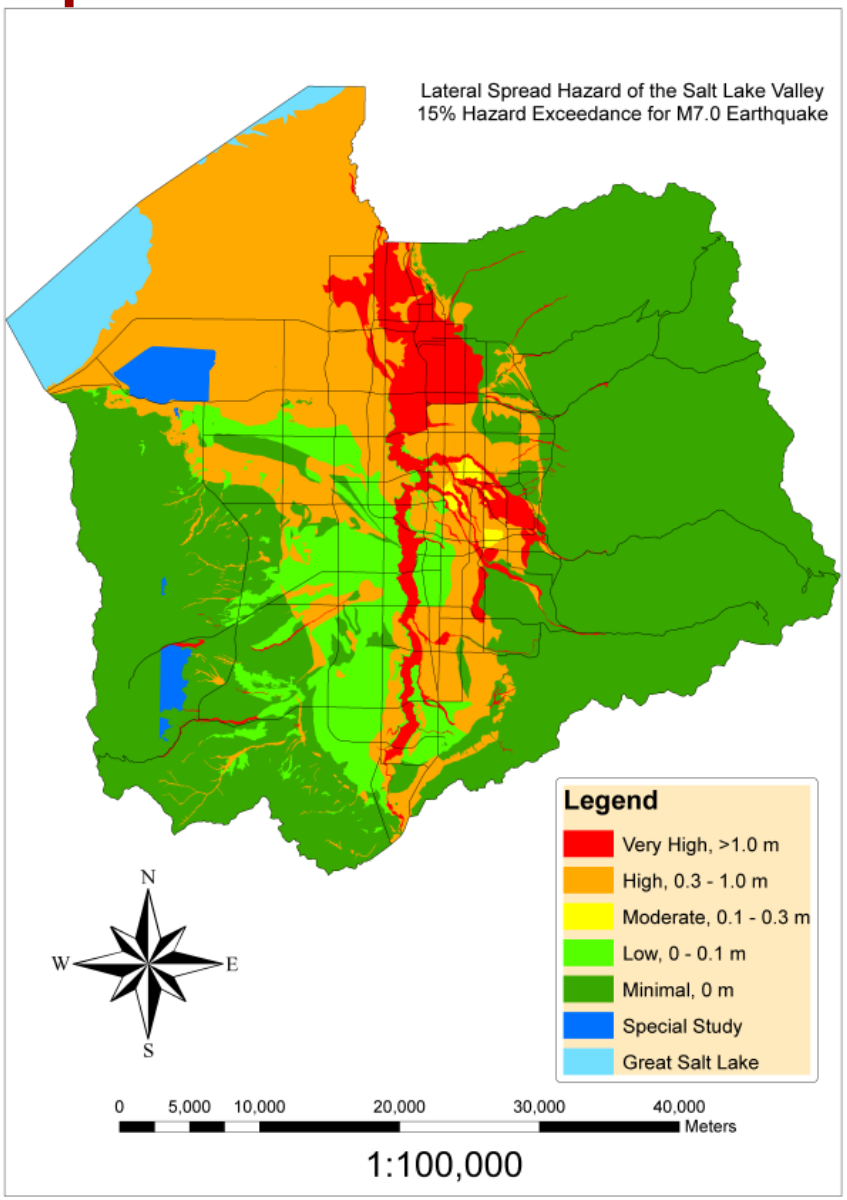


Probabilistic ground settlement maps for 2500 and 500-year return periods

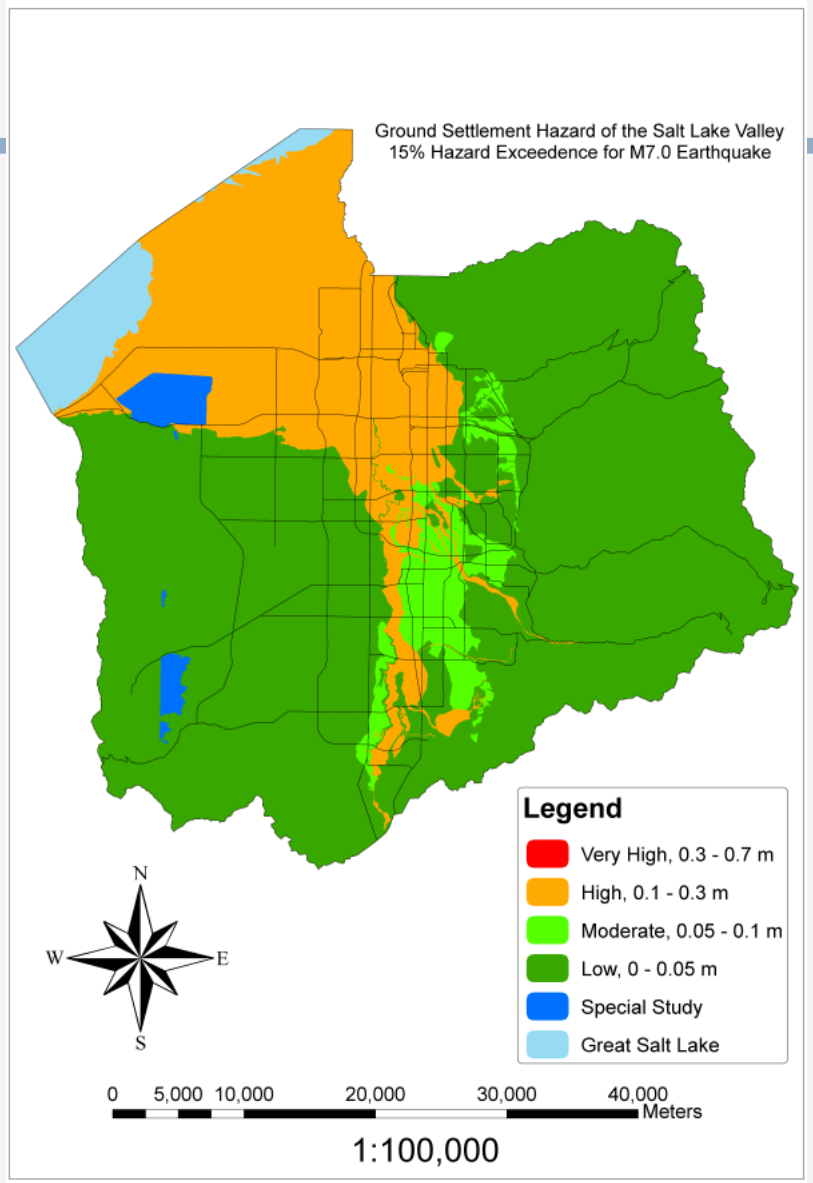




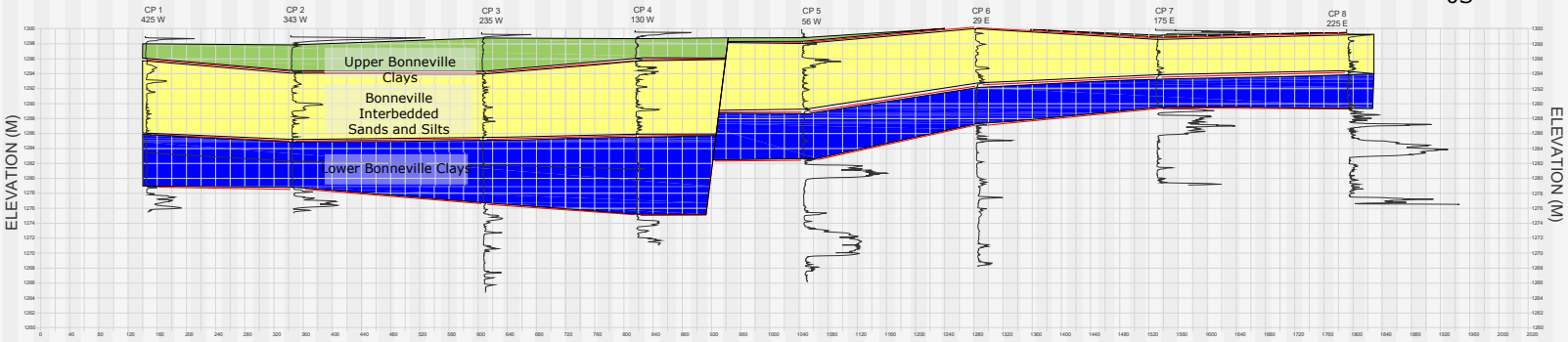
M 7.0 Lateral spread displacement map
15 percent chance of exceedance



M 7.0 ground settlement map
15 percent chance of exceedance



Downtown Displacement Investigations



HORIZONTAL DISTANCE ALONG EXPLORATION LINE (M)
(Measured From the Southeast Corner of 500W and 400S)

Possible Extension of the Warm Springs Fault

Approximate CPT Sounding Locations

Previous Work

FY 2008 (No Funding)

FY 2009 (No Funding)

FY 2010 (No Funding)

FY 2010 (Partial Funding from WBWCD for Mapping Weber Co.)

FY 2011 (USGS –Funding for Mapping Weber Co.)

Weber County Liquefaction Hazard Mapping

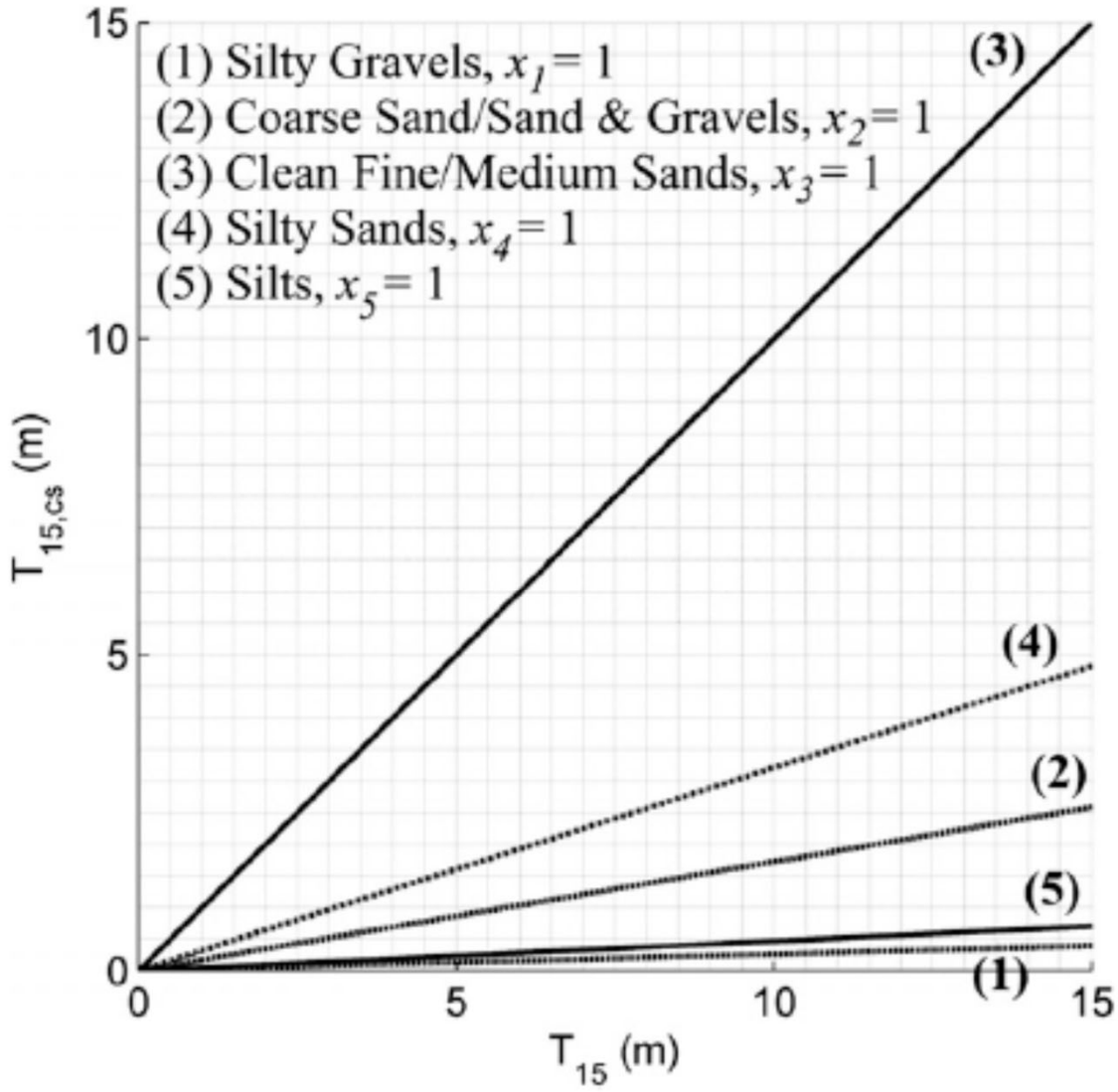


Fig. 3. T_{15} versus $T_{15,cs}$ according to soil index

Weber County Liquefaction Hazard Mapping

$$LogD_H = \begin{array}{c} b_o + b_{off}\alpha + b_1 M + b_2 LogR^* + b_3 R + b_4 LogW + b_5 LogS + \\ + b_6 LogT_1 + a_{31}x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 \end{array}$$

$$\overline{Log(D_H)} = \left(\begin{array}{c} -8.453 + 1.348 \cdot M_w - 1.068 \cdot Log(R^*) - 0.017 \cdot R + 0.334 \cdot Log(S) + \\ + 0.588 \cdot Log(T_{15,cs}) + 0.278 \end{array} \right) \qquad (4.2)$$

$$\overline{Log(D_H)} = \left(\begin{array}{c} -8.795 + 1.348 \cdot M_w - 1.068 \cdot Log(R^*) - 0.017 \cdot R + 0.453 \cdot Log(W) + \\ + 0.588 \cdot Log(T_{15,cs}) + 0.278 \end{array} \right) \qquad (4.3)$$

Weber County Liquefaction Hazard Mapping

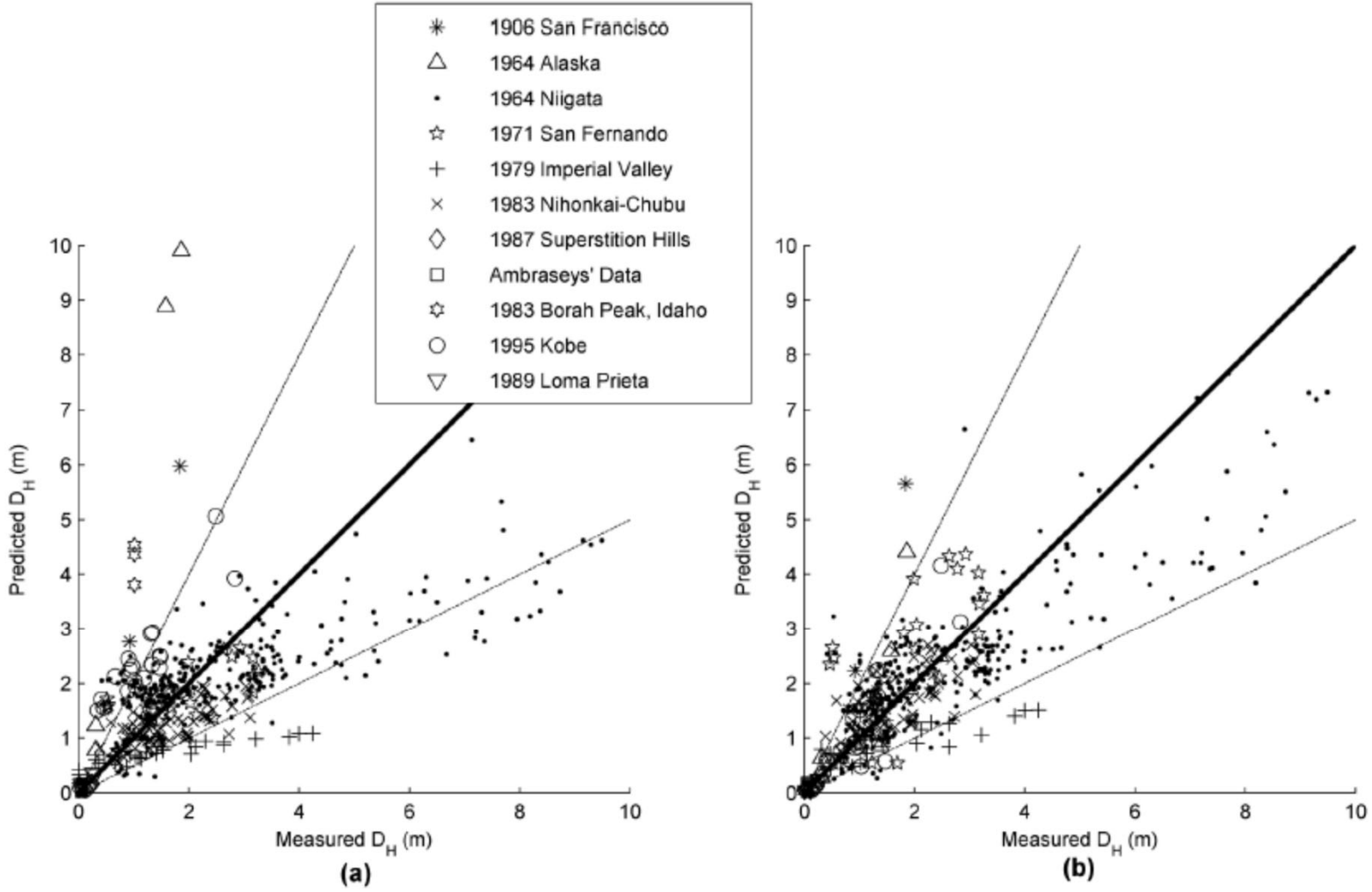


Figure 3.1. Predicted lateral spread displacement using (a) eqn. (3.3), or (b) eqn. (3.4), versus measured lateral spread displacement from the case history database of Youd et al., 2002

Weber County Liquefaction Hazard Mapping

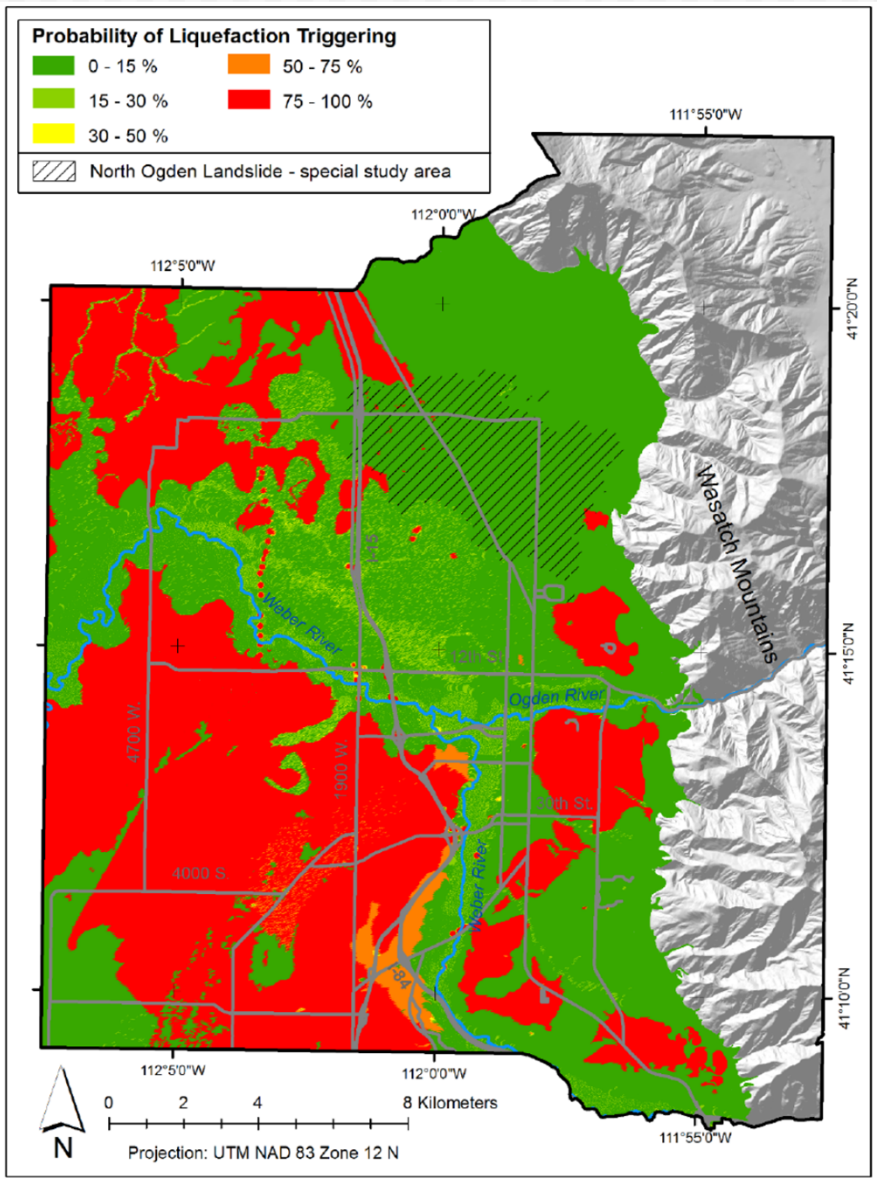


Figure 5.4. 50th percentile probabilities of liquefaction triggering given a 500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

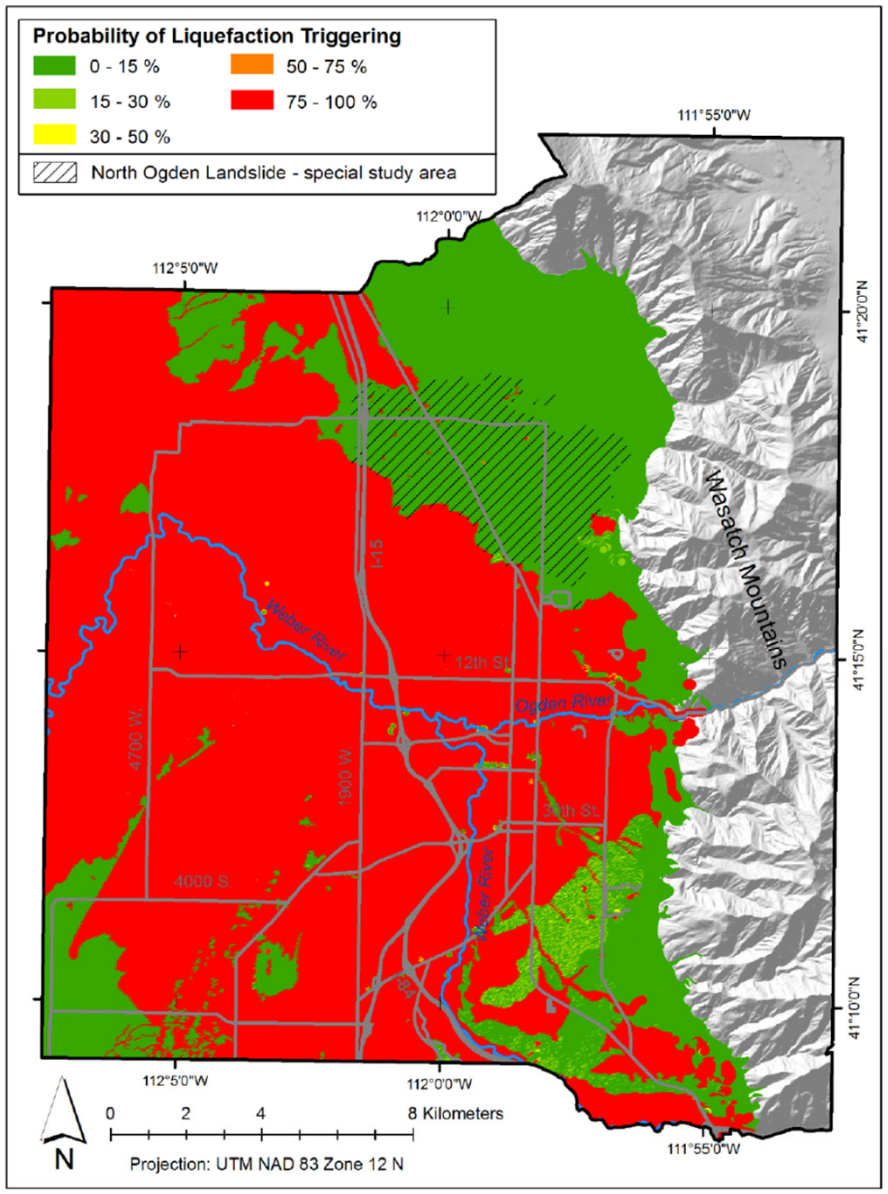


Figure 5.5. 50th percentile probabilities of liquefaction triggering given a 2,500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

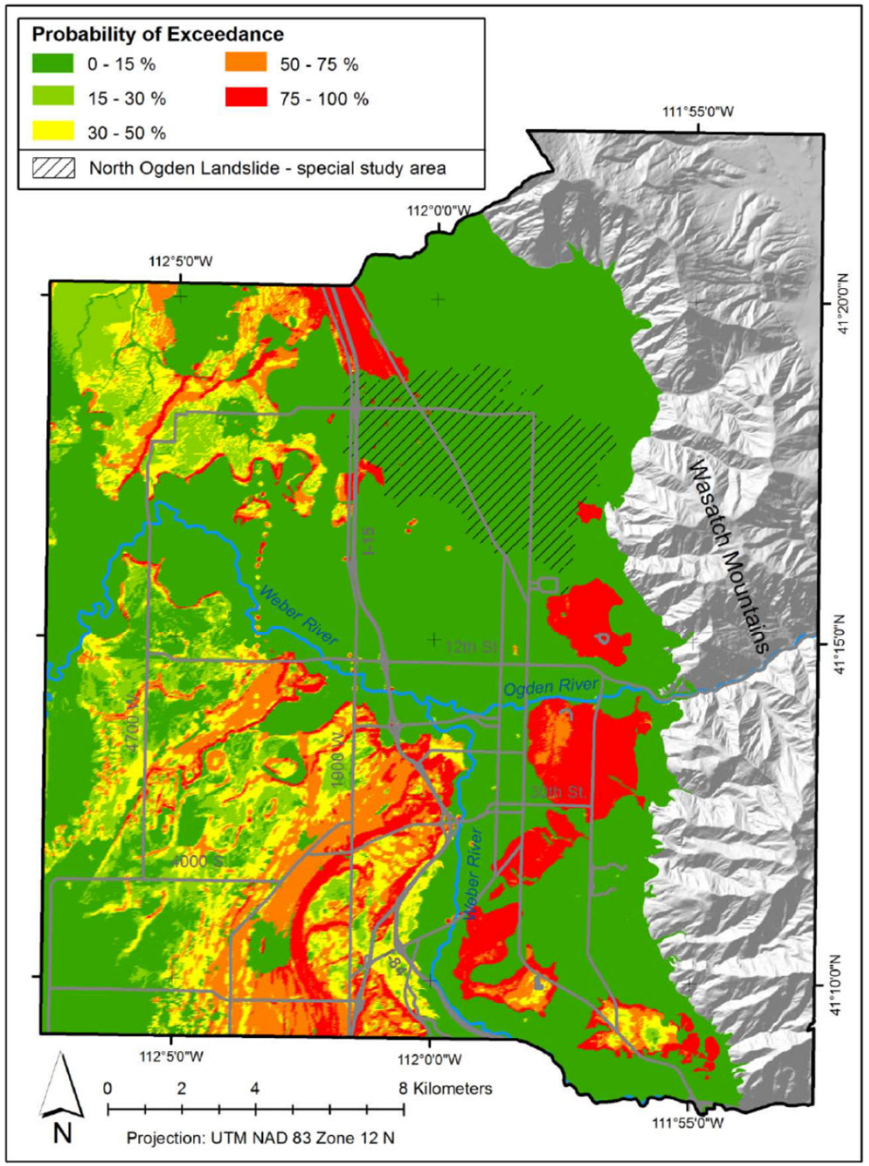


Figure 5.6. 50th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

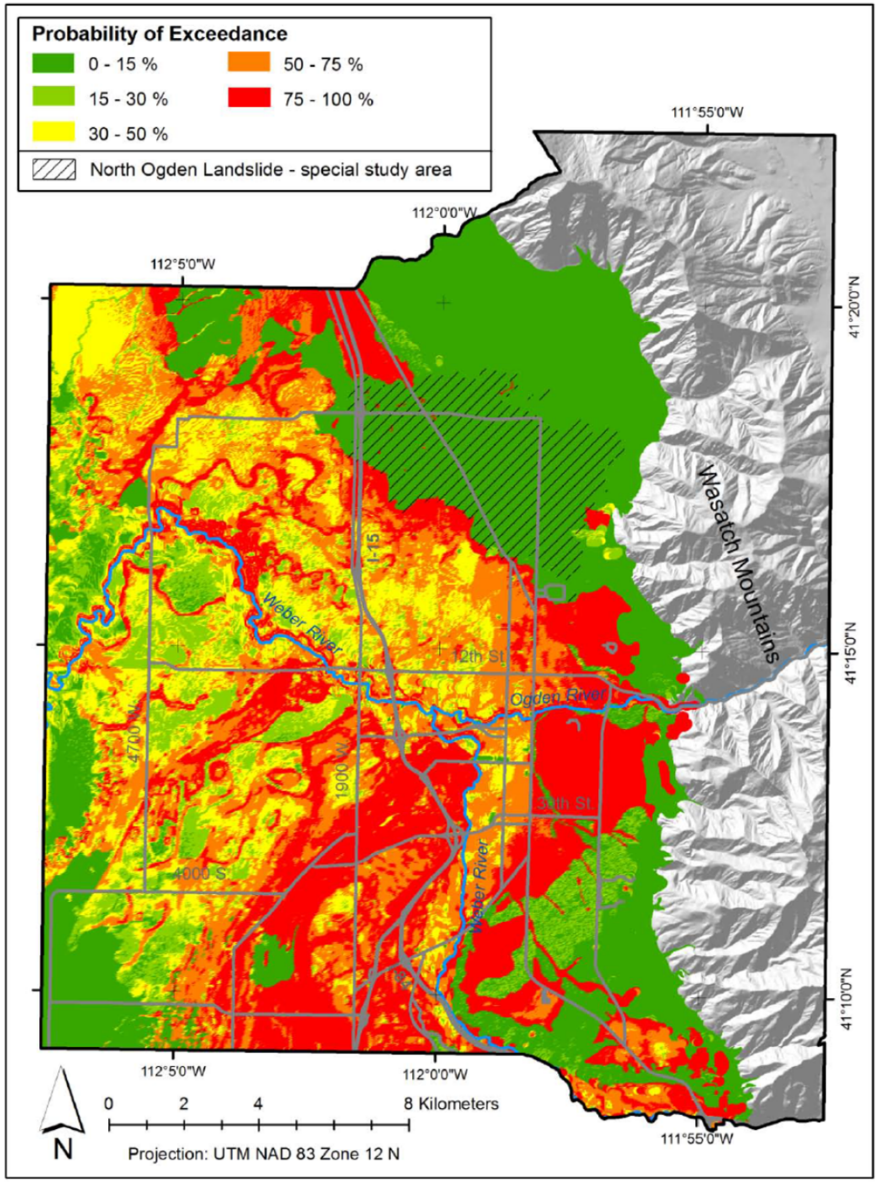


Figure 5.7. 84th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

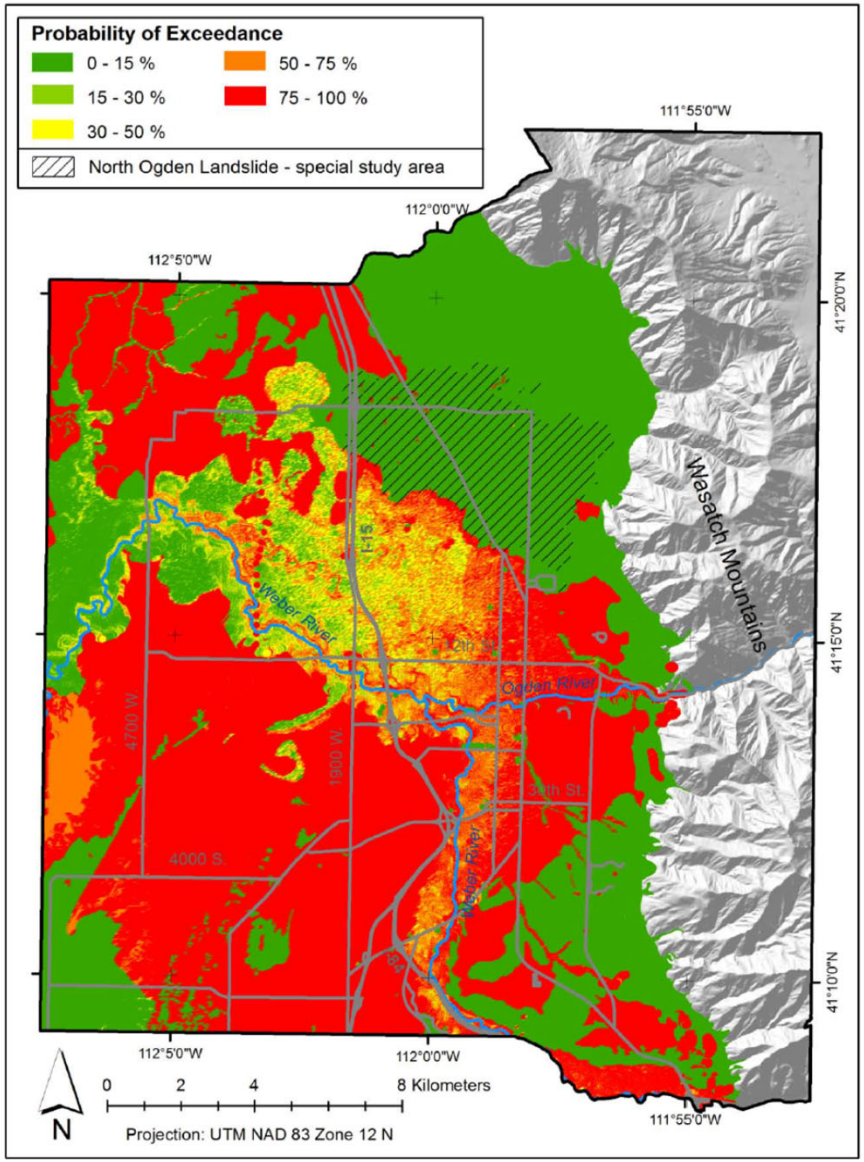


Figure 5.10. 50th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 2,500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

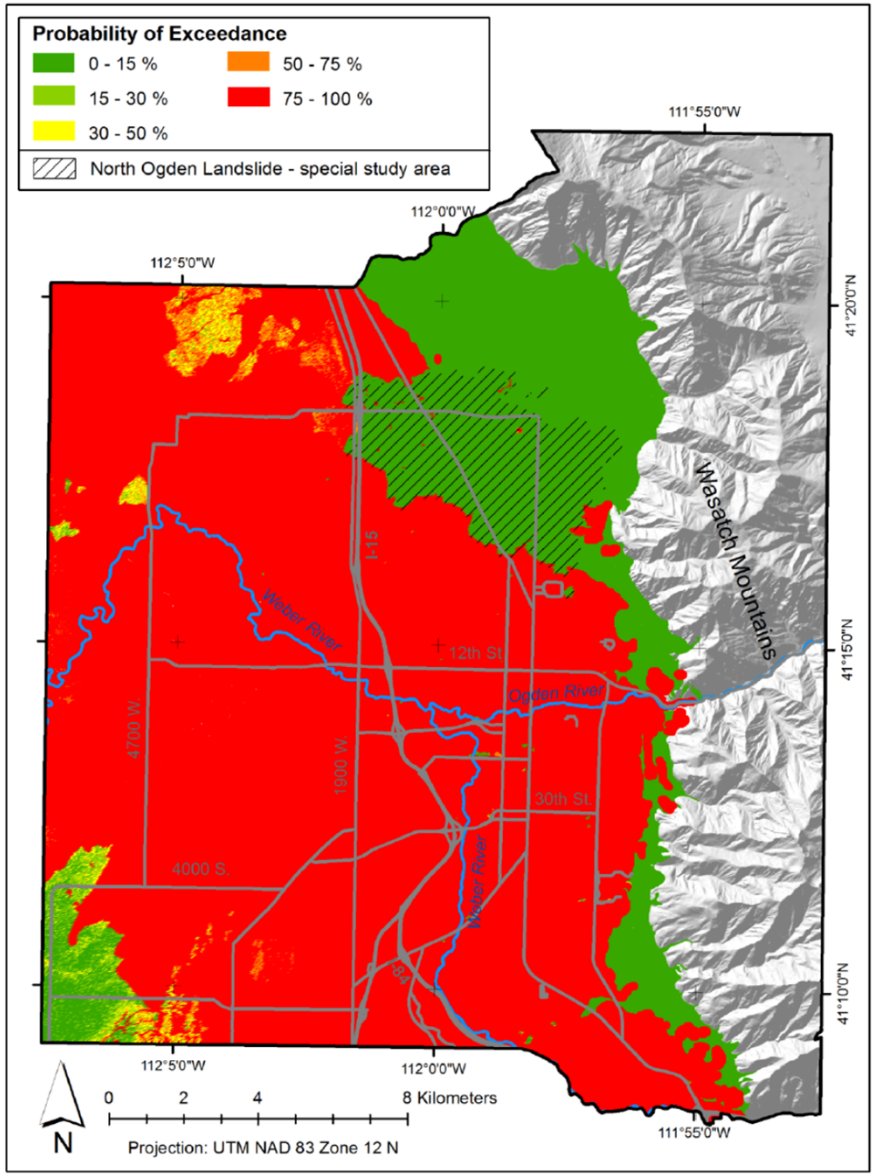


Figure 5.11. 84th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 2,500-year seismic event; Weber County, Utah

Previous Work

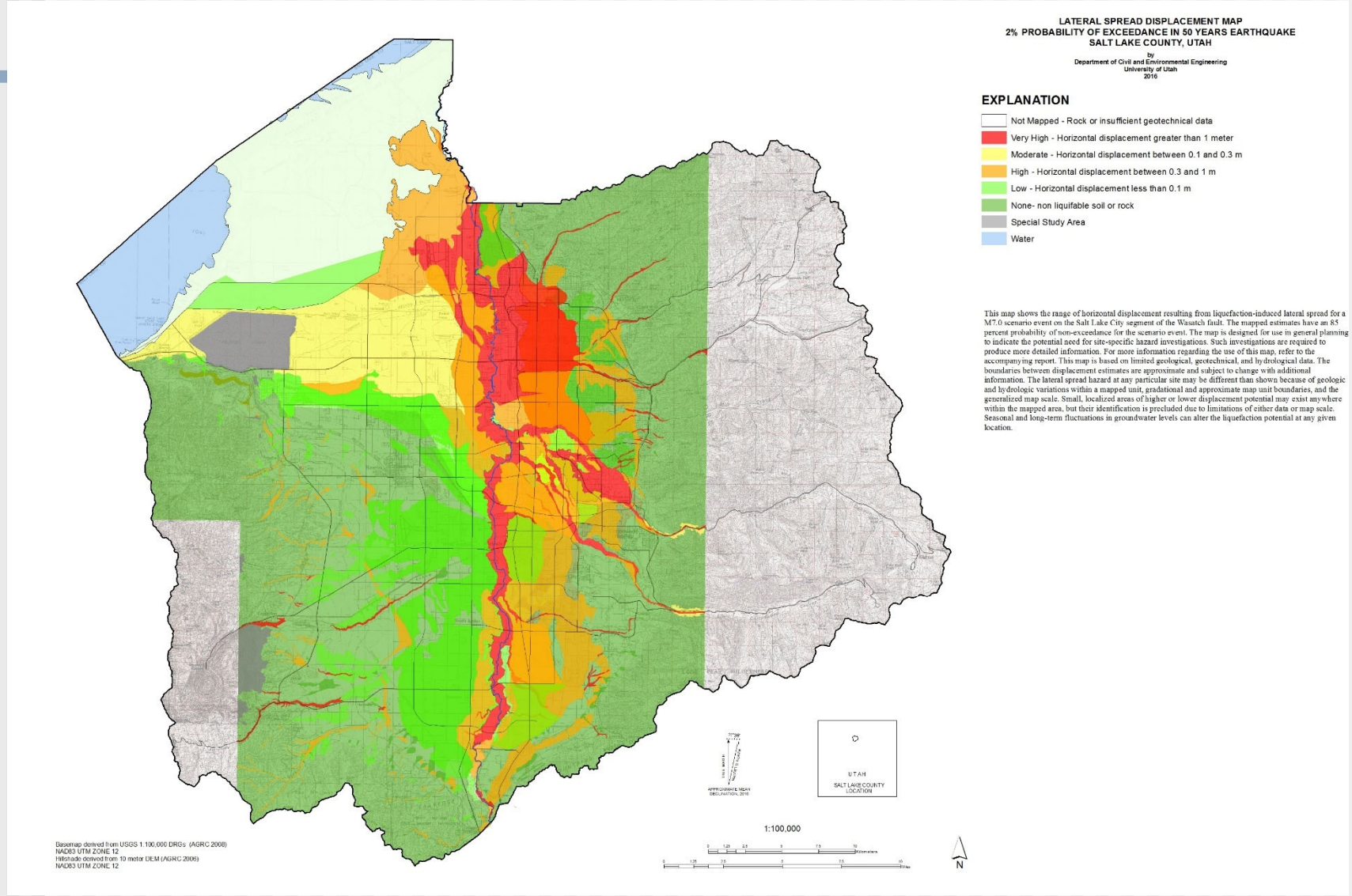
FY 2013 (FEMA – Funding for Salt Lake Co.)

FY 2014 (USGS – Funding for Mapping Utah Co.)

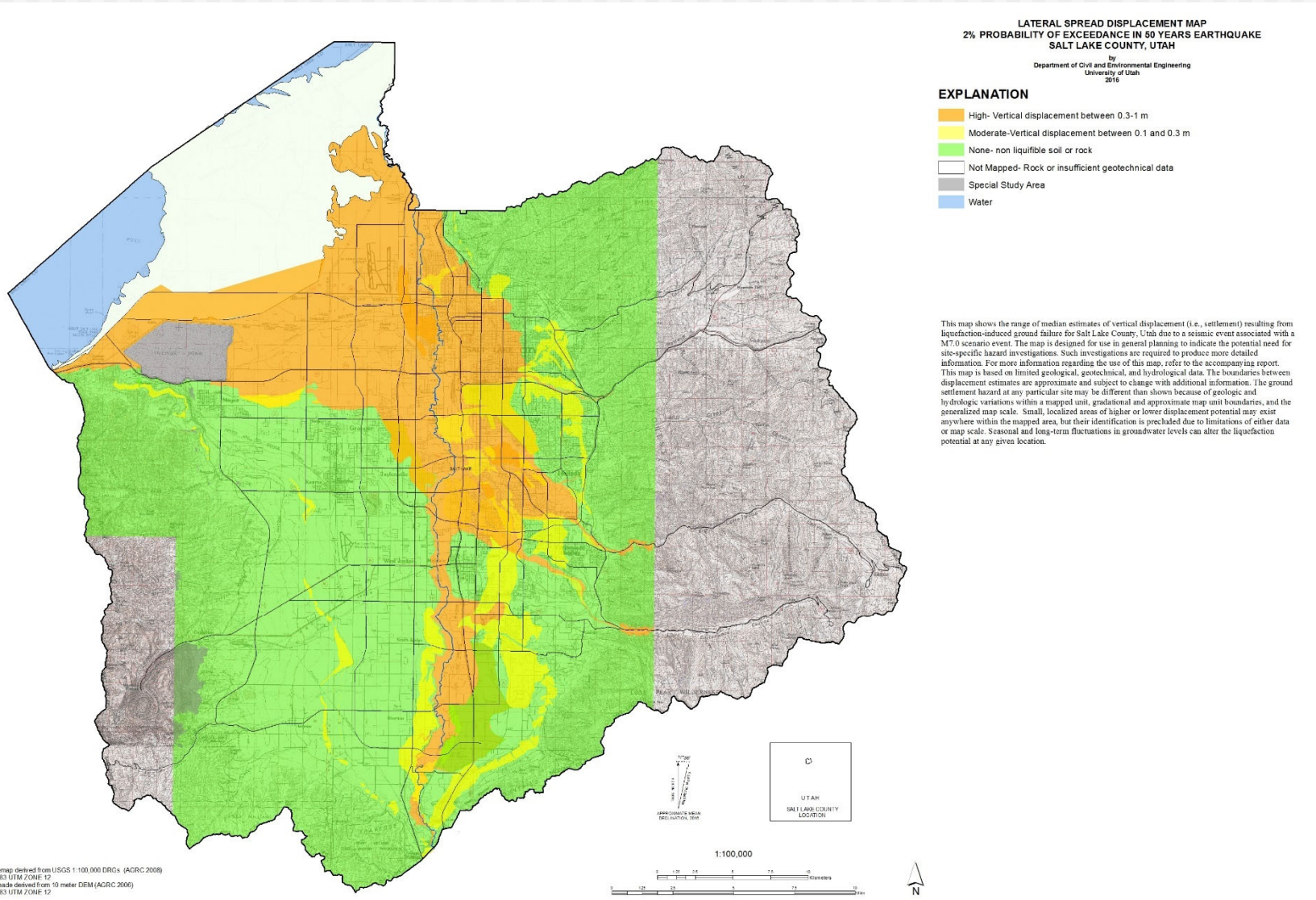
2013 FEMA Project
U of U and UGS)

1. Develop a new model ordinance for liquefaction hazards based on input and feedback from municipalities, technical advisory groups, and others.
2. Educate various municipalities and their stake holders regarding risk-based decision making and hazard mitigation using the newly developed hazard ordinance that is coupled with the recently developed ULAG liquefaction hazard maps and support and encourage the implementation/adoption of the new liquefaction hazard ordinance in the various municipalities along the urban Wasatch Front.
3. Develop methods to apply the liquefaction hazard maps to assess post-event traffic interruptions resulting from liquefaction-induced damage
4. Educate the next generation of Utahans about earthquake hazards by focusing on a secondary education outreach curriculum and program delivered to Salt Lake and Weber Counties.

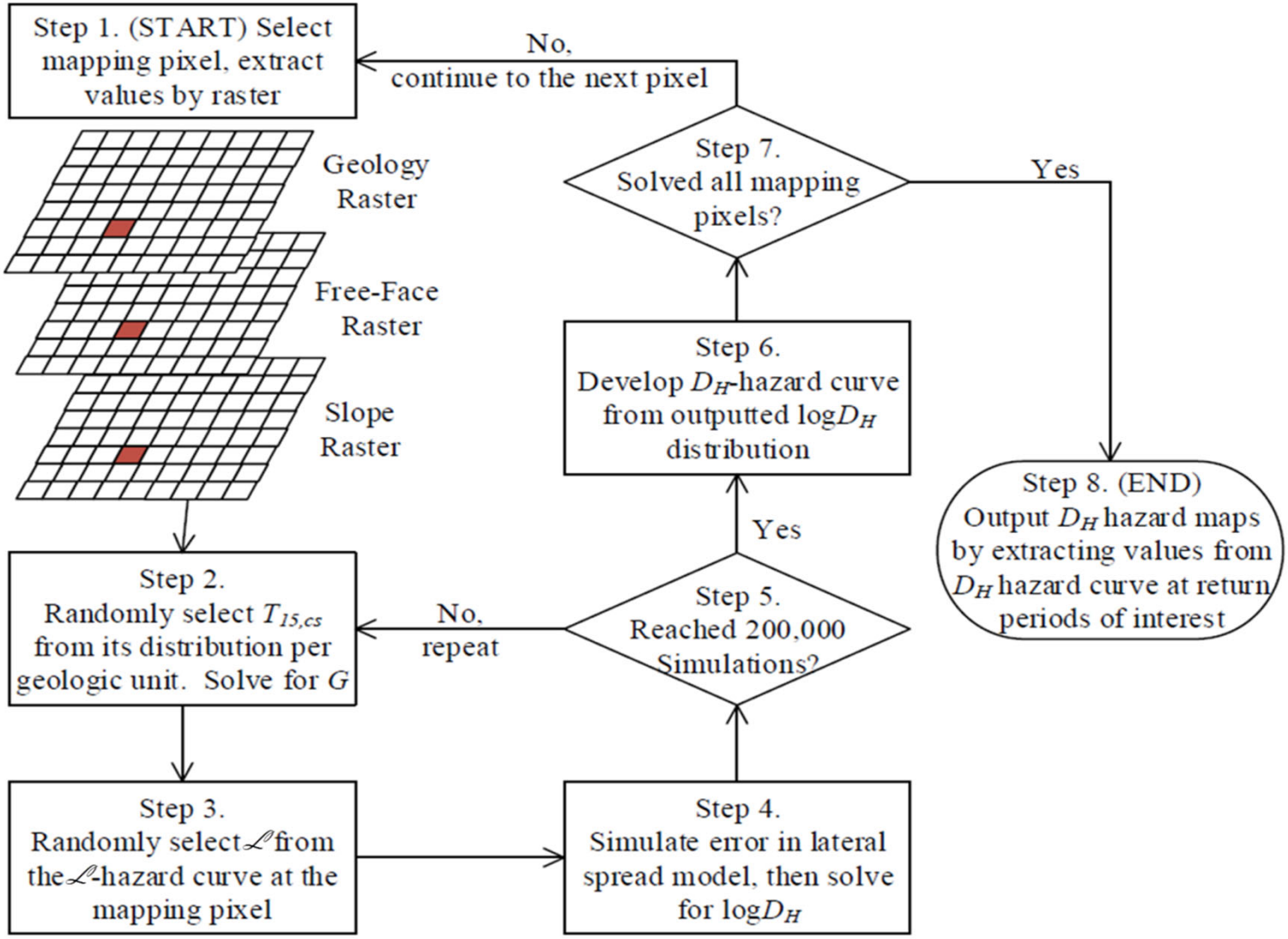
Lateral Spread Displacement Map Salt Lake Co. (85th Percentile Maps)



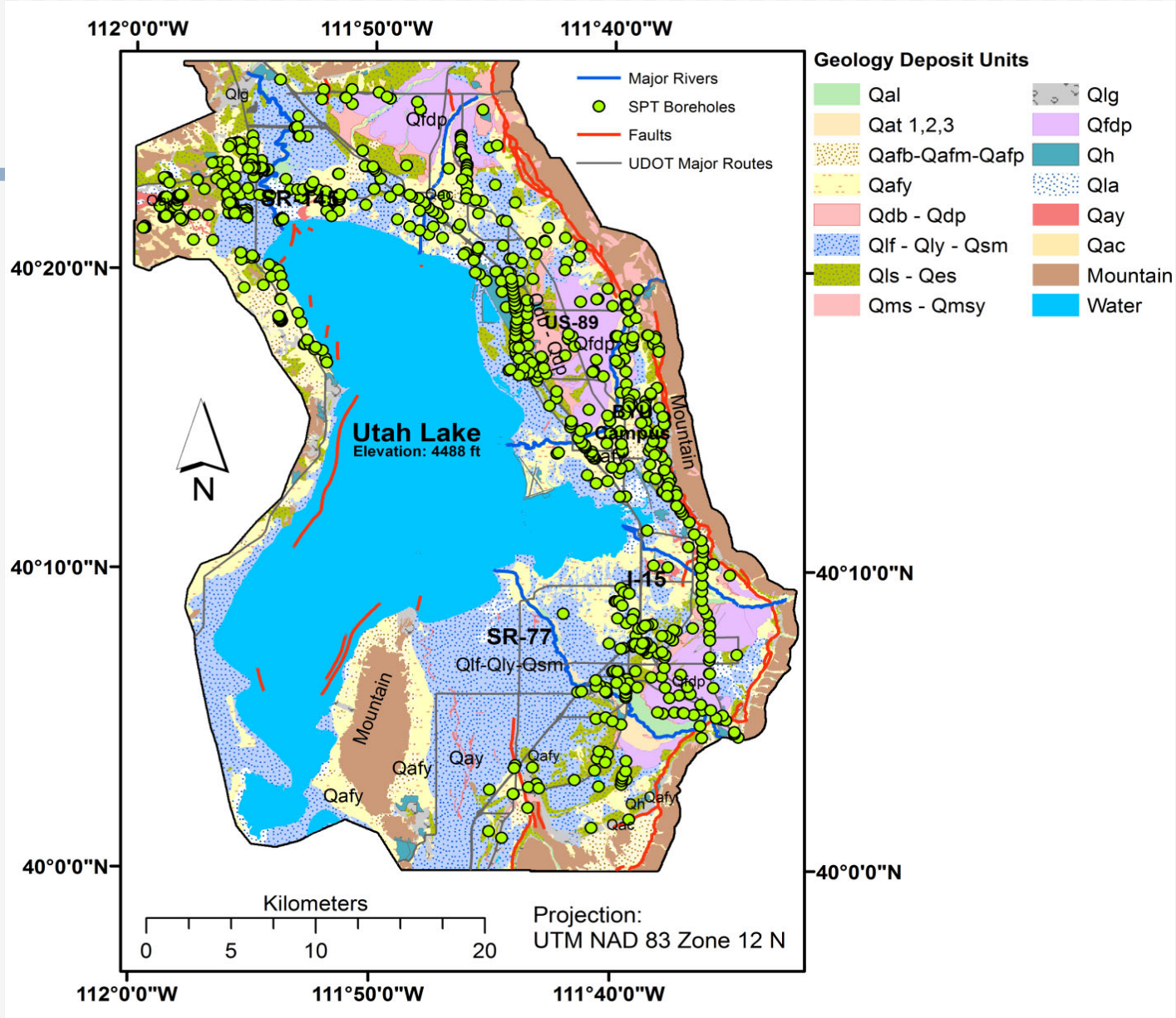
Ground Settlement Map
Salt Lake Co. (85th Percentile Maps)



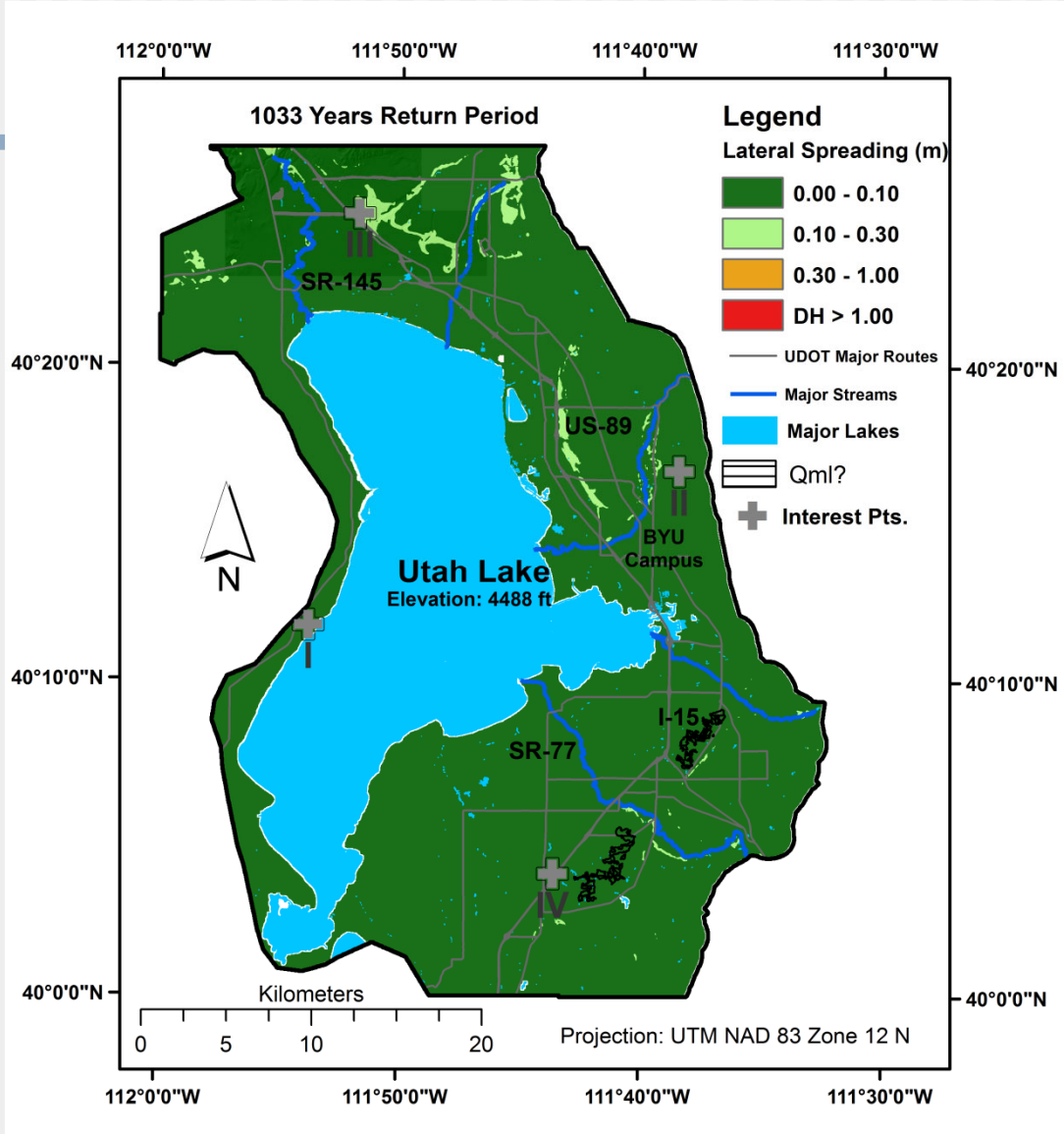
Utah Co Mapping Procedure



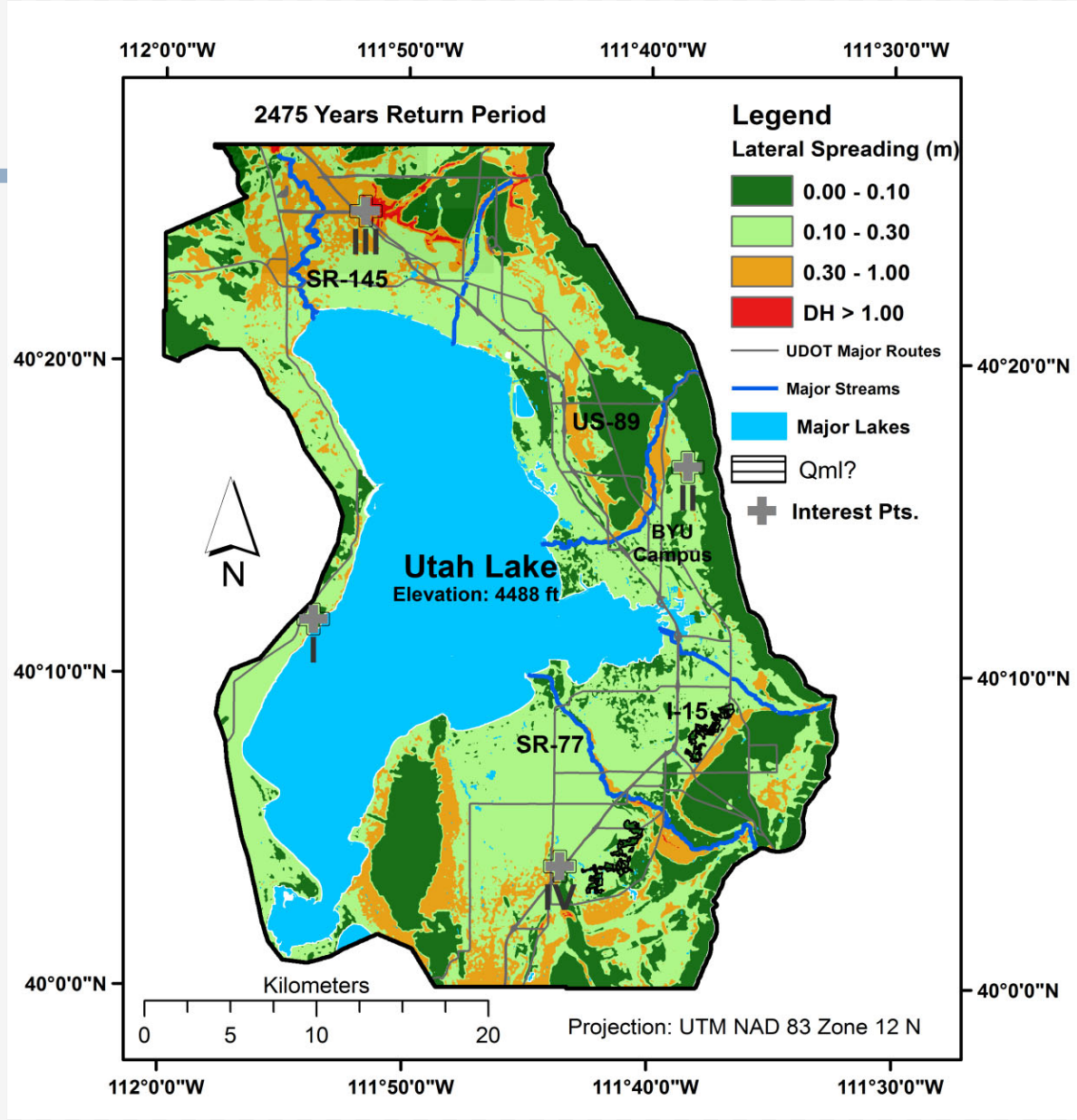
Utah Co Mapping Procedure



Utah Co Mapping Procedure



Utah Co Mapping Procedure



Current Work

FY 2017 (USGS & UDOT – Funding for Mapping Utah Co.)

- **Subsurface Data Collection**
- **Map Davis Co using methods for Utah Co.**
- **Map Salt Lake Co. using methods from Utah Co.**
- **Map Weber Co. using methods from Utah Co.**