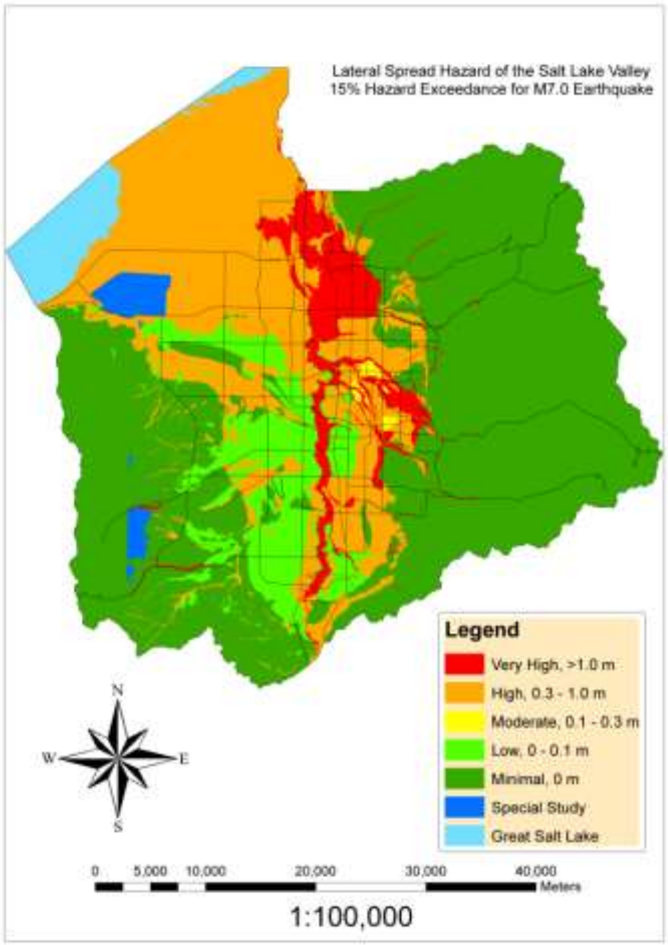
Utah Liquefaction Advisory Group (ULAG)



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

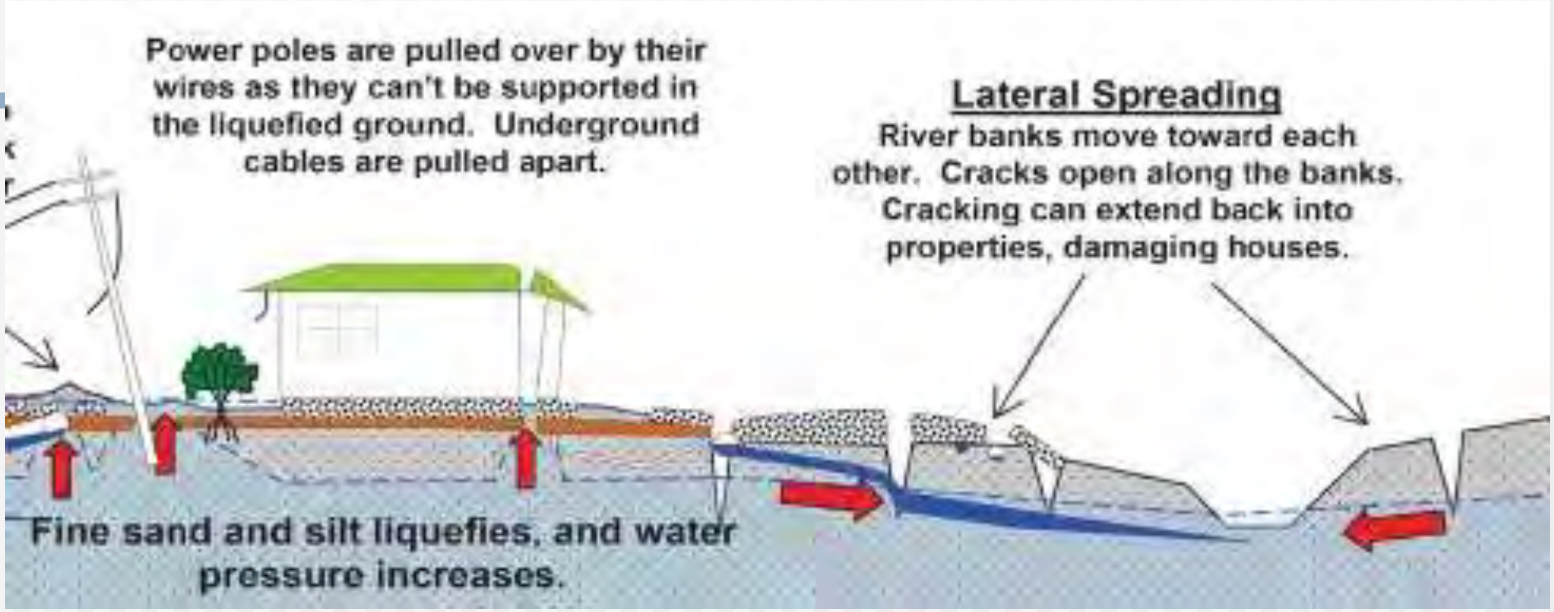
Types of Liquefaction Displacement

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

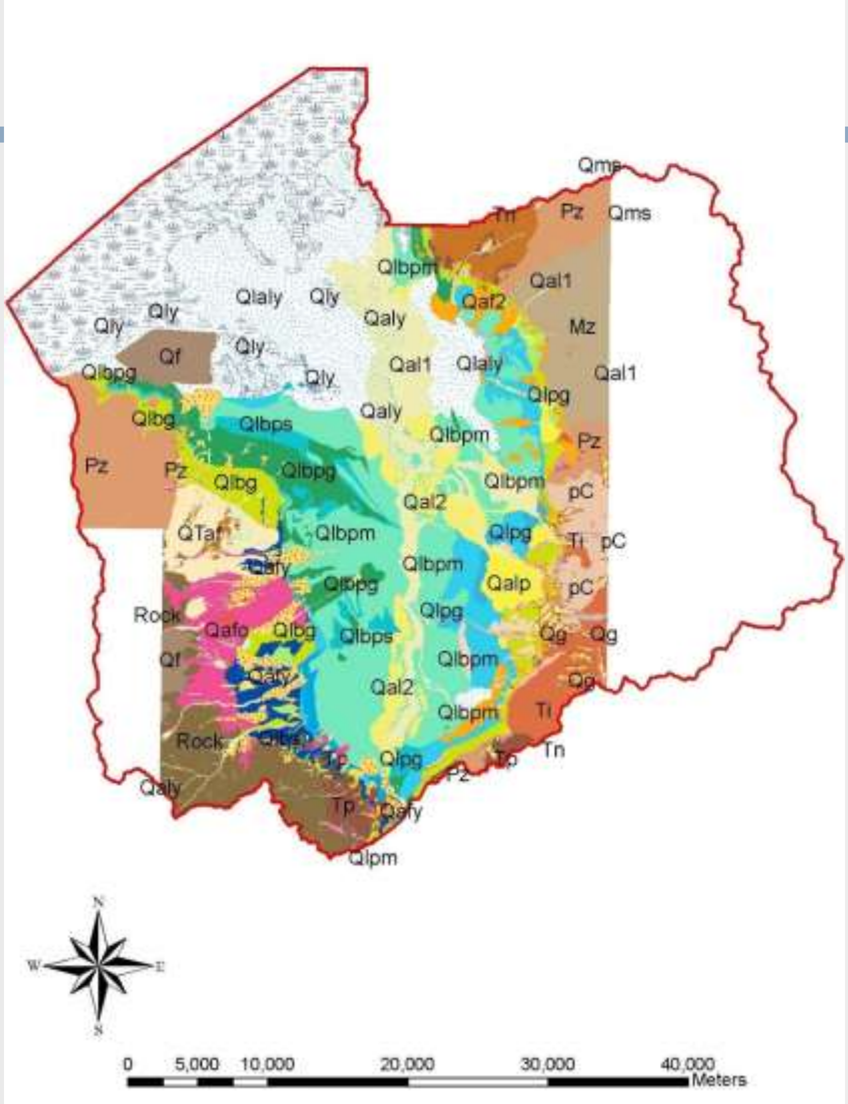
FY 2004

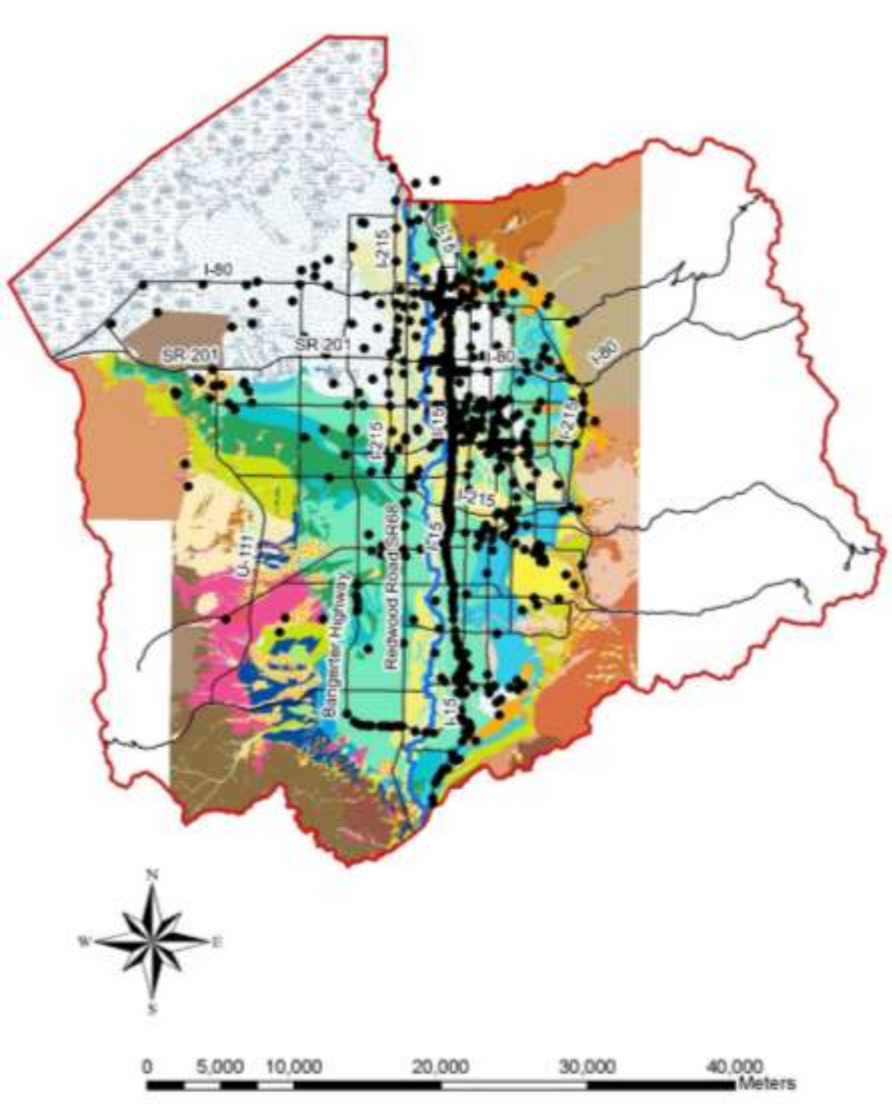
- **Geotechnical Database (N. Salt Lake Co.)**
- **M7.0 lateral spread displacement hazard map (N. Salt Lake Co.) published in *Earthquake Spectra.***

FY 2005

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

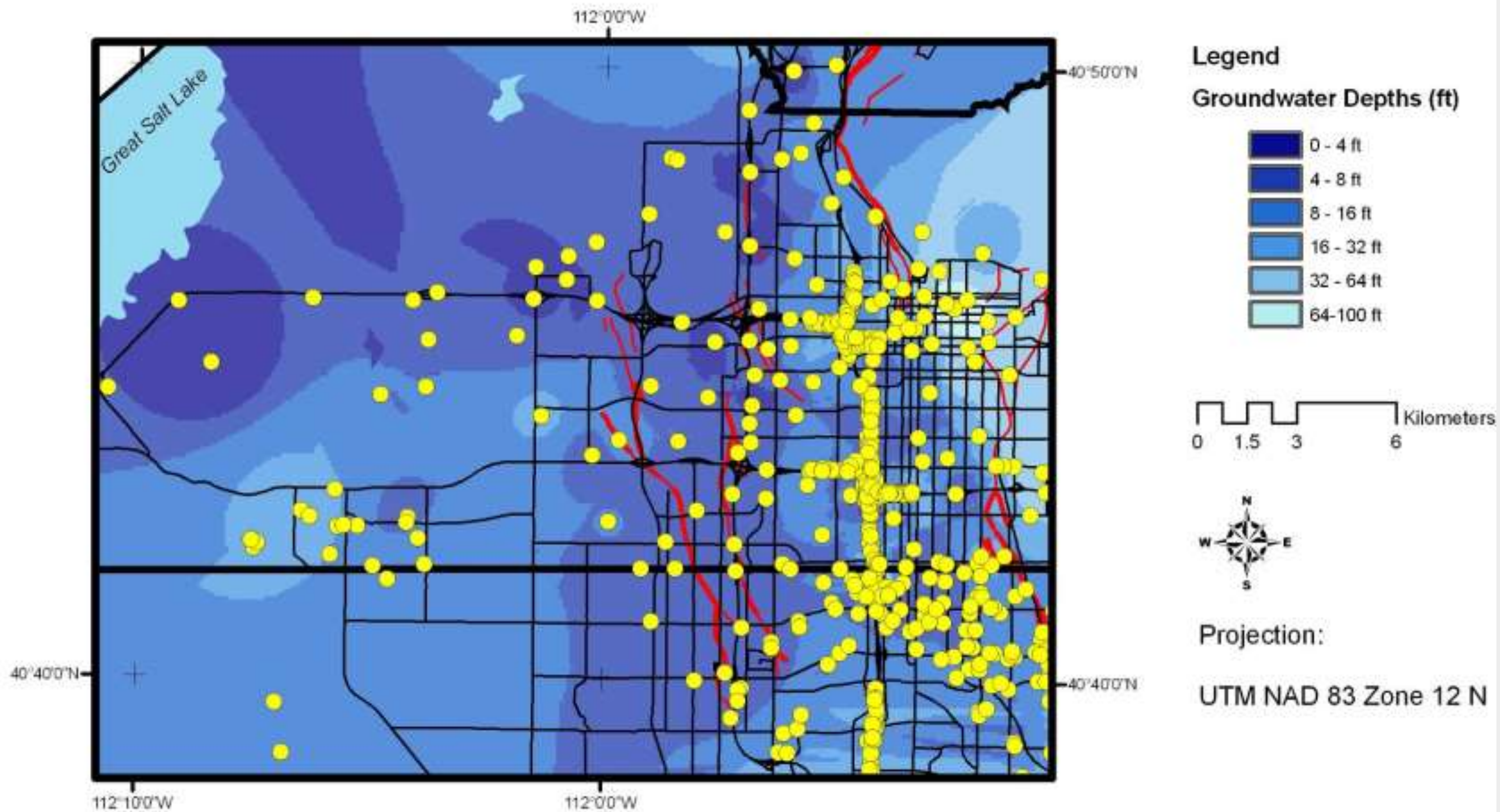
Mapping Inputs





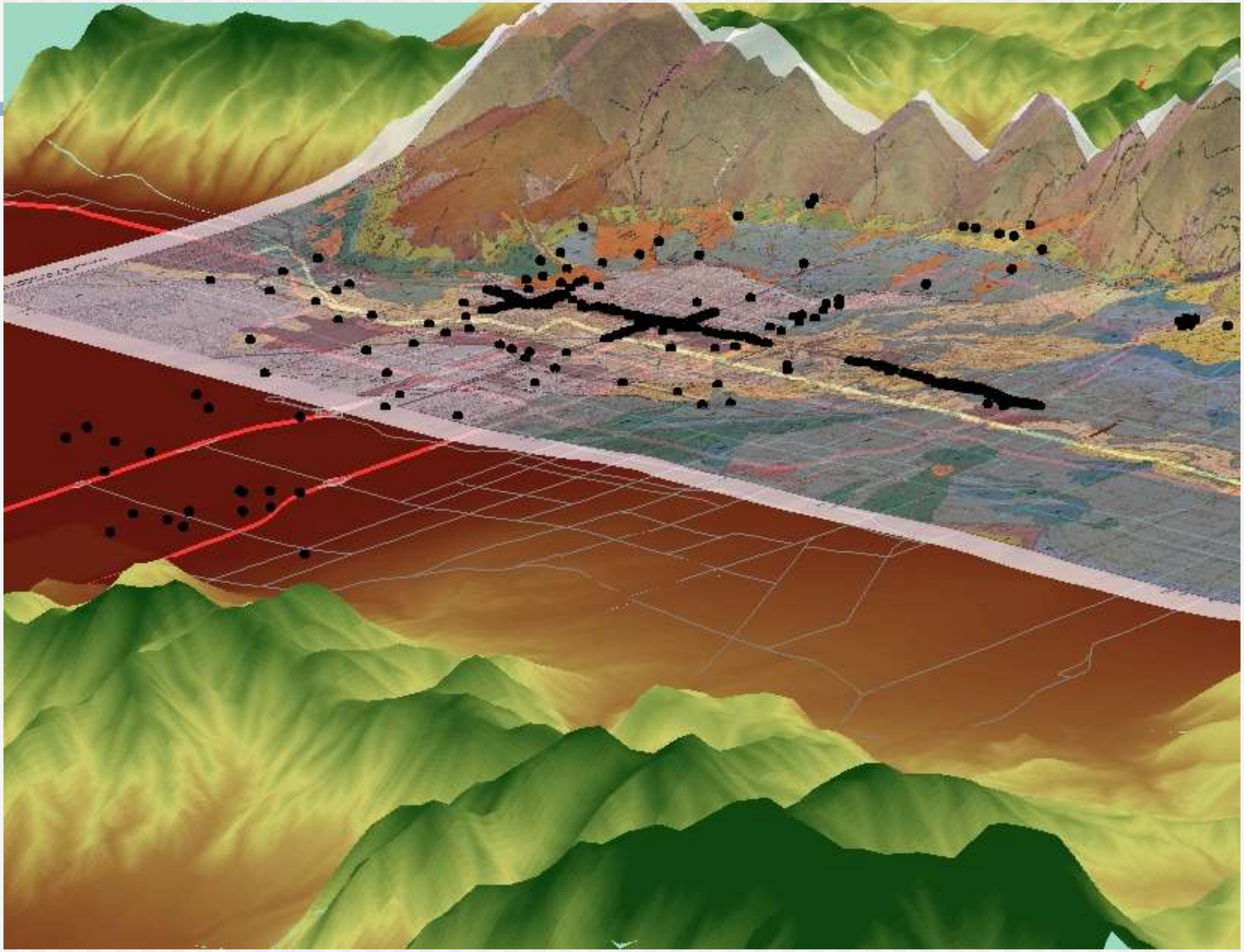
Geologic Map

Mapping Inputs



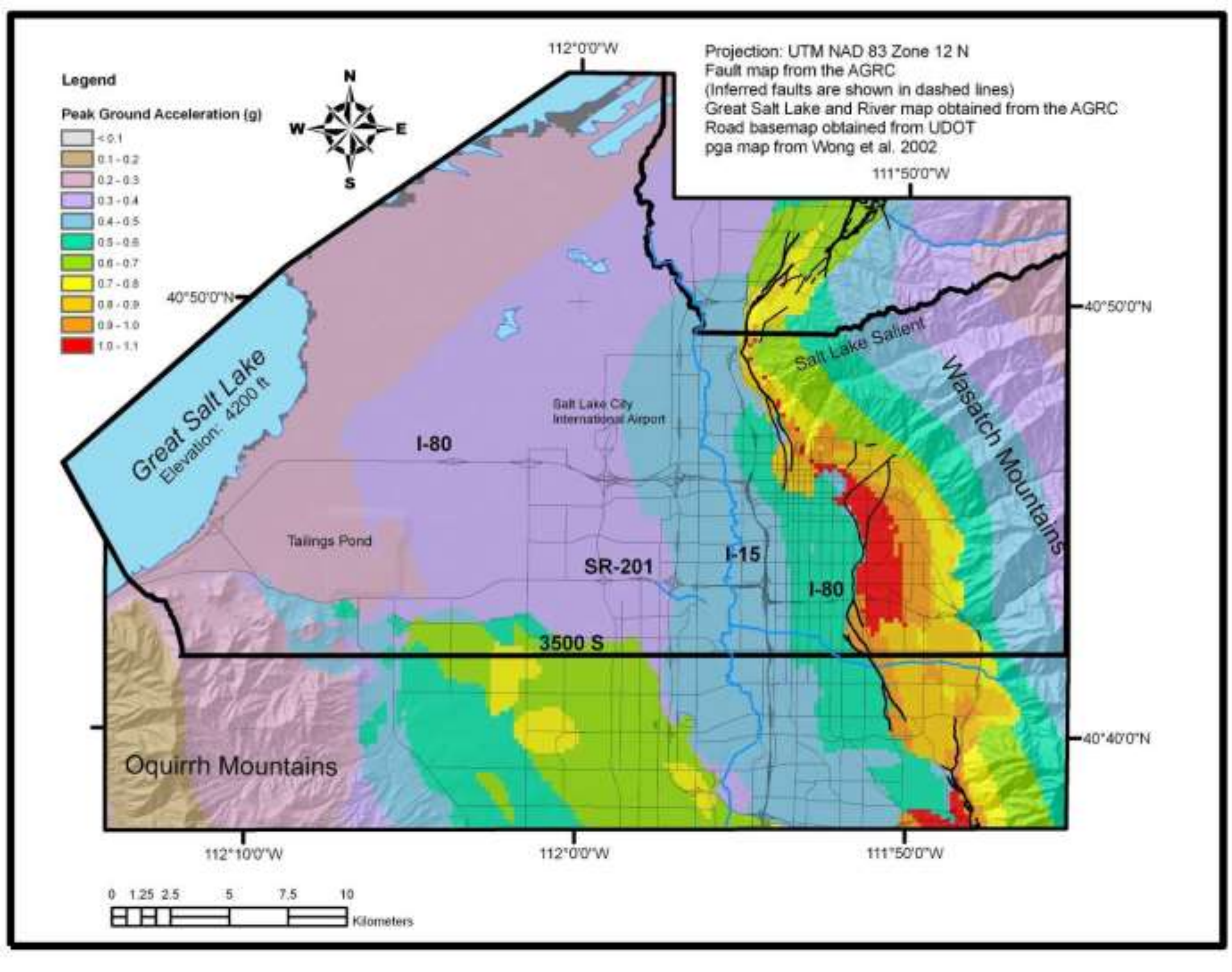
Groundwater Depth Map

Mapping Inputs



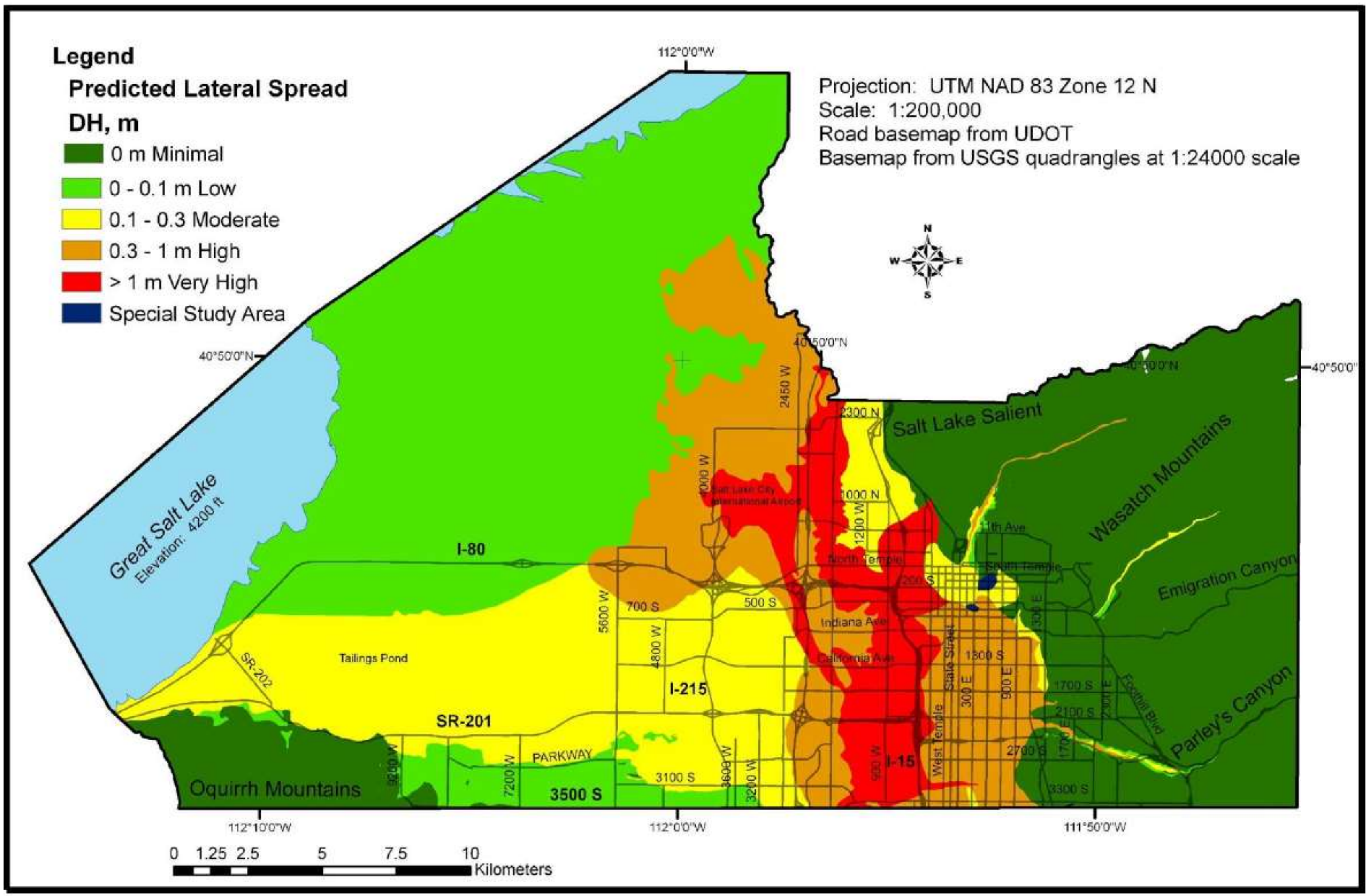
Digital Elevation Model

Mapping Inputs

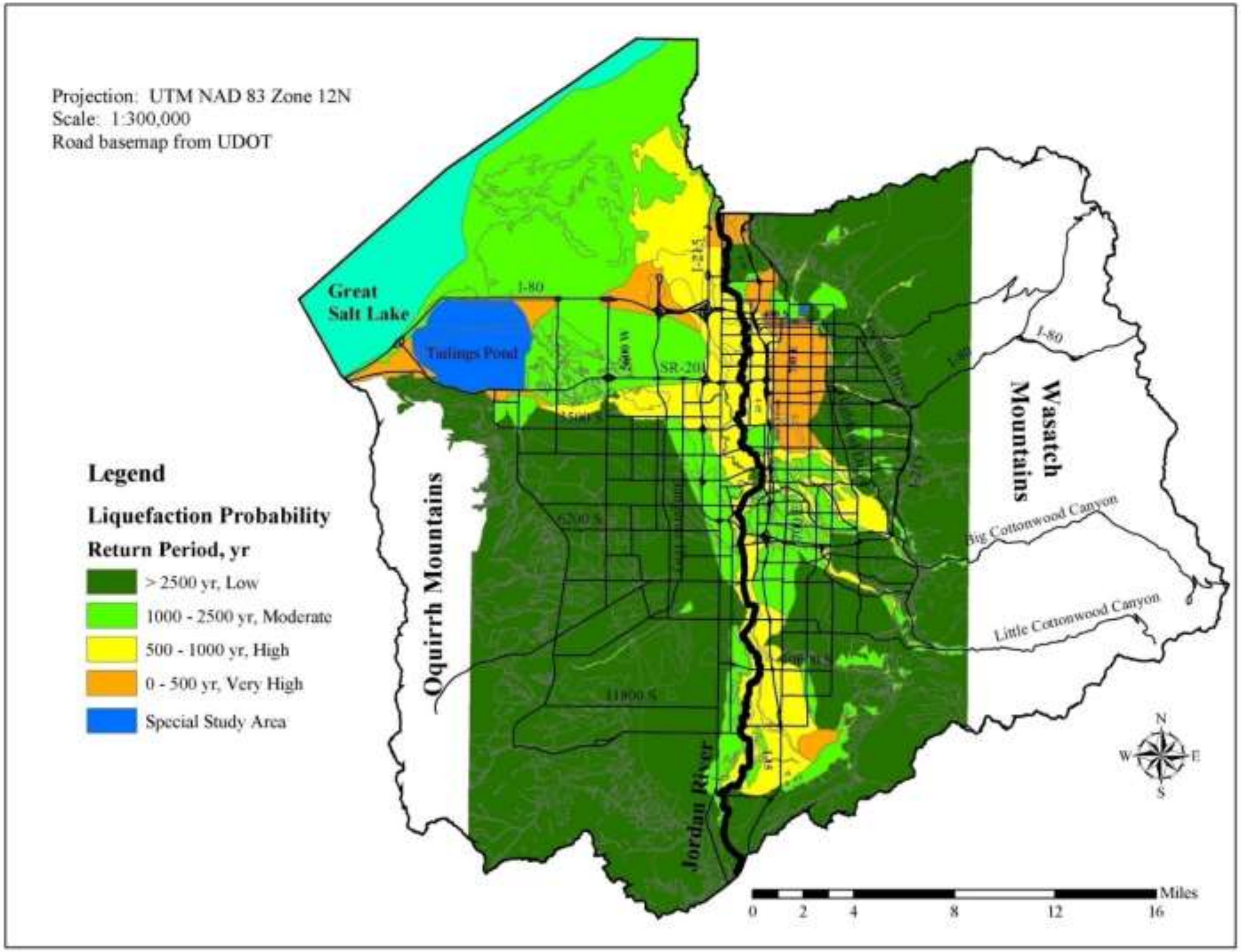


Estimates of peak ground acceleration (Wong et al., 2002)

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

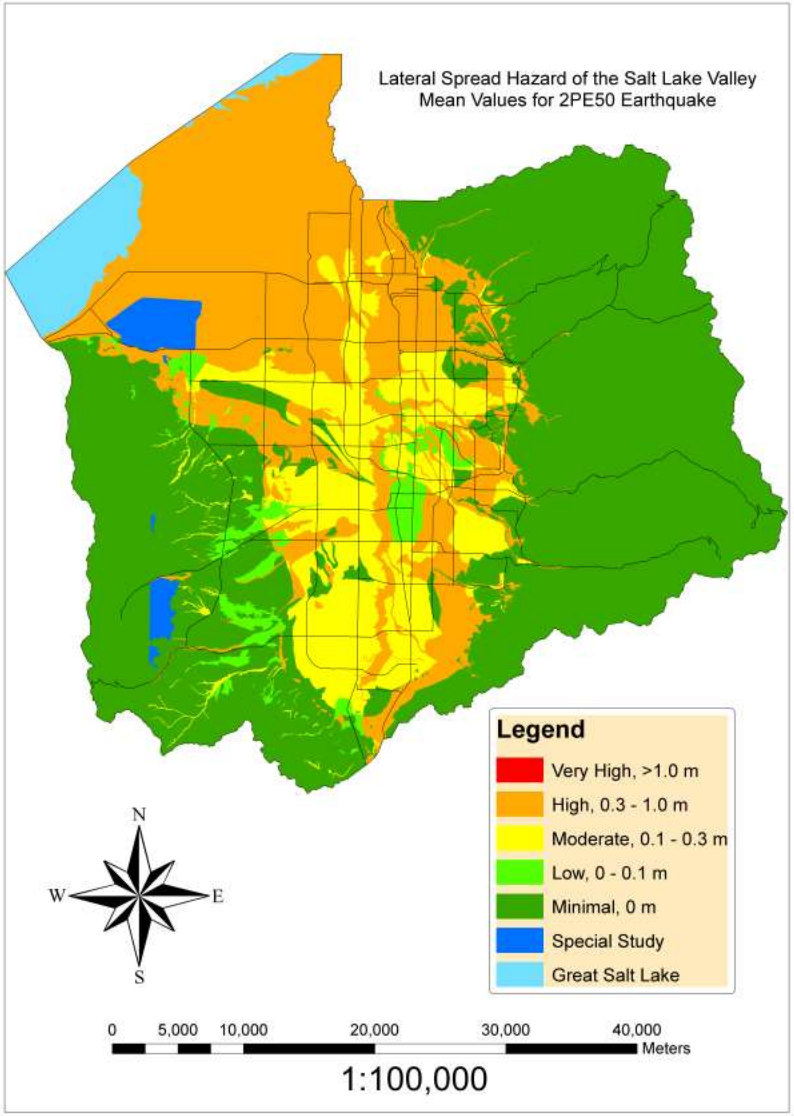
FY 2006 – 2007 (cont.)

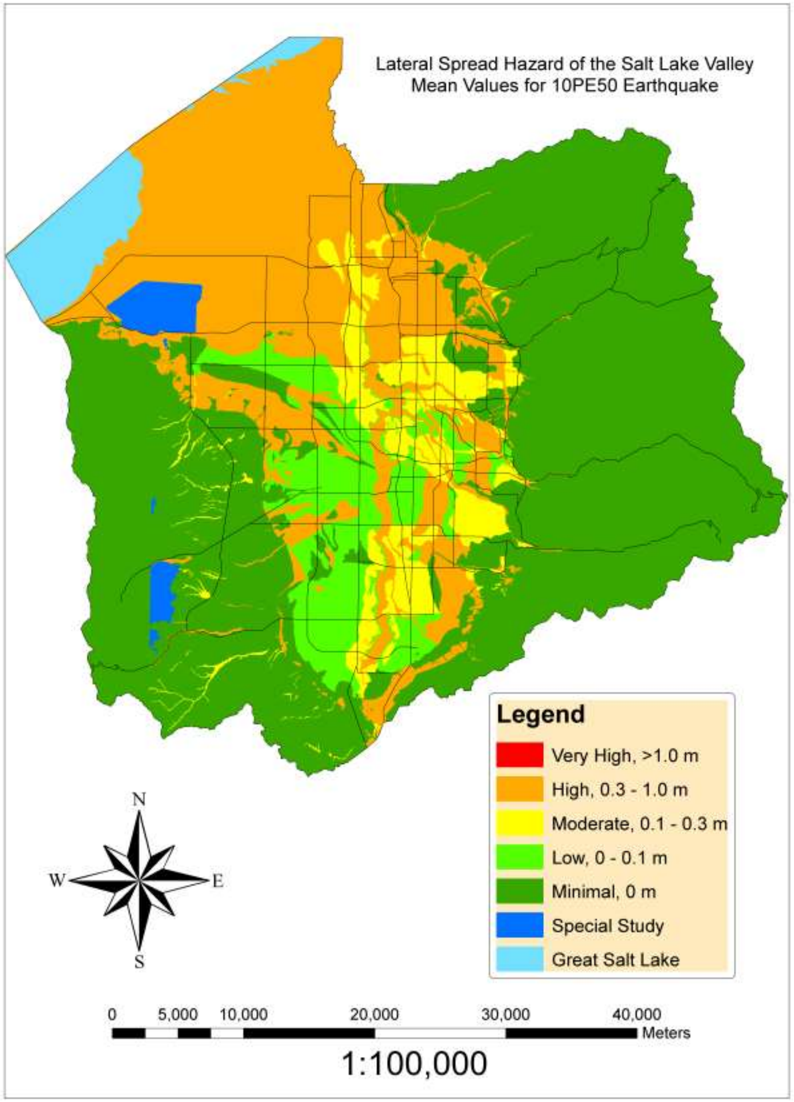
FY 2008 (No Funding)

FY 2009 (No Funding)

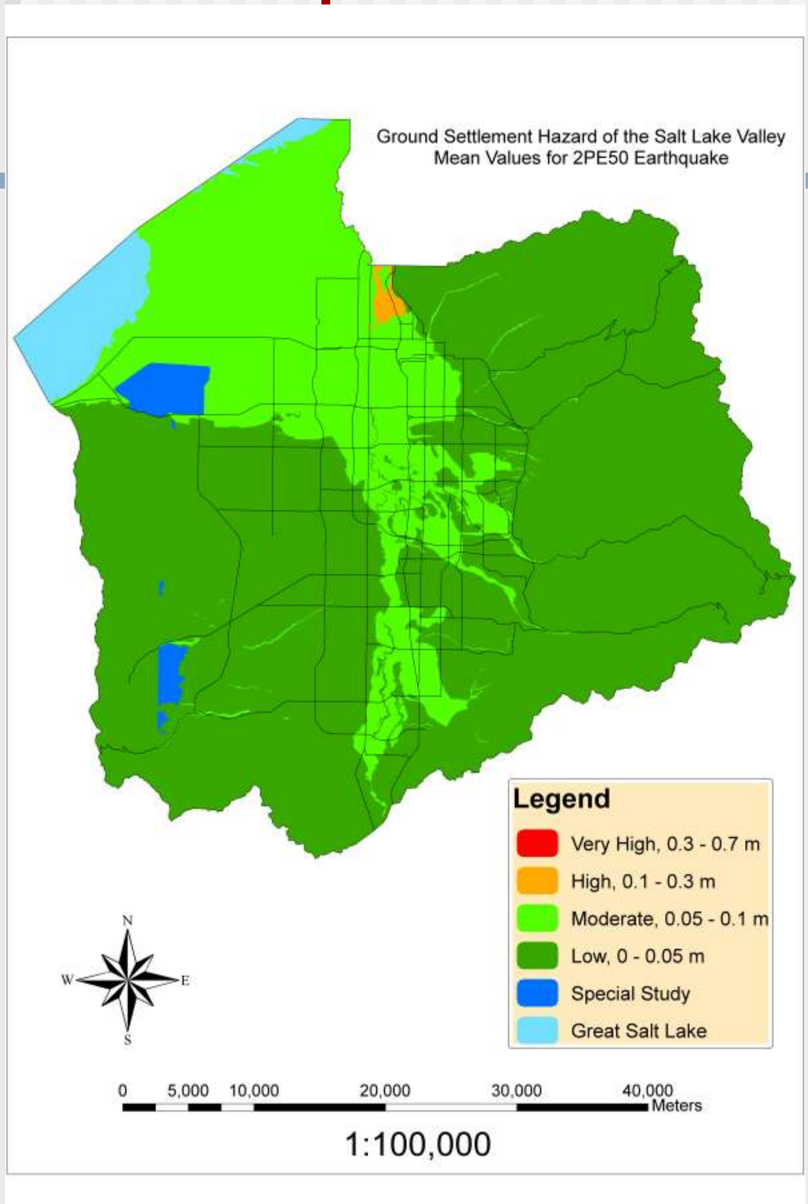
FY 2010 (No Funding)

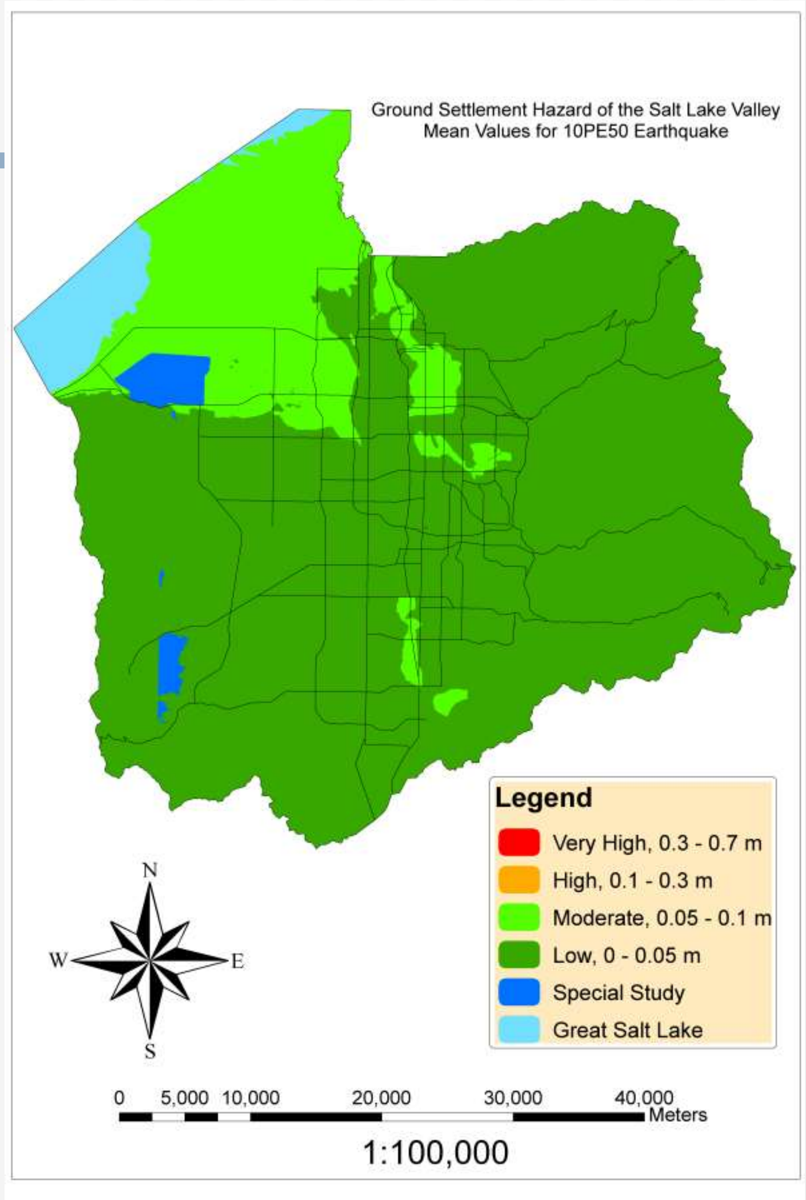
Probabilistic liquefaction potential maps for 2500 and 500-year return periods



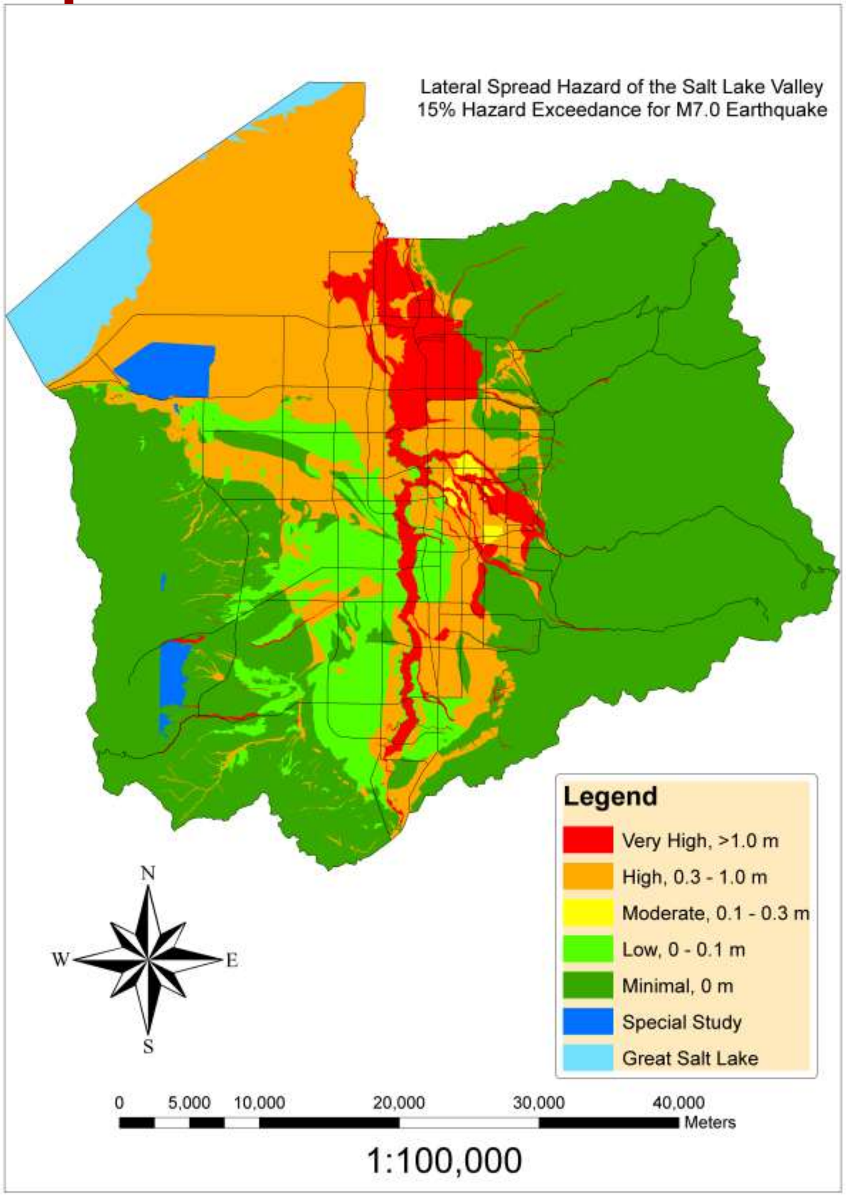


Probabilistic ground settlement maps for 2500 and 500-year return periods

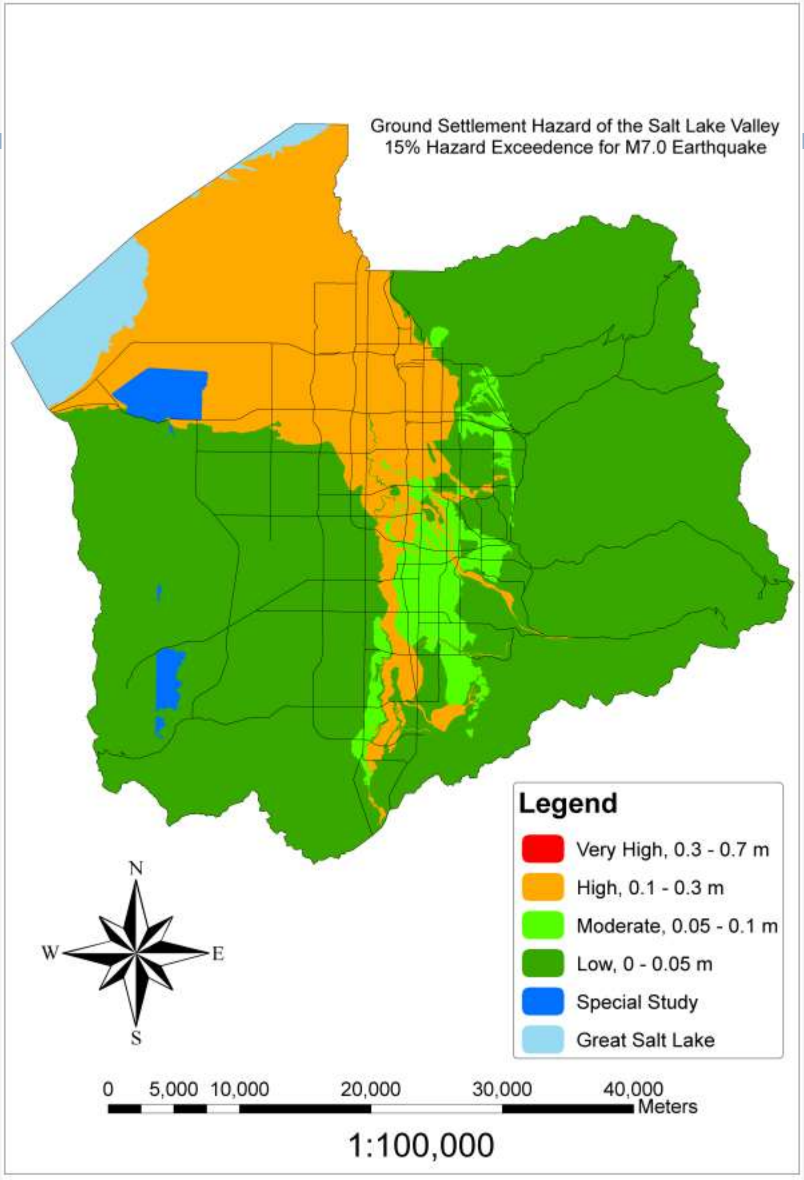




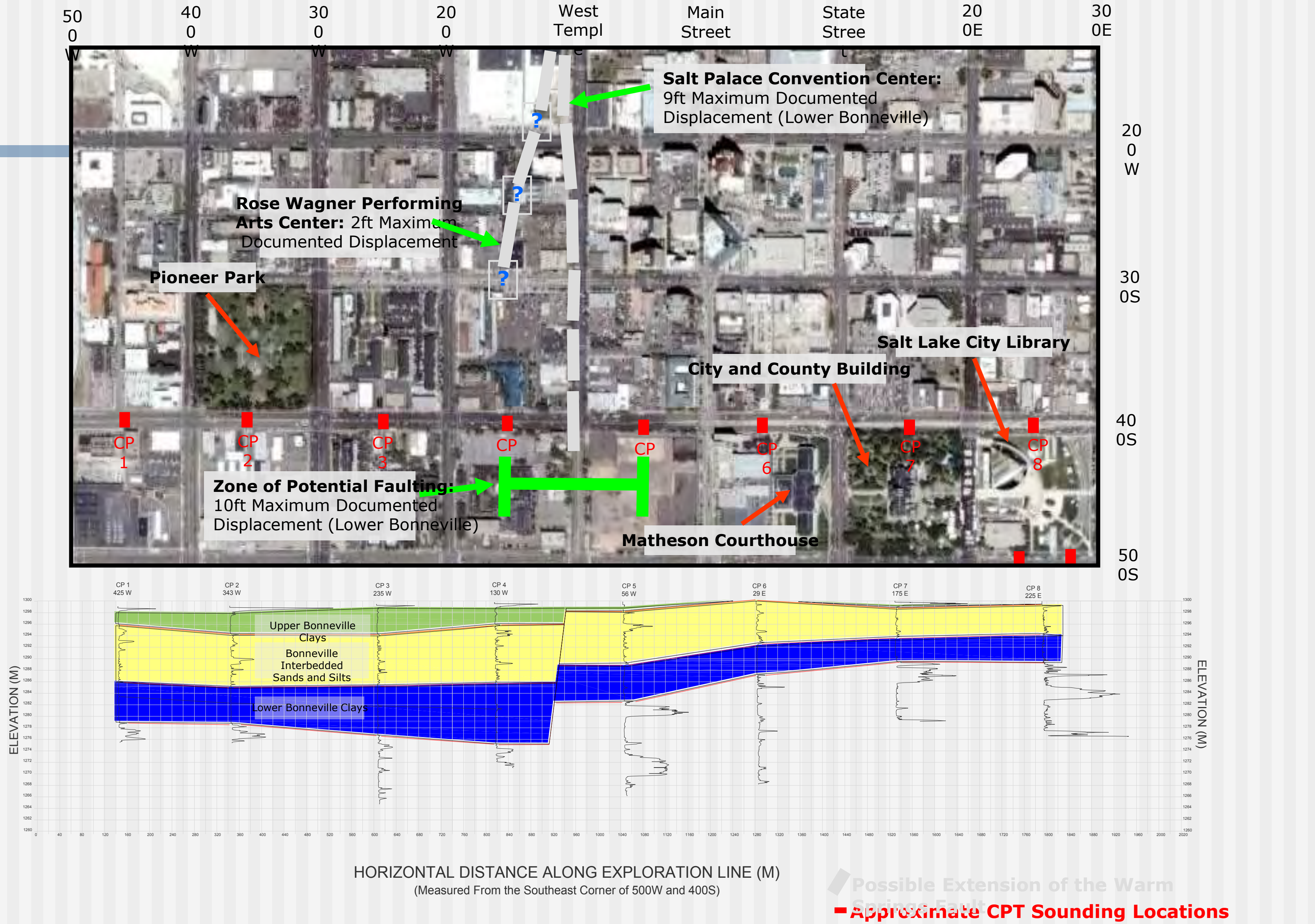
M 7.0 Lateral spread displacement map 15 percent chance of exceedance



M 7.0 ground settlement map
15 percent chance of exceedance



Downtown Displacement Investigations



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

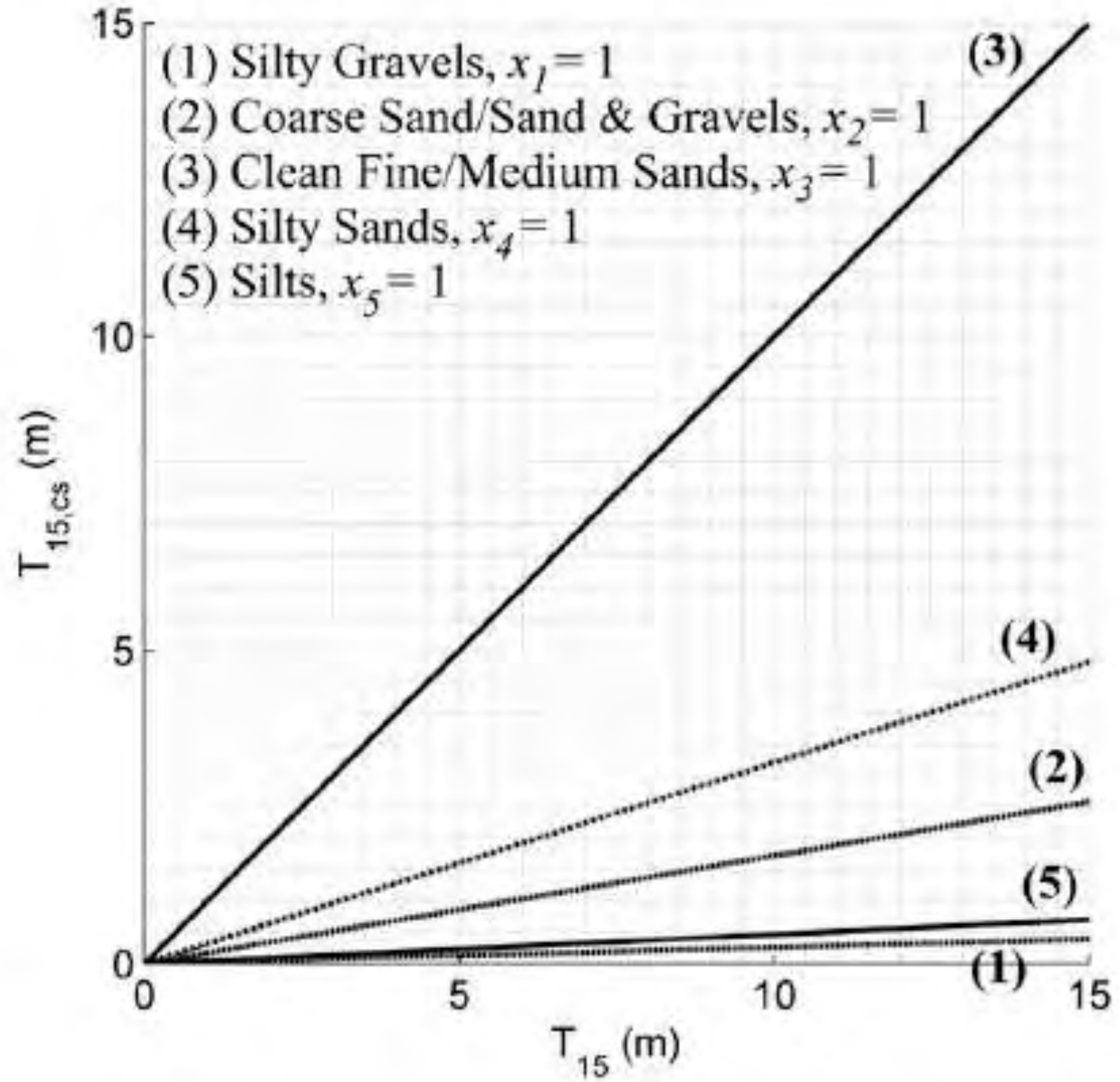


Fig. 3. T_{15} versus $T_{15,cs}$ according to soil index

Weber County Liquefaction Hazard Mapping

$$LogD_H = \begin{array}{c} b_o + b_{off}\alpha + b_1 M + b_2 LogR^* + b_3 R + b_4 LogW + b_5 LogS + \\ + b_6 LogT_1 \ + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 \end{array}$$

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

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

Weber County Liquefaction Hazard Mapping

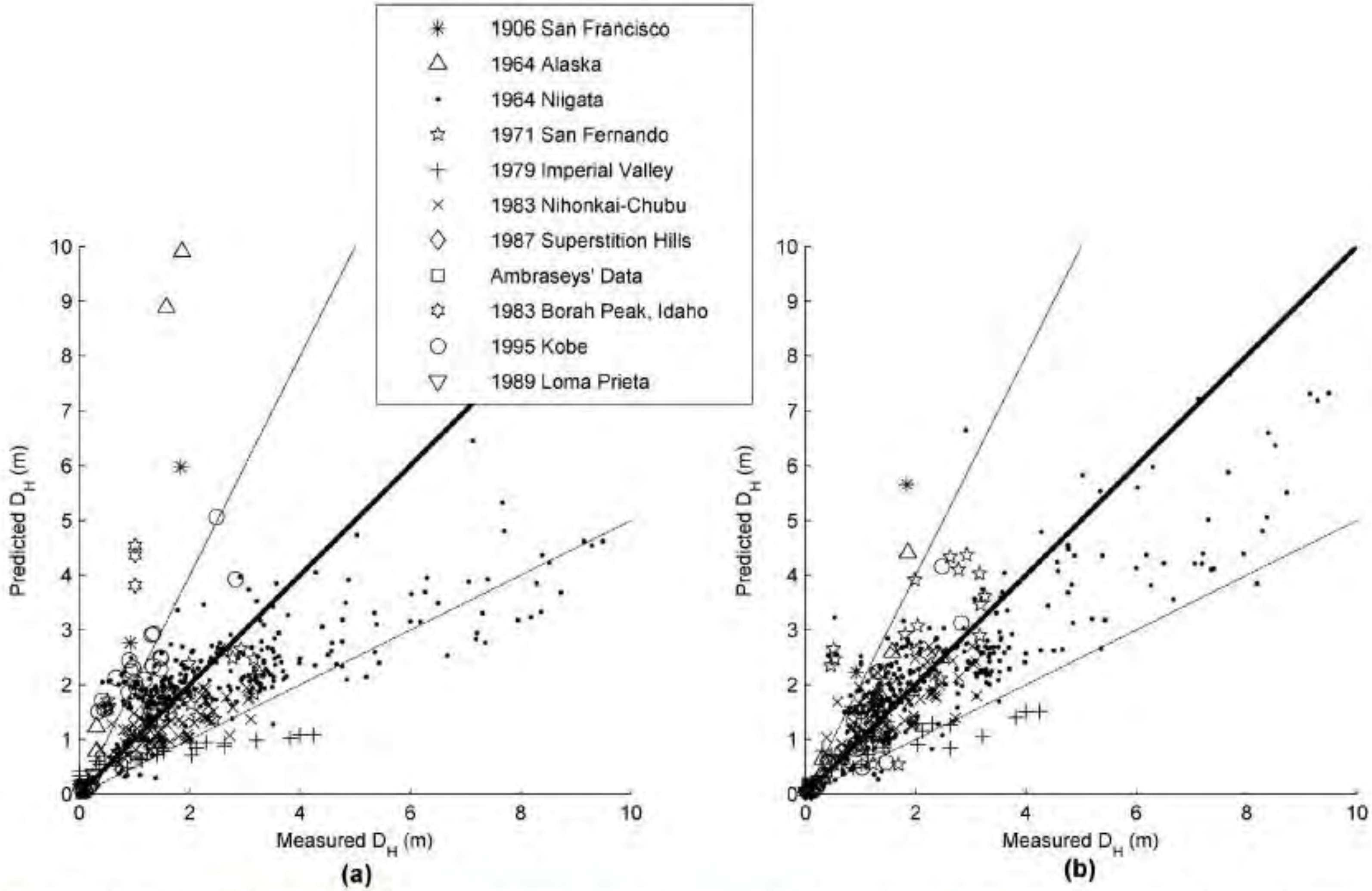


Figure 3.1. Predicted lateral spread displacement using (a) eqn. (3.3), or (b) eqn. (3.4), versus measured lateral spread displacement from the case history database of Youd et al., 2002

Weber County Liquefaction Hazard Mapping

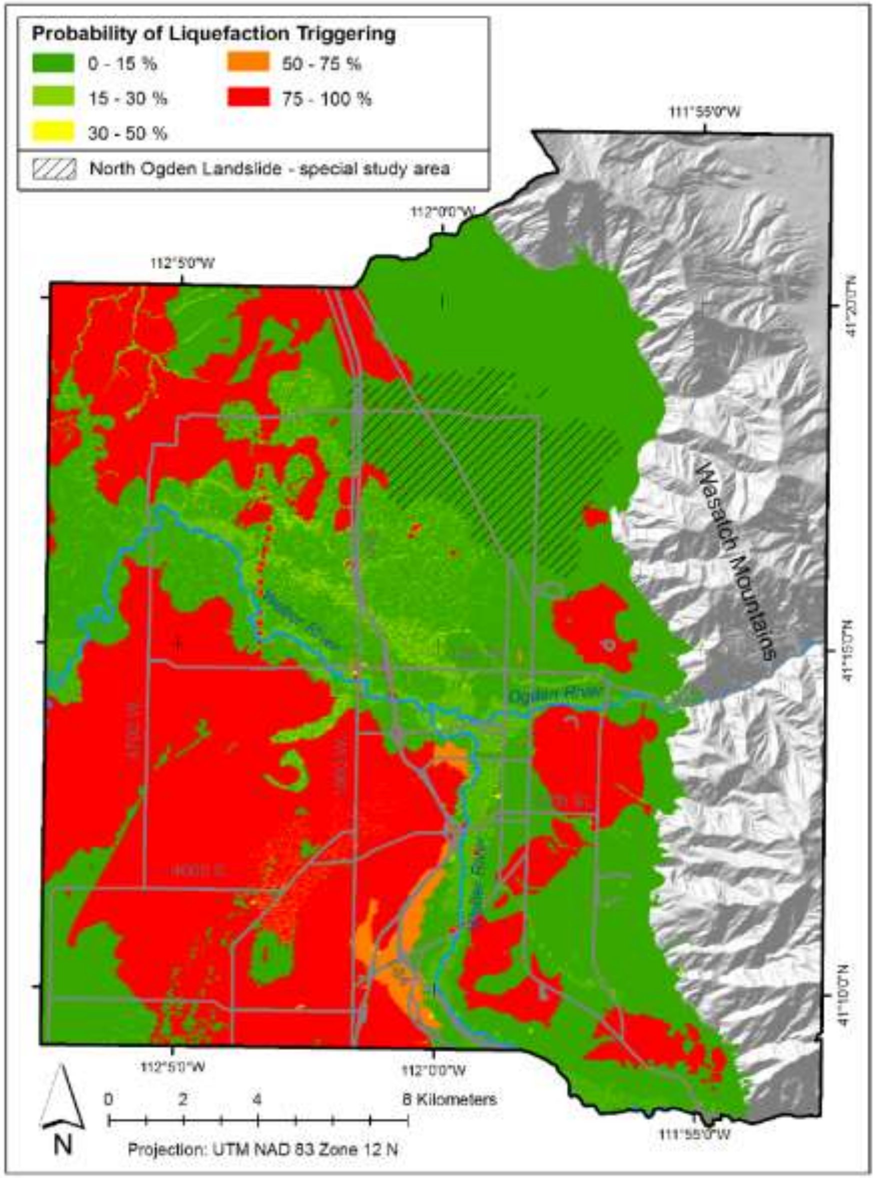


Figure 5.4. 50th percentile probabilities of liquefaction triggering given a 500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

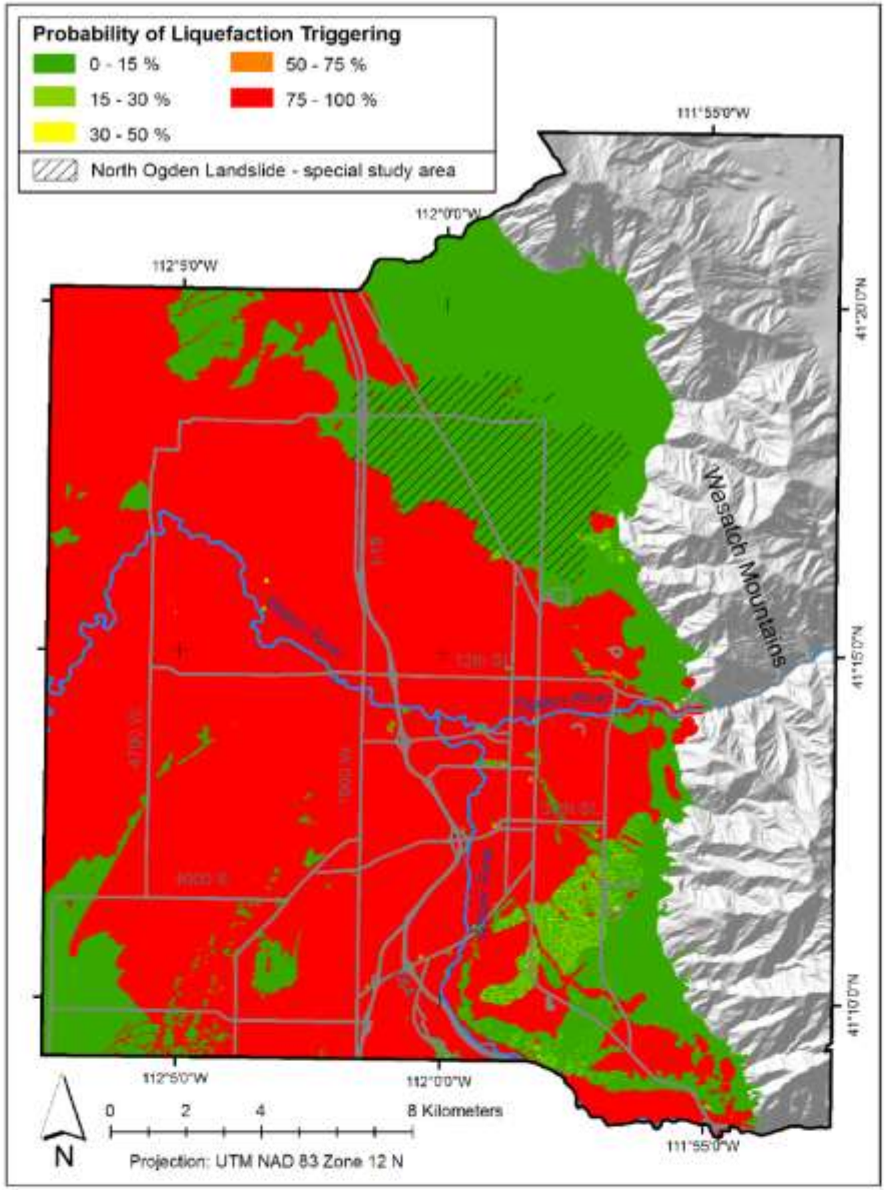


Figure 5.5. 50th percentile probabilities of liquefaction triggering given a 2,500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

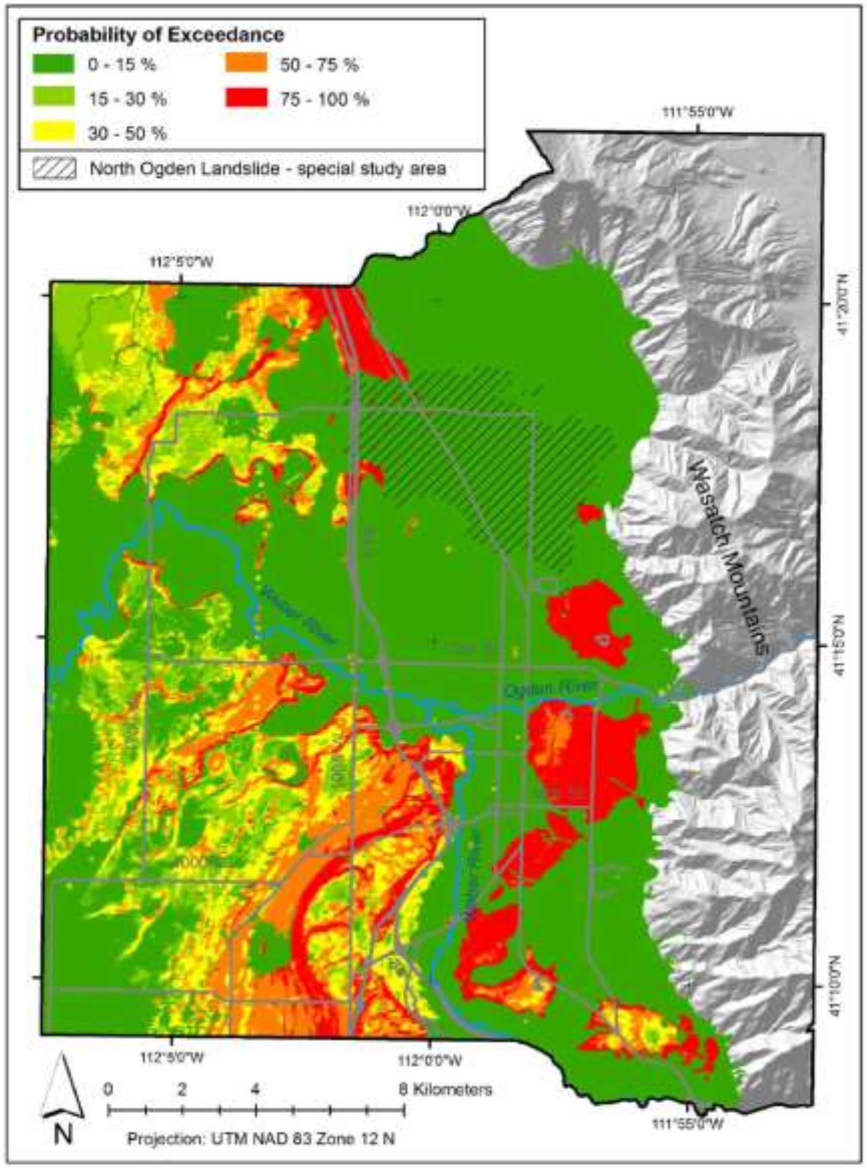


Figure 5.6. 50th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

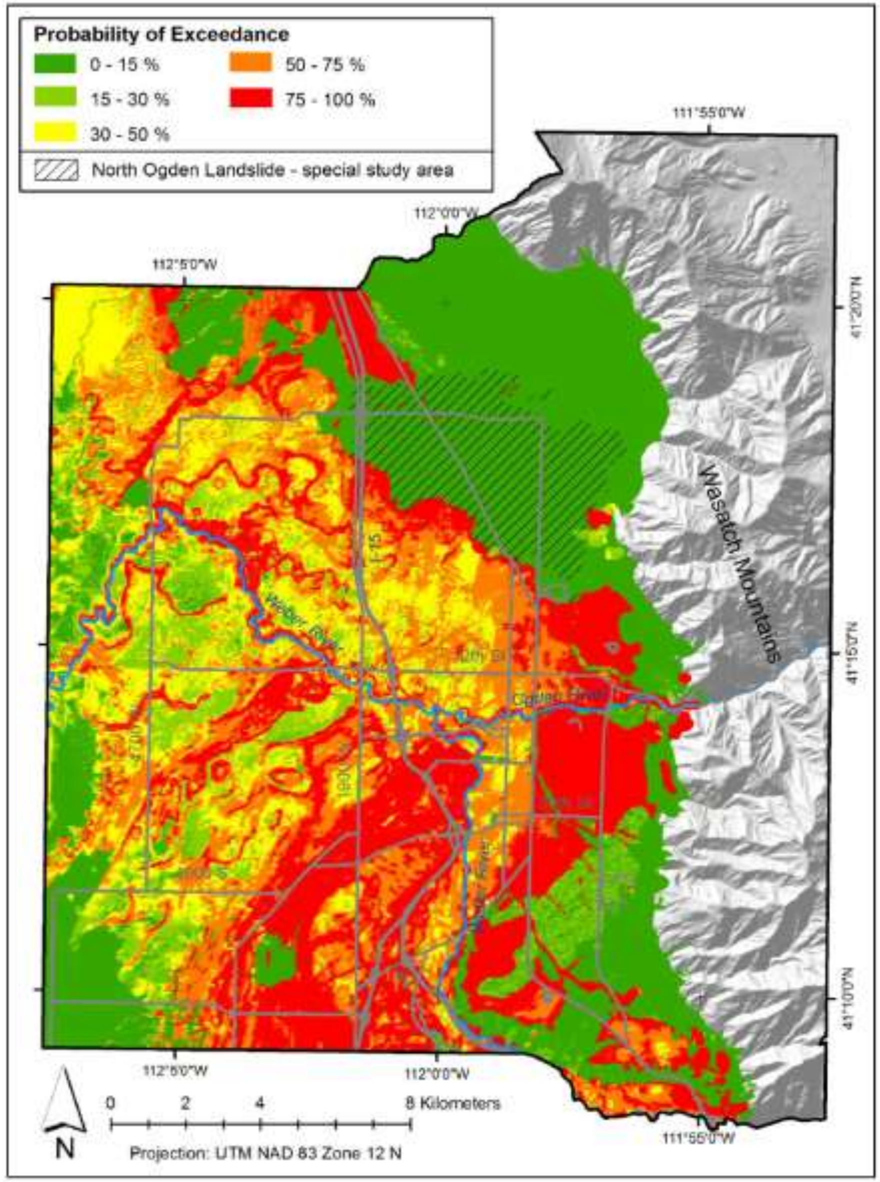


Figure 5.7. 84th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

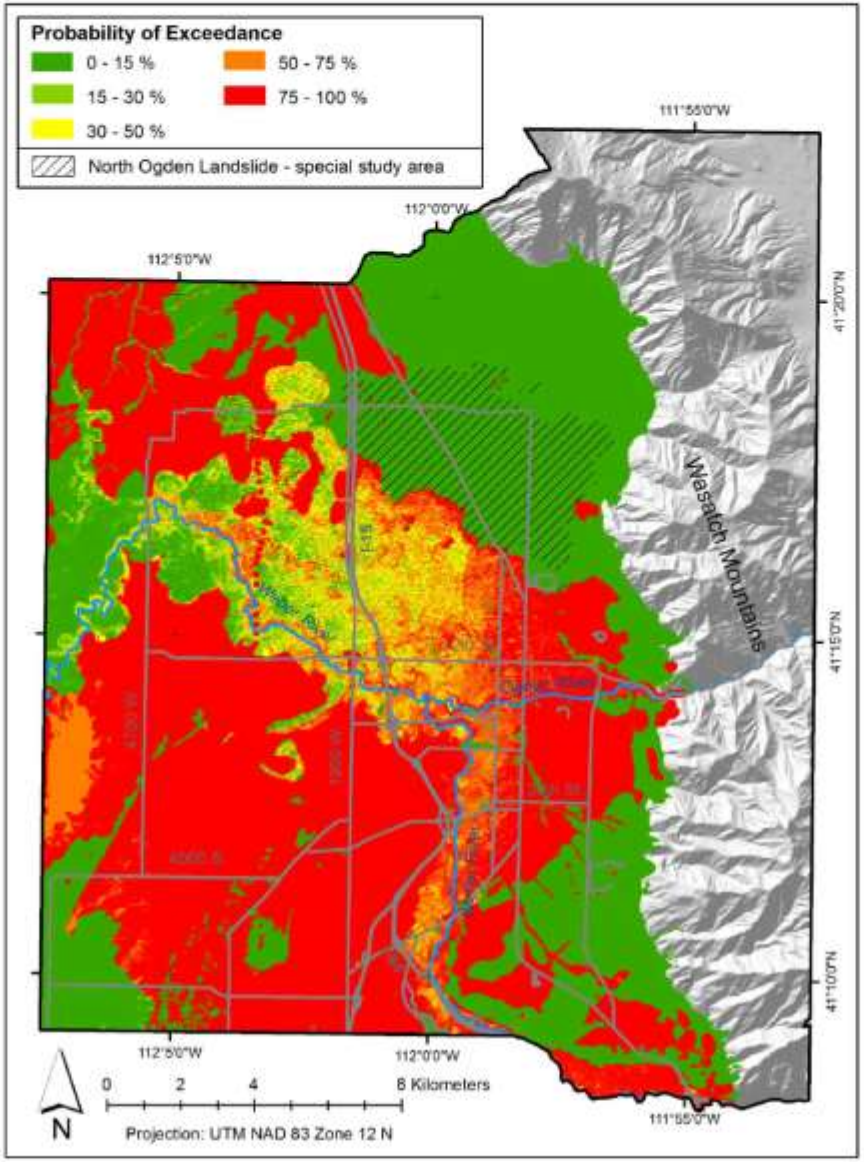


Figure 5.10. 50th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 2,500-year seismic event; Weber County, Utah

Weber County Liquefaction Hazard Mapping

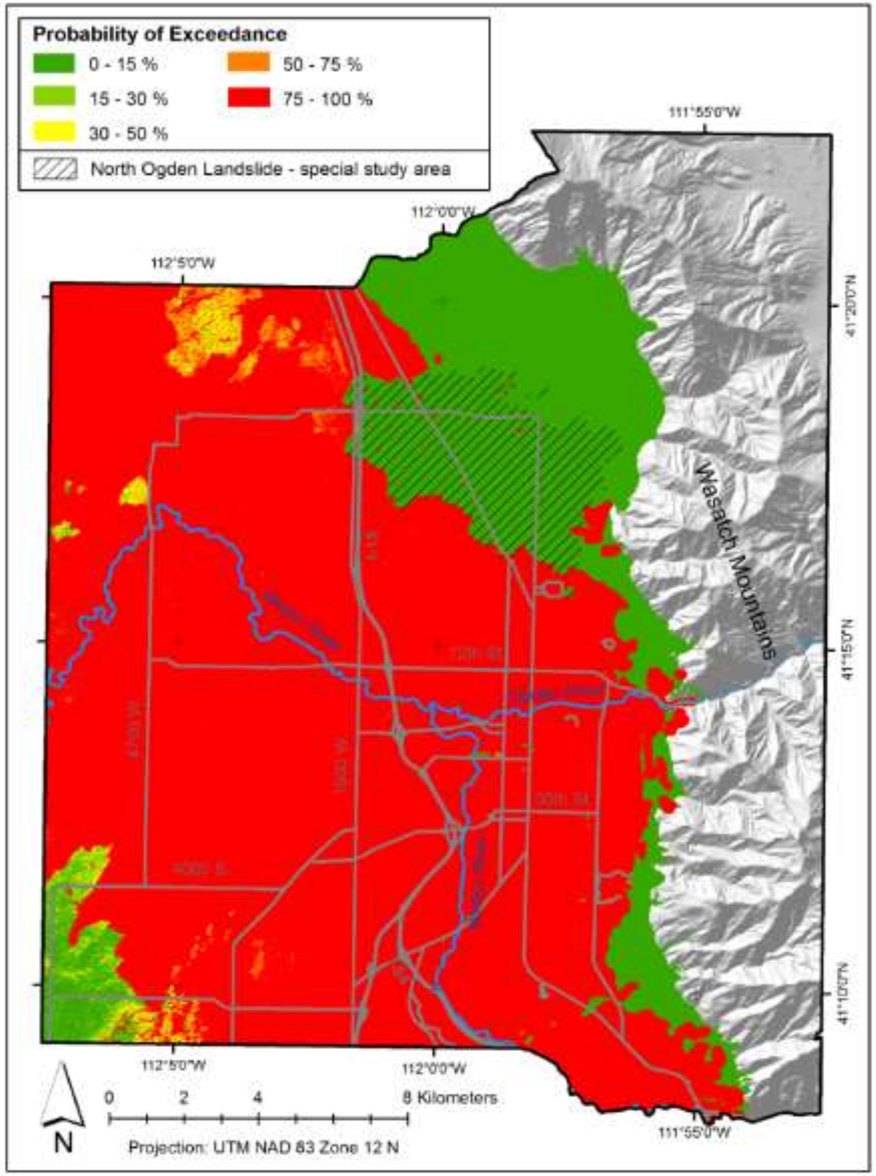


Figure 5.11. 84th percentile probabilities of lateral spread displacement exceeding 0.1 meters given a 2,500-year seismic event; Weber County, Utah

Previous Work

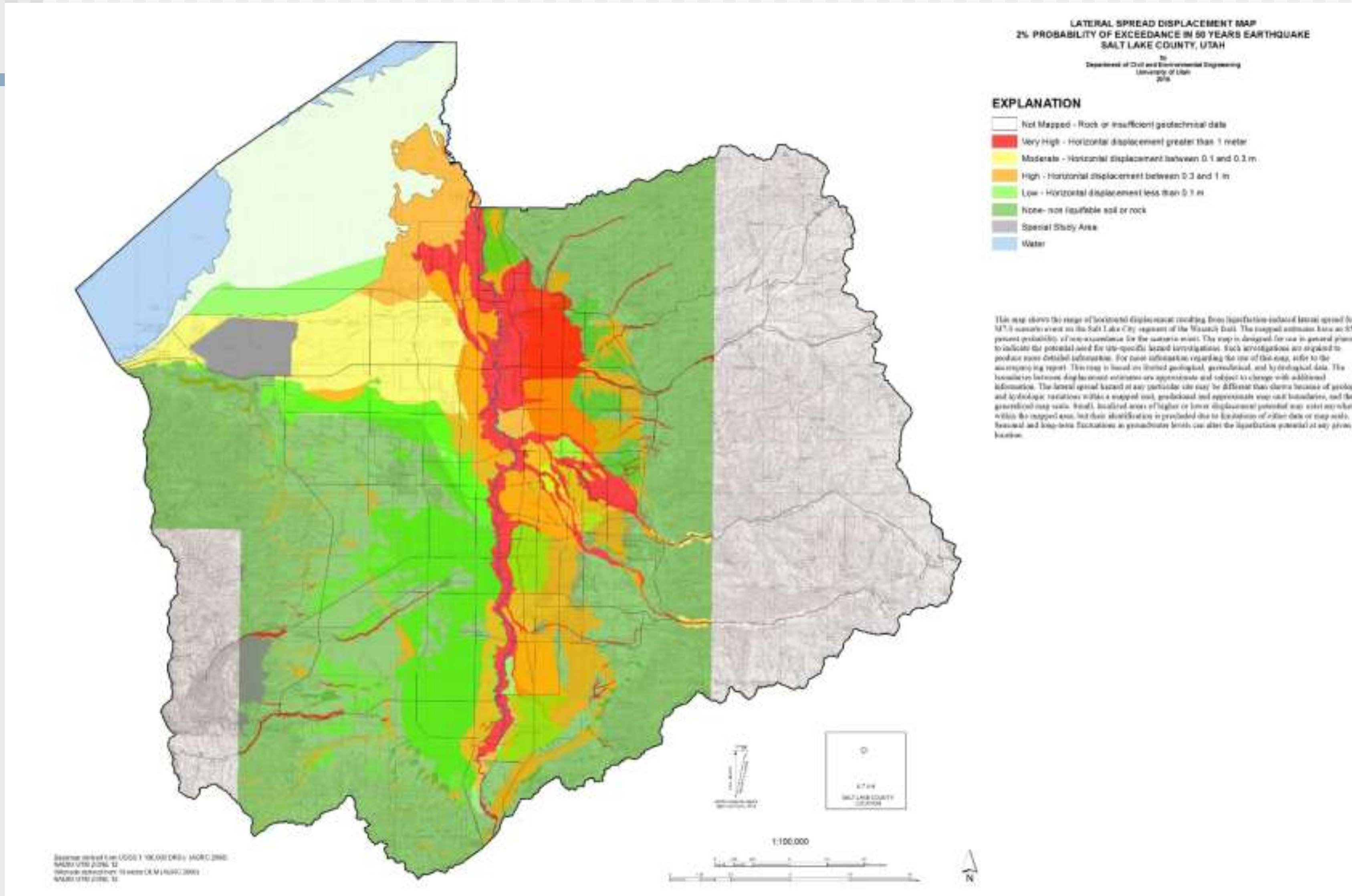
FY 2013 (FEMA – Funding for Salt Lake Co.)

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

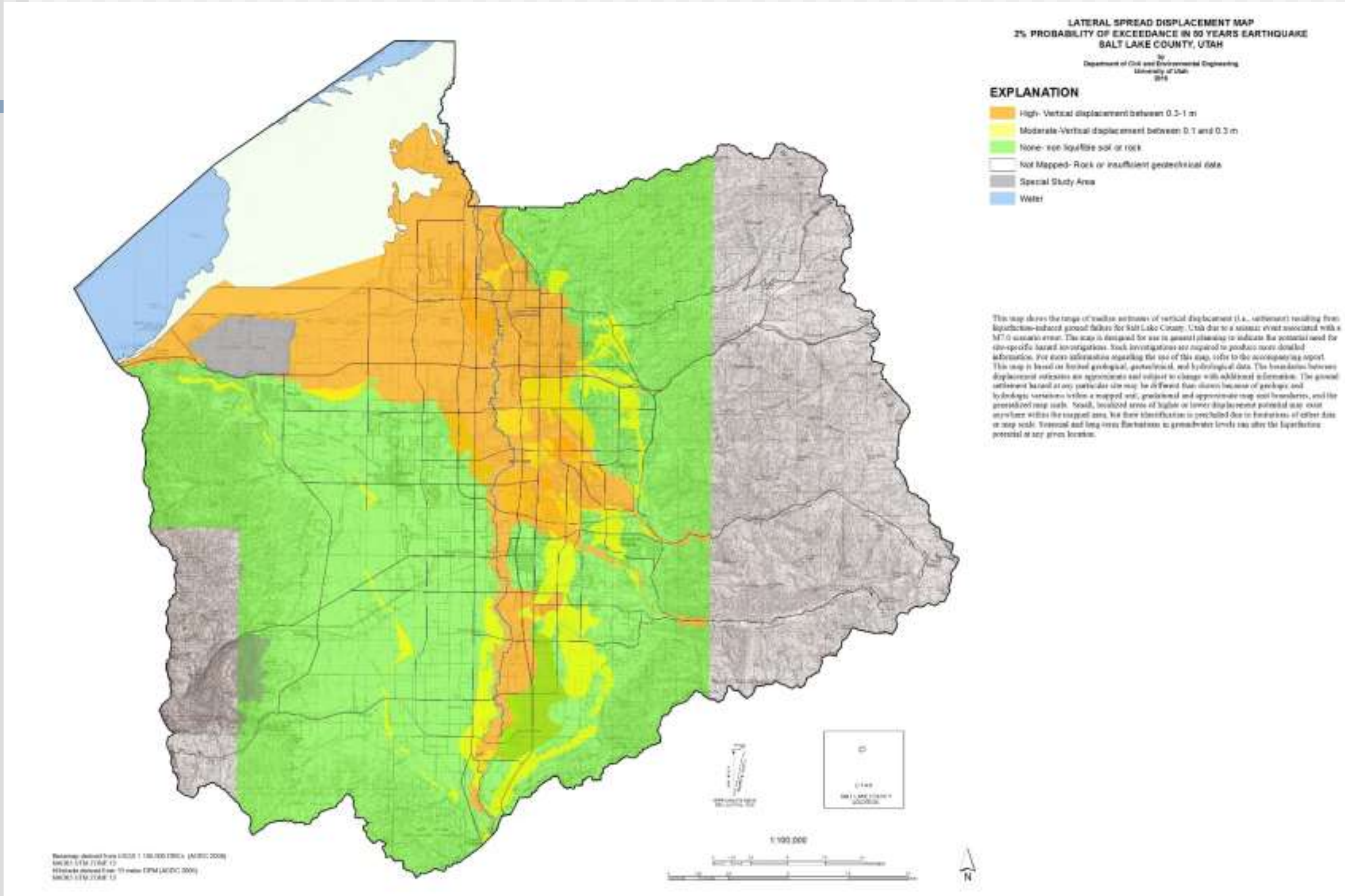
2013 FEMA Project
U of U and UGS)

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.

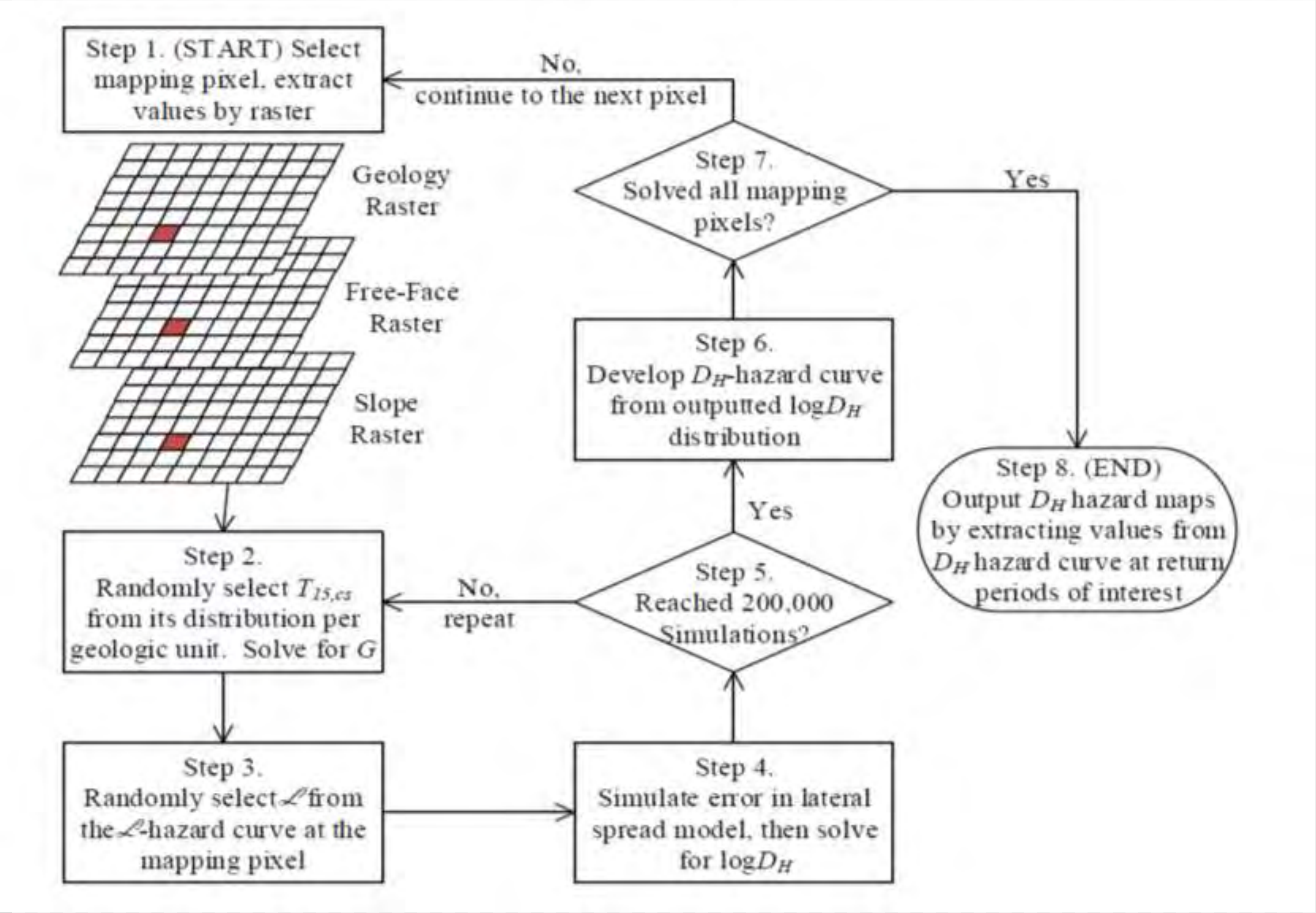
Lateral Spread Displacement Map Salt Lake Co. (85th Percentile Maps)



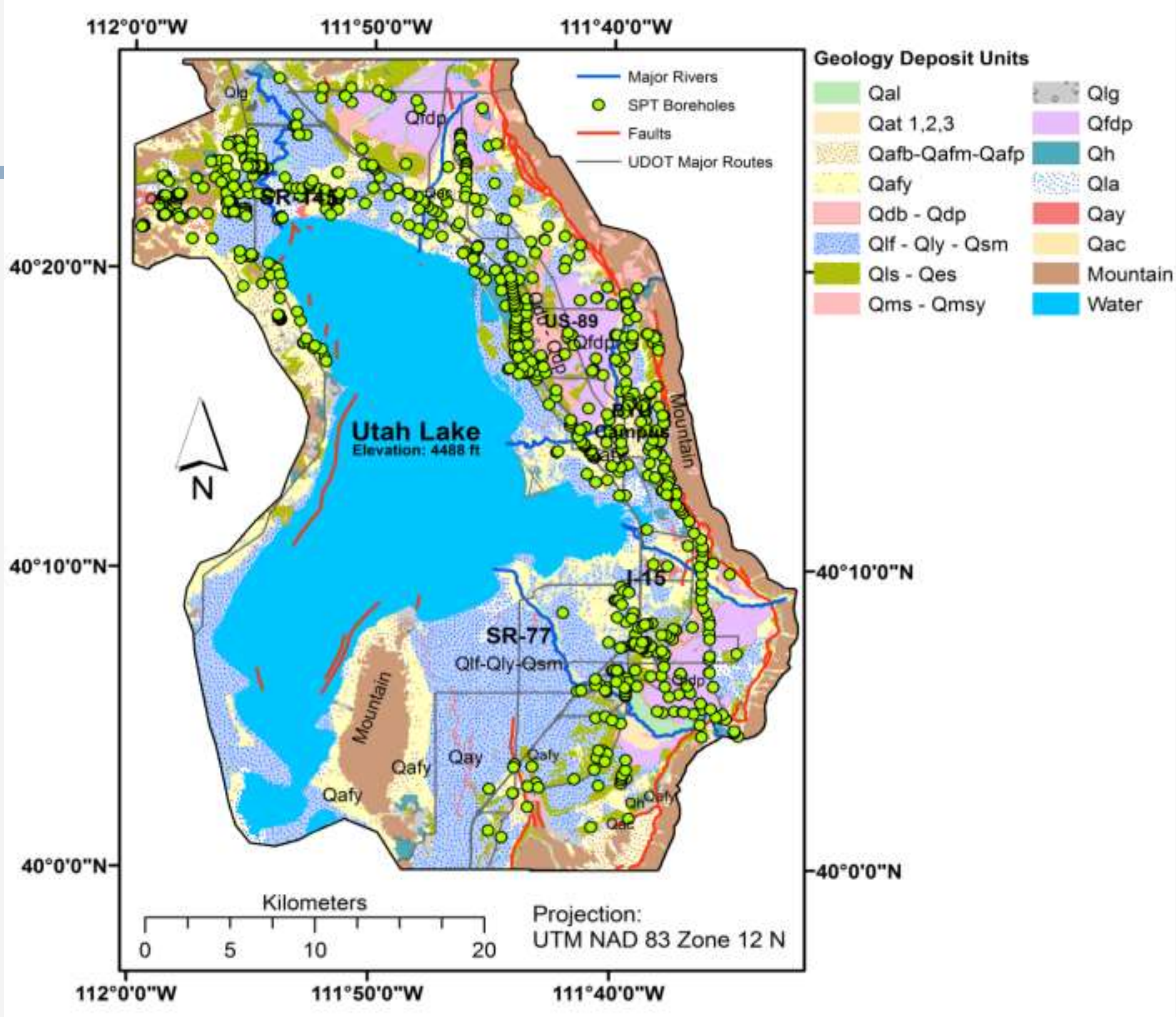
Ground Settlement Map
Salt Lake Co. (85th Percentile Maps)



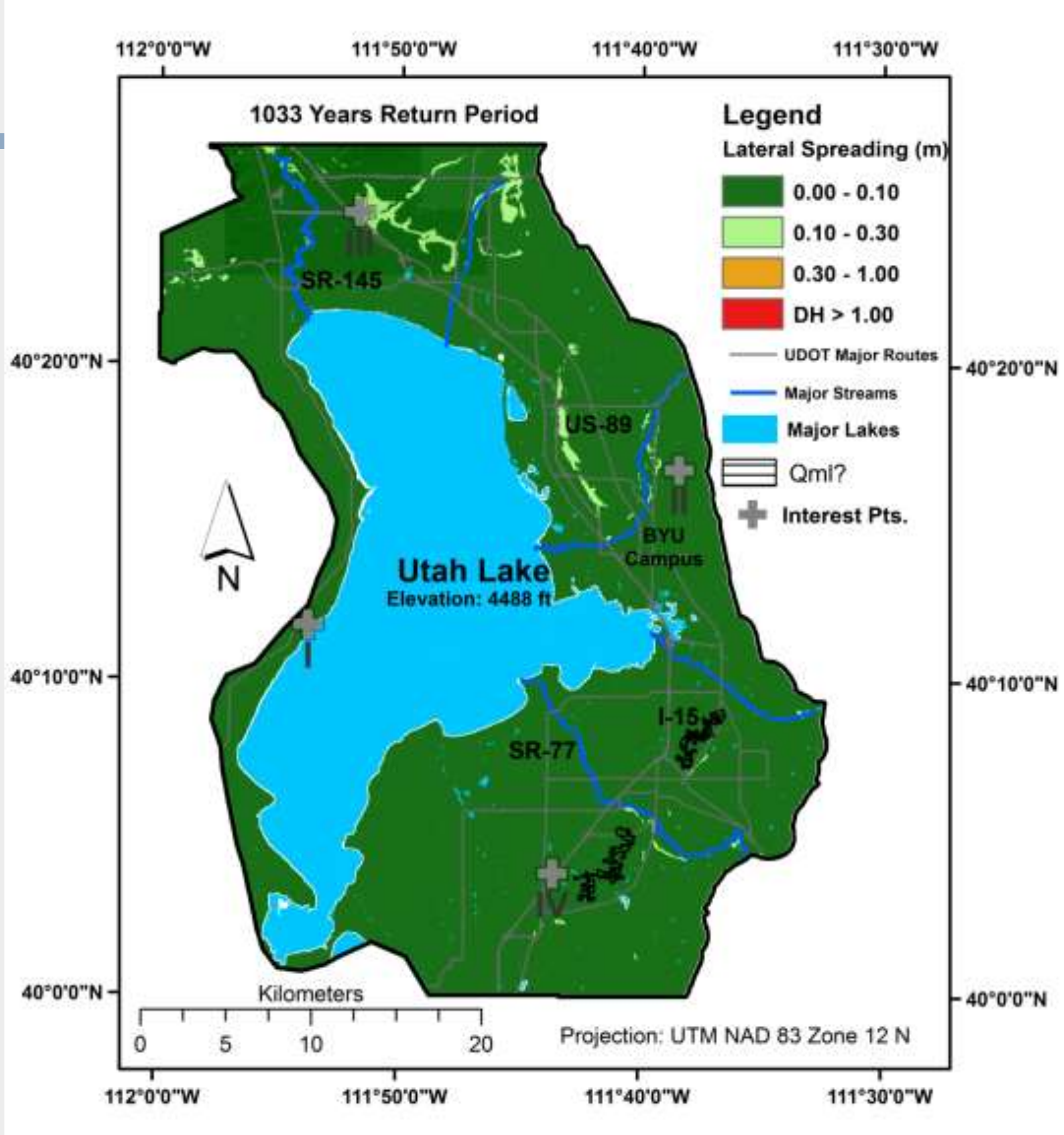
Utah Co Mapping Procedure



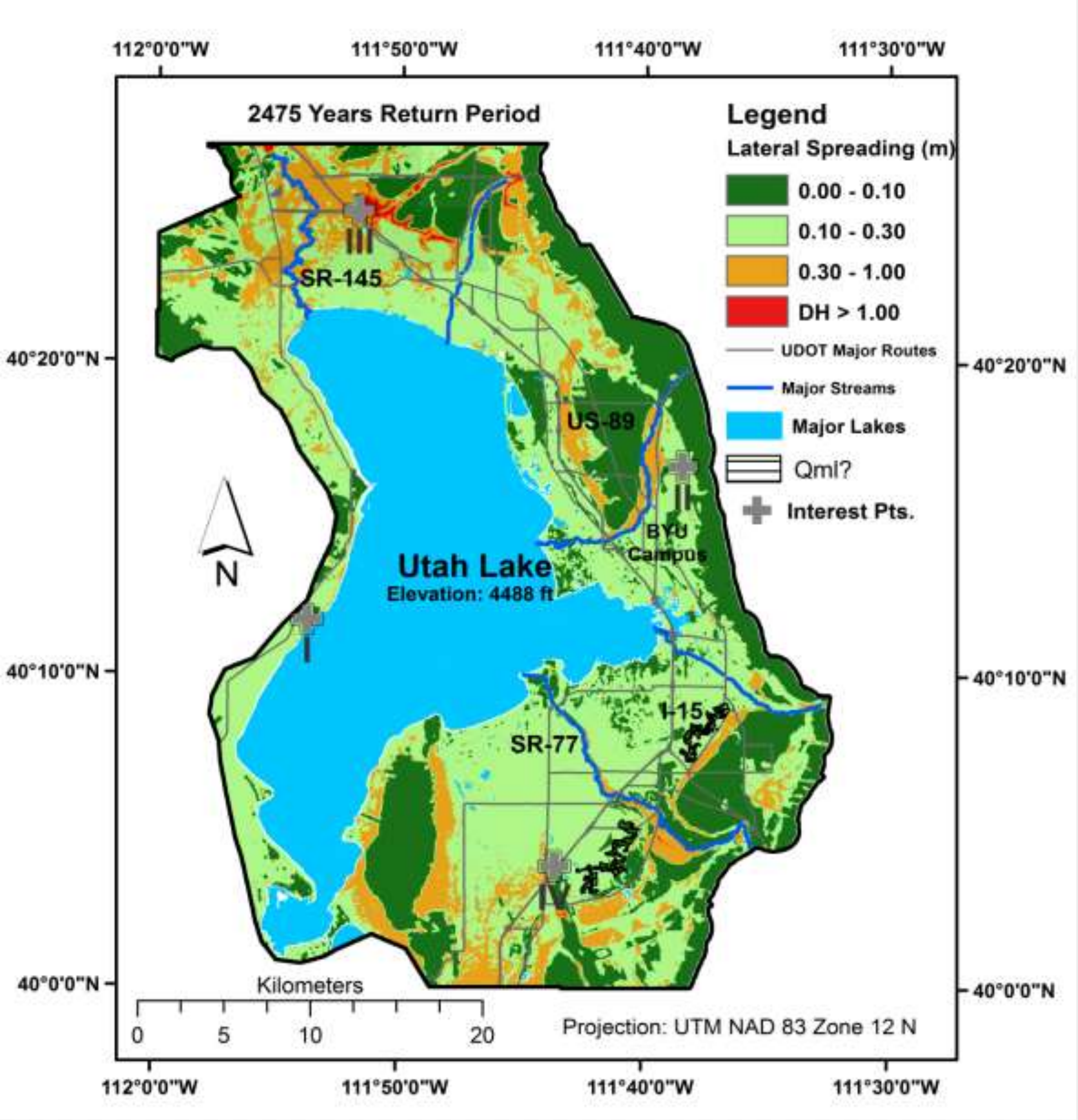
Utah Co Mapping Procedure



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.**

Liquefaction Evaluation in Gravelly Soils using Dynamic Cone Penetration Test (DPT) and Shear Wave Velocity

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Michael Talbot

US Bureau of Reclamation, Provo, Utah, USA

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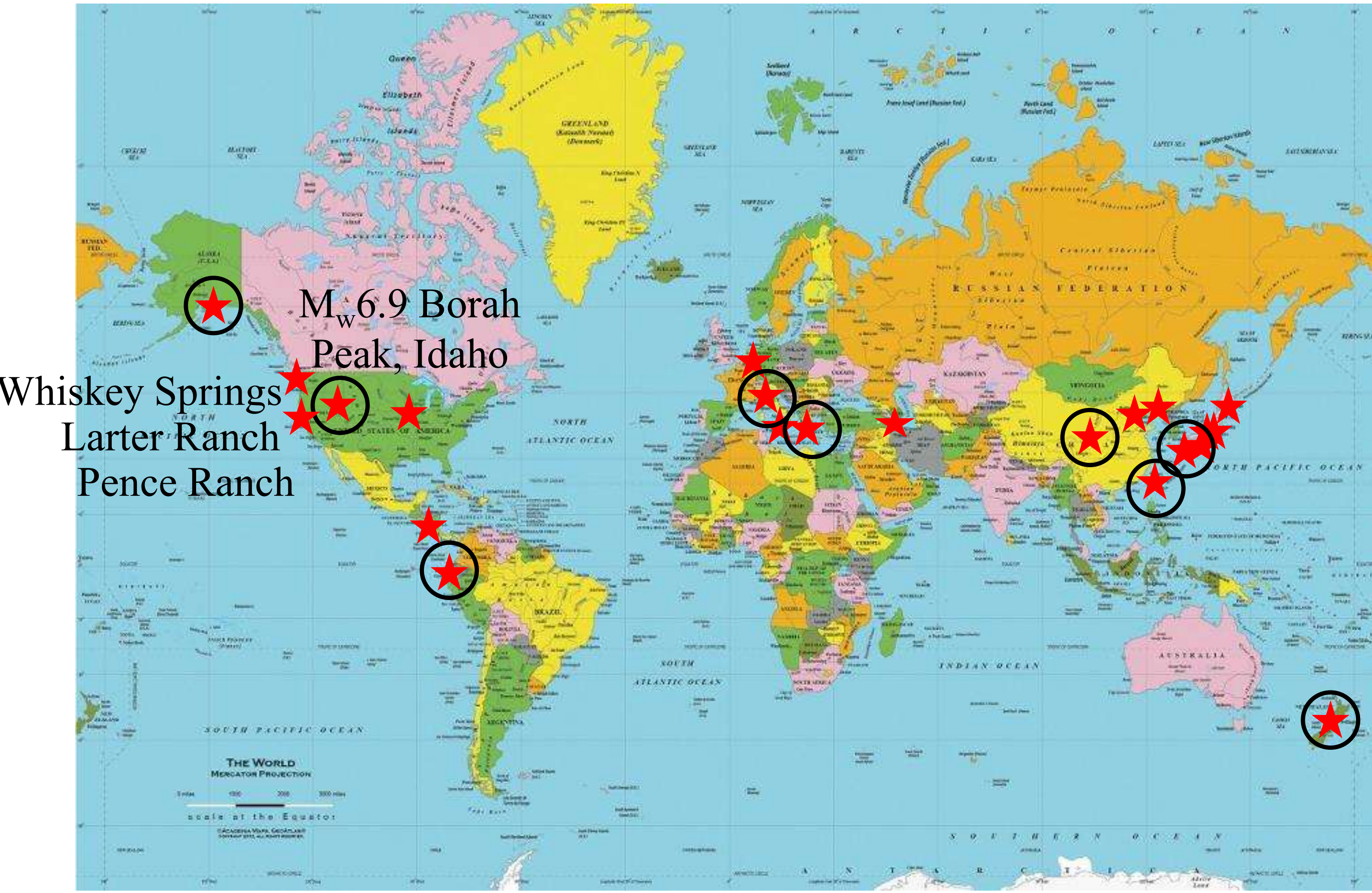
Research Sponsors

- US Geological Survey
- US Bureau of Reclamation
- National Science Foundation

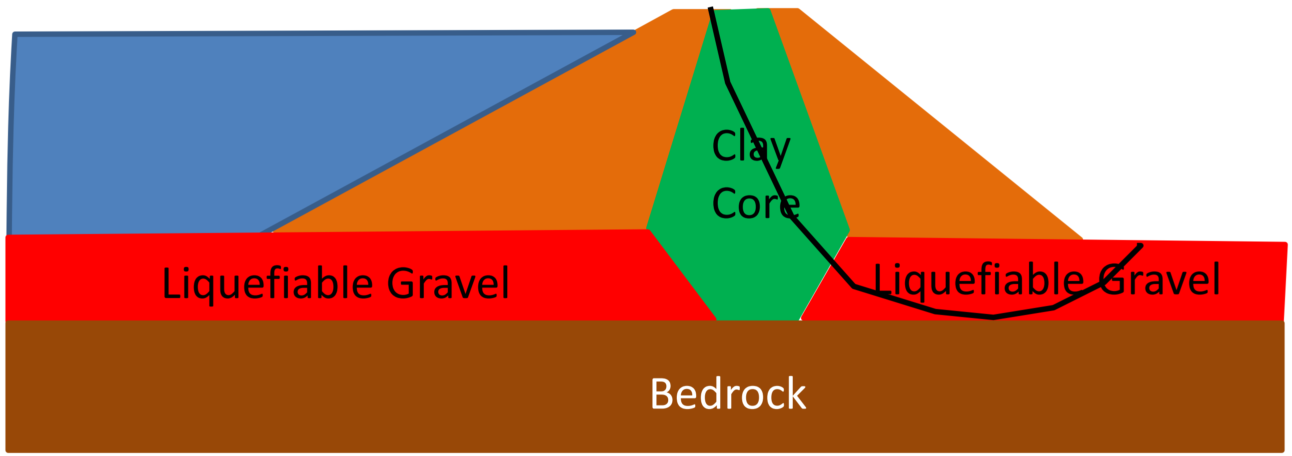
Gravel Liquefaction in the Literature

Year	M_w	Earthquake	Reference
1891	7.9	Mino-Owari, Japan	Tokimatsu & Yoshimi (1983)
1905	7.1	Messina, Italy	Baratta (1910)
1906	8.2	San Francisco, CA	Youd and Hoose (1978)
1948	7.3	Fukui, Japan	Ishihara (1985)
1964	9.2	Seward, Alaska	McCulloch & Bonilla (1970)
1975	7.3	Haicheng, China	Wang (1984)
1976	7.8	Tangshan, China	Wang (1984)
1976	6.5	Friuli, Italy	Sirovich (1996)
1978	7.4	Miyagiken-Oki, Japan	Tokimatsu & Yoshimi (1983)
1983	6.9	Borah Peak, Idaho	Youd et al (1985), Harder (1986)
1988	6.8	Armenia	Yegian et al (1994)
1991	7.6	Limon, Costa Rica	Franke & Rollins (2017)
1993	7.8	Hokkaido, Japan	Kokusho et al (1995)
1995	7.2	Kobe, Japan	Kokusho & Yoshida (1997)
1999	7.6	Chi-Chi, Taiwan	Chu et al (2000)
2008	7.9	Wenchuan, China	Cao et al (2013)
2014	6.1	Cephalonia Island, Greece	Nikolaou et al (2014)
2016	7.8	Muisne, Ecuador	Vera Grunauer et al (2017)
2016	7.8	Kaikora, New Zealand	Cubrinovsky et al (2017)

Gravel Liquefaction Sites



Gravel Liquefaction in Older Dams

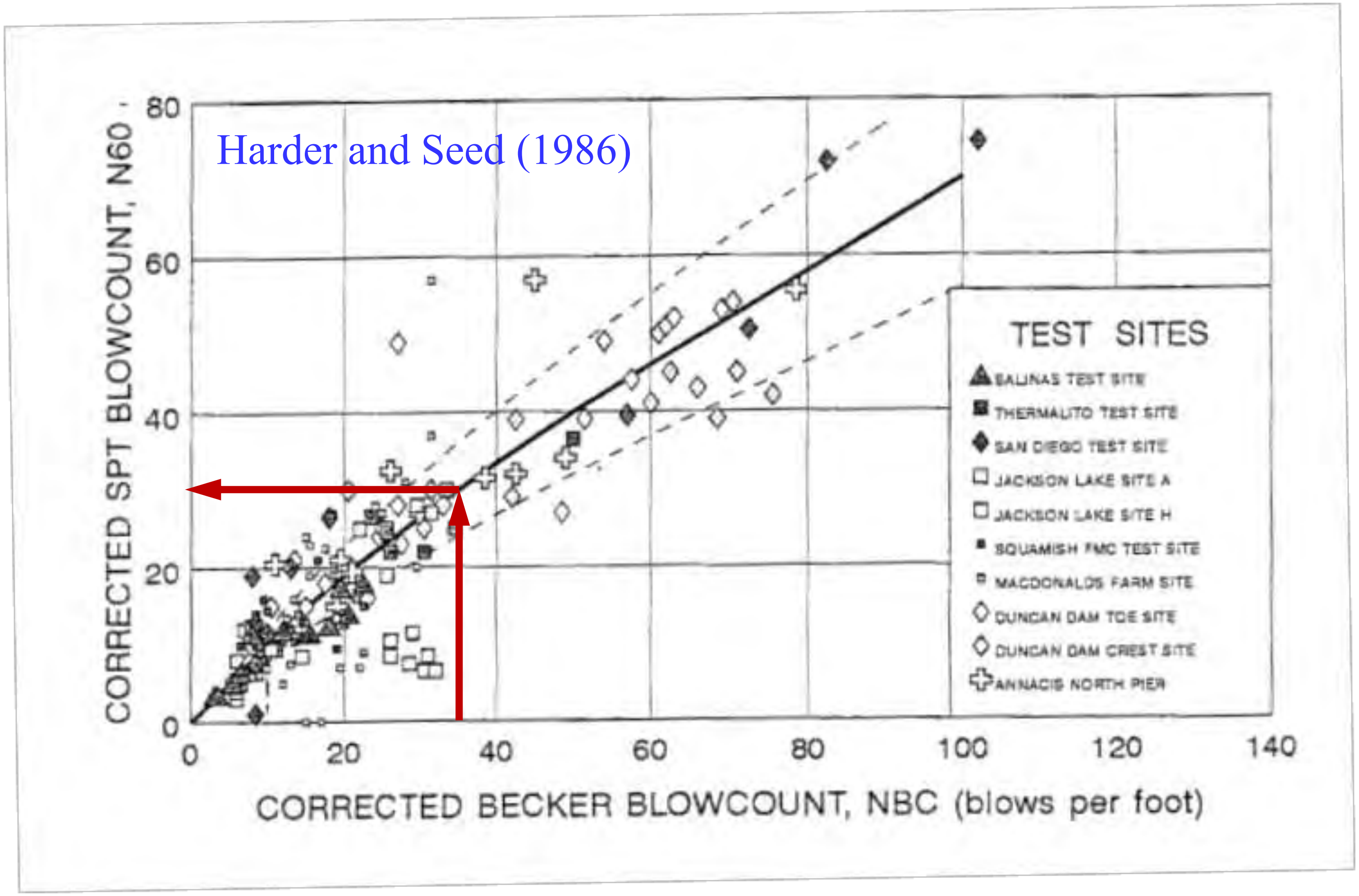


- Liquefaction hazard recognized after construction
- Liquefaction evaluation & remediation are often "multi-million dollar" decisions

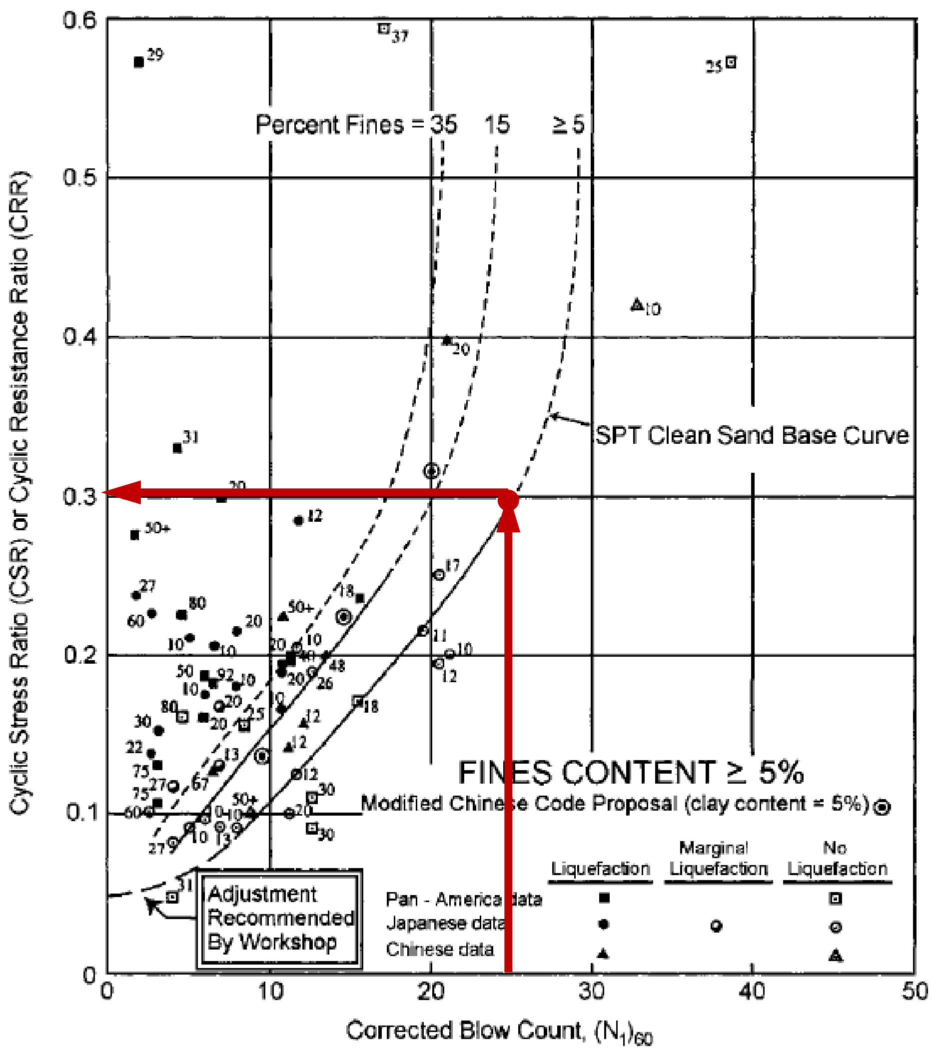
Becker Penetration Test (BPT)

- SPT & CPT unreliable in gravels because of particle size
- BPT Developed in Canada in late 1950s
- 6.6 inch diameter, 10 ft. long double core barrel driven into ground
- Measures blows/30 cm, NBC

Correlation Between Becker & SPT Blow Counts



SPT Liquefaction Triggering Curve



Youd et al (2001)

iBPT Correlation with SPT N_{60}

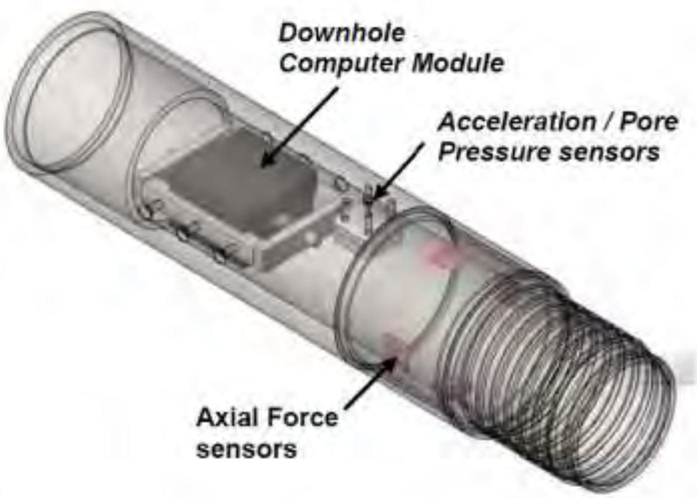


FIG. 1. iBPT testing equipment (after Thurairajah 2013).

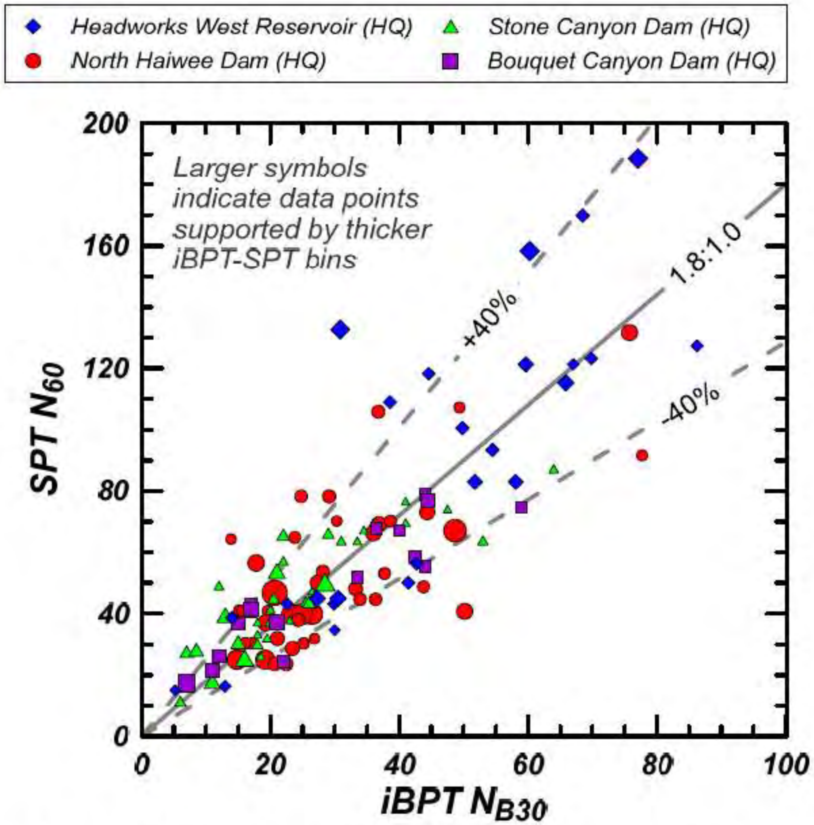


Figure 5. Correlation between medians of iBPT N_{B30} from tip measurements, and SPT N_{60}; high quality (HQ) data from four sites

De Jong et al (2017), JGGE

Limitations of Becker Testing

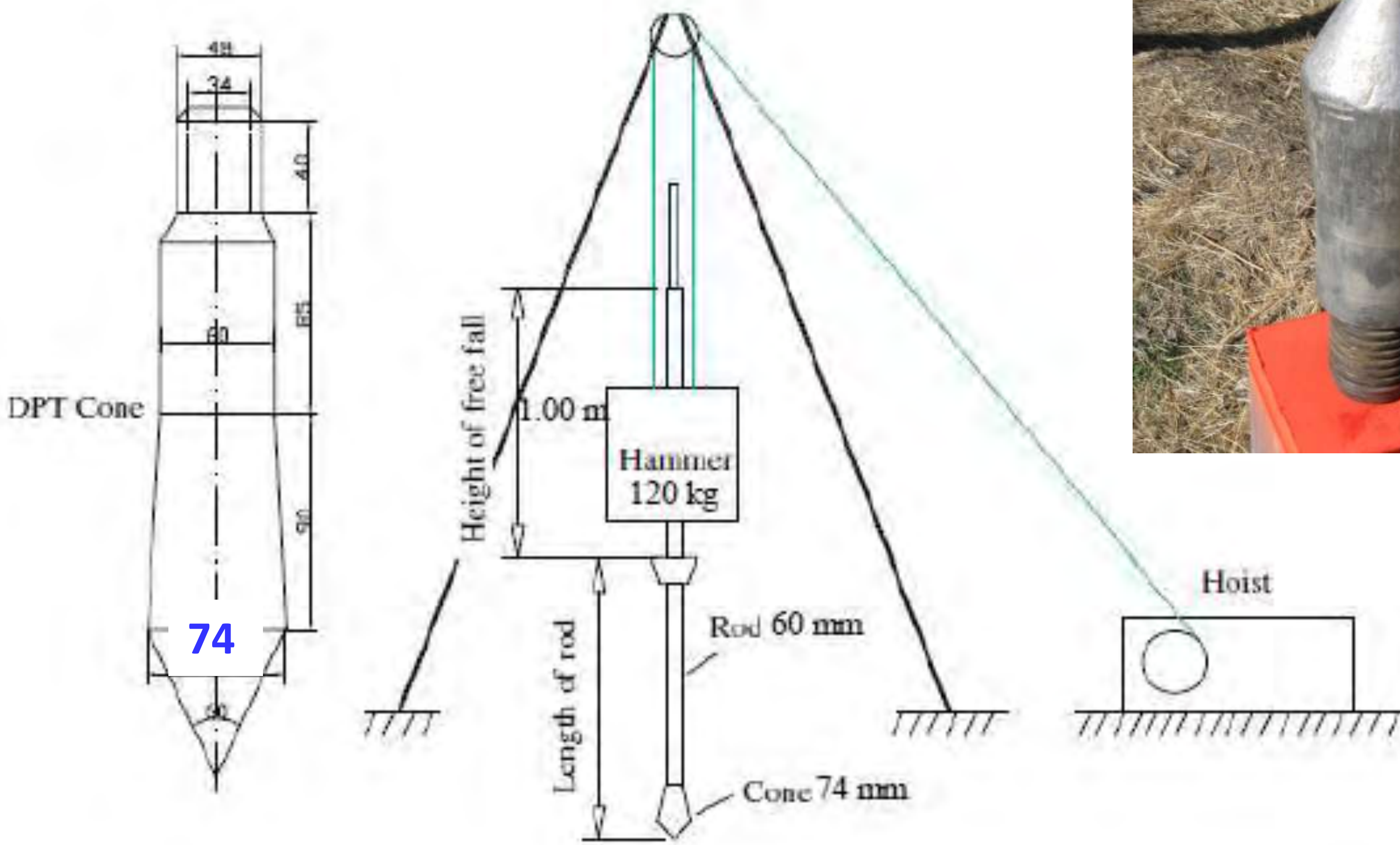
- High cost of mobilization & testing often limits BPT to major projects
- Uncertainty with correction factors for BPT
- Uncertainty with correlations between BPT NBC or iBPT N_{B30} and equivalent sand SPT N_{60}

Chinese Dynamic Cone Penetrometer, DPT

- Capable of penetrating loose to moderately dense gravels
- Relatively fast, simple, and economical
- Can be used for routine projects.
- Liquefaction triggering curve **directly based on field performance data**

Chinese Dynamic Cone Penetration Test (DPT)

2.5 times the SPT energy



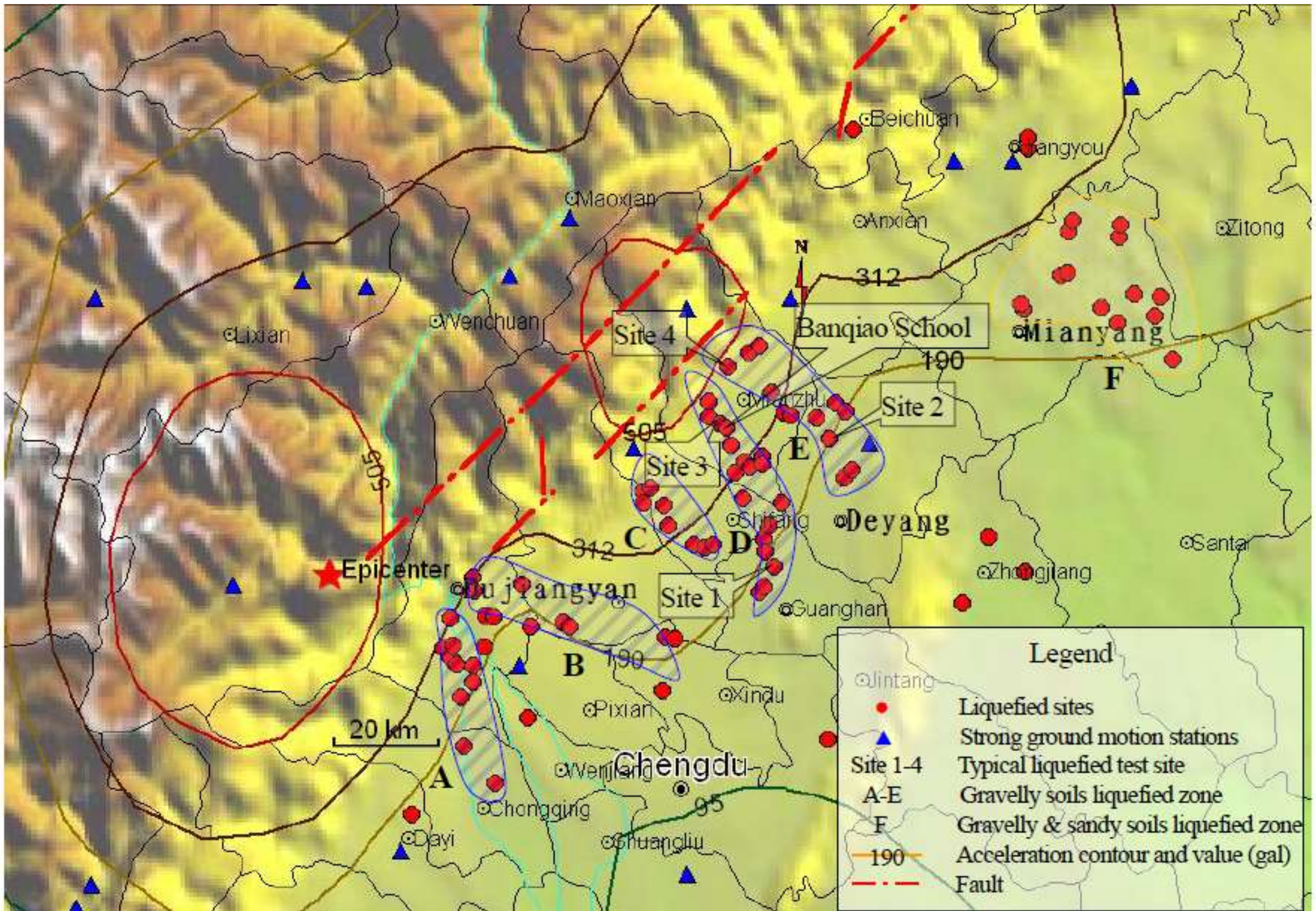
Cao, Yuan, Youd and Rollins (2012), ISC4, Brazil
Cao et al (2013), JGGE,

DPT Penetration Resistance (N'_{120})

- $N'_{120} = N_{120}\,(100\text{ kPa}/\sigma'_v)^{0.5}$

- Reported every 10 cm but multiplied by 3 to get the equivalent value for 30 cm
- No consideration of fines content at present

Gravel Liquefaction in M_w7.9 Wenchuan China Earthquake in 2008



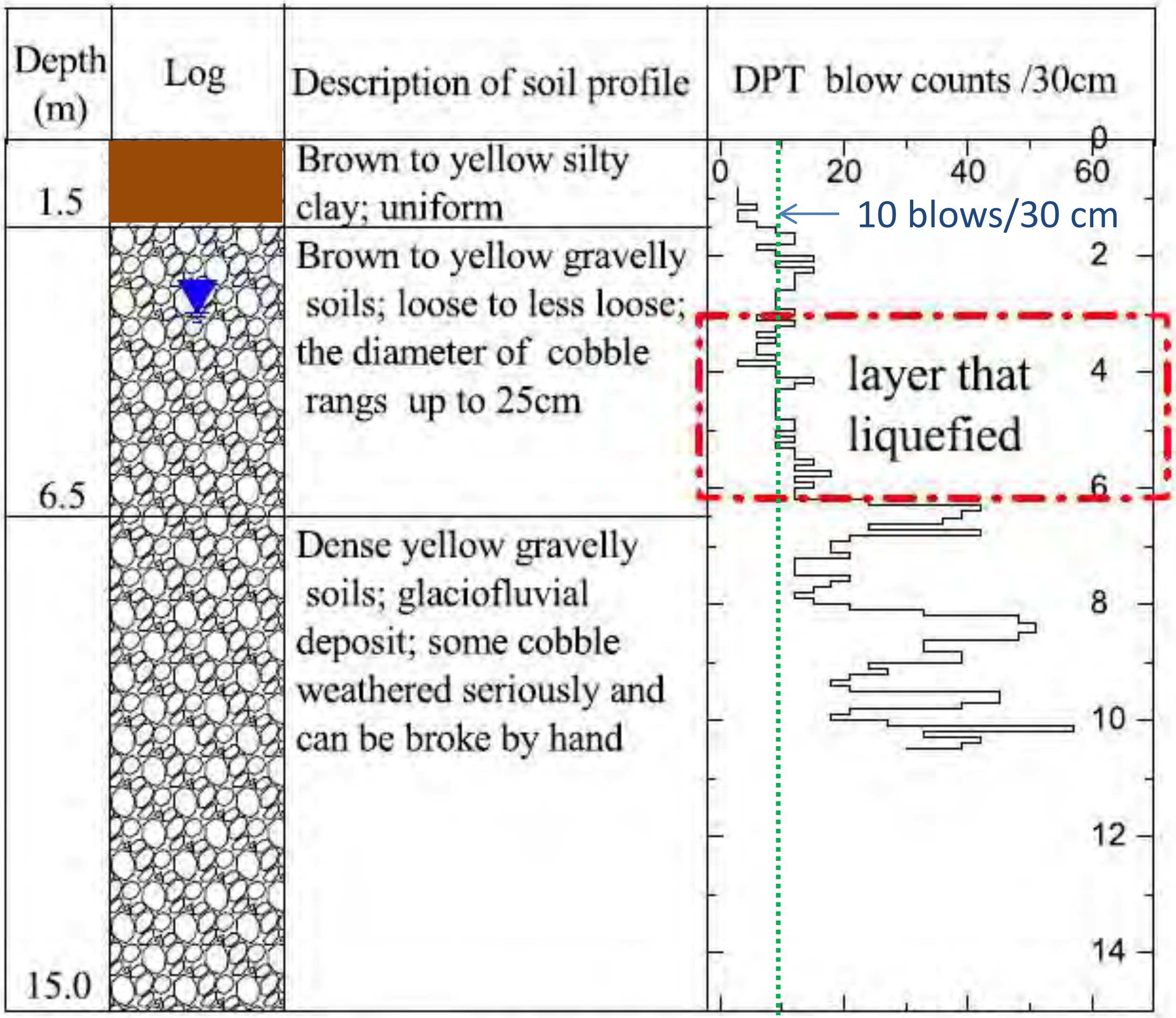
118 Gravel Liquefaction Sites in Chengdu Plain

Cao Ph.D. Dissertation, 2012, Chinese Inst. of Engineering Mech.

2008 M_w7.9 Wenchuan Earthquake

Sand & Gravel Ejecta

Lateral Spread at Banqiao School

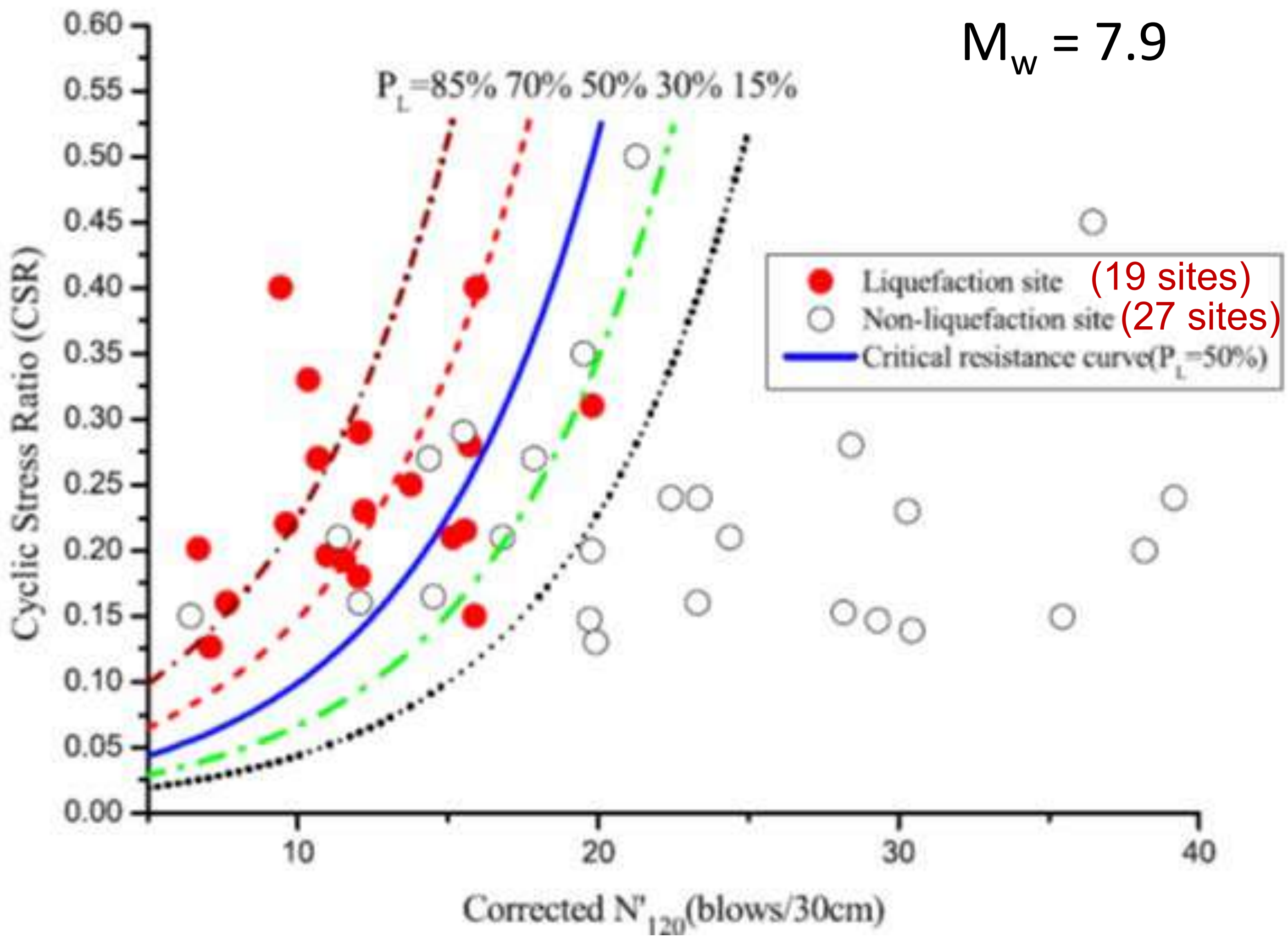


(b) Banqiao School, Mianzhu (Site 3)

Soil profile and DPT Log from Chengdu

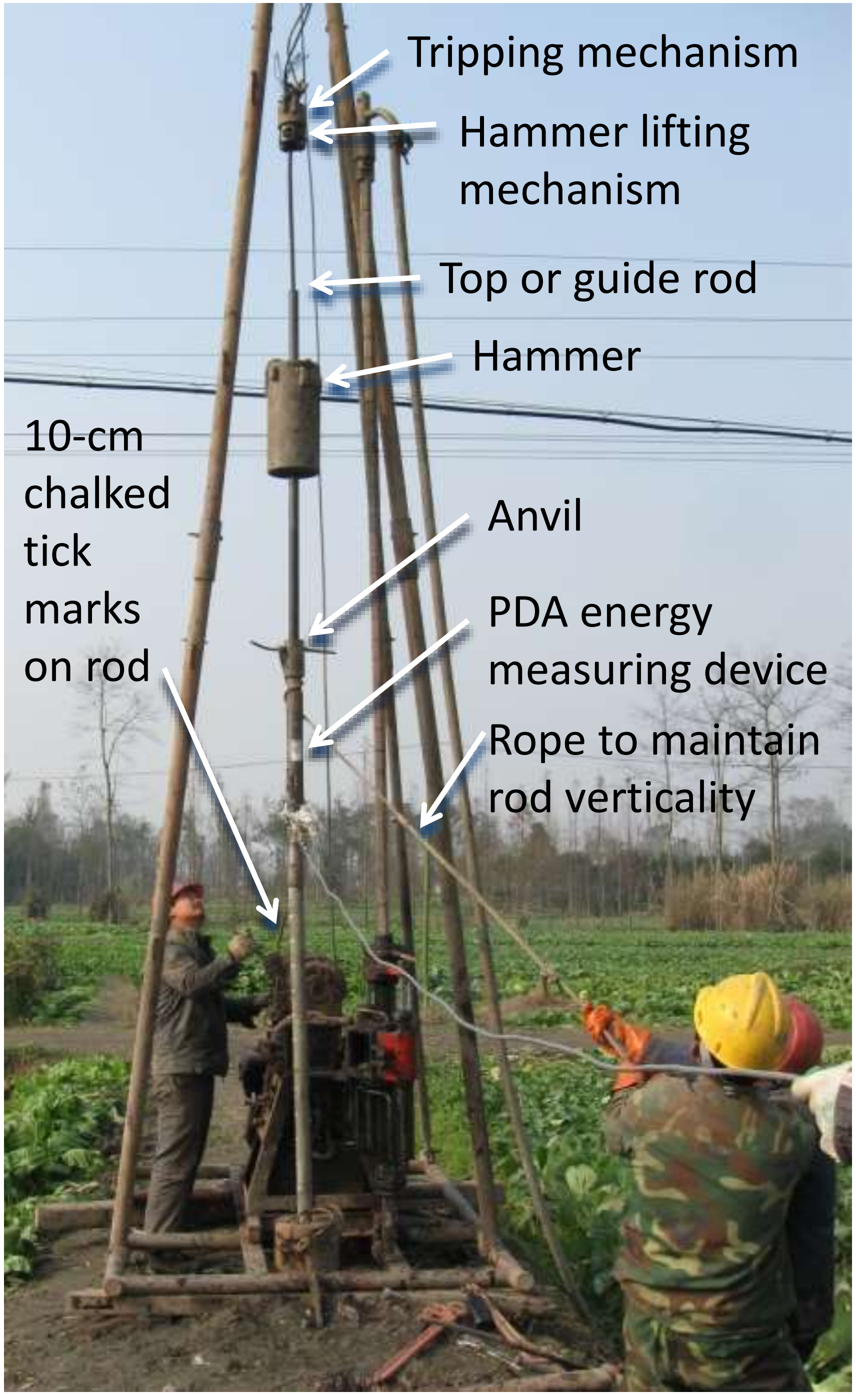
Cao et al (2013), JGGE

DPT Liquefaction Triggering Curve

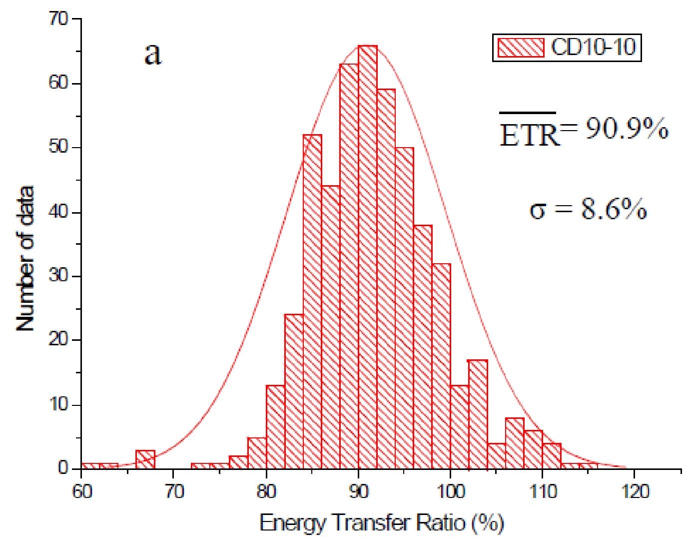


Cao et al (2013), JGGE, August

Core samples from borehole near a DPT sounding showing gravelly and cobbly composition of sediment penetrated beneath Chengdu Plain



Energy Transfer measurements in China

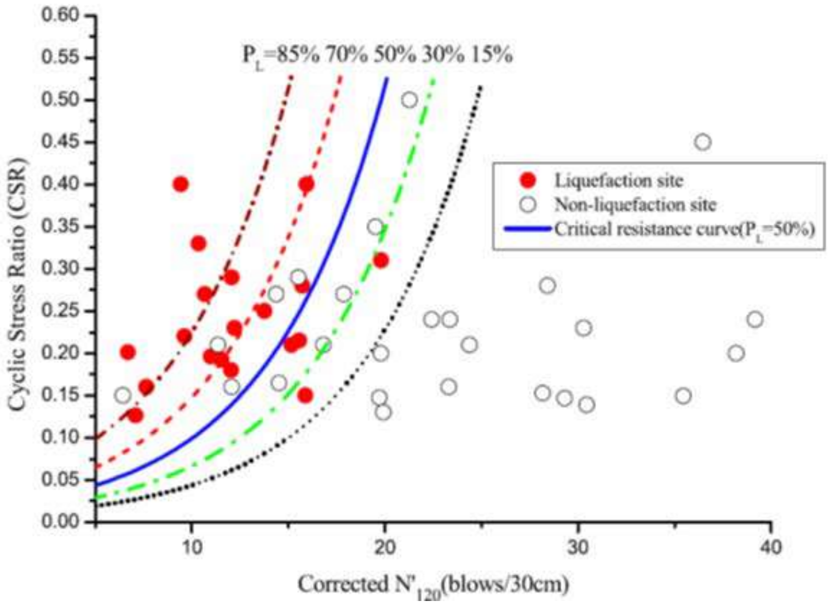


Standard DPT Procedure
Avg. Energy Transfer = 90%
Std. Dev. = 8.6%

Cao et al (2013), JGGE, August

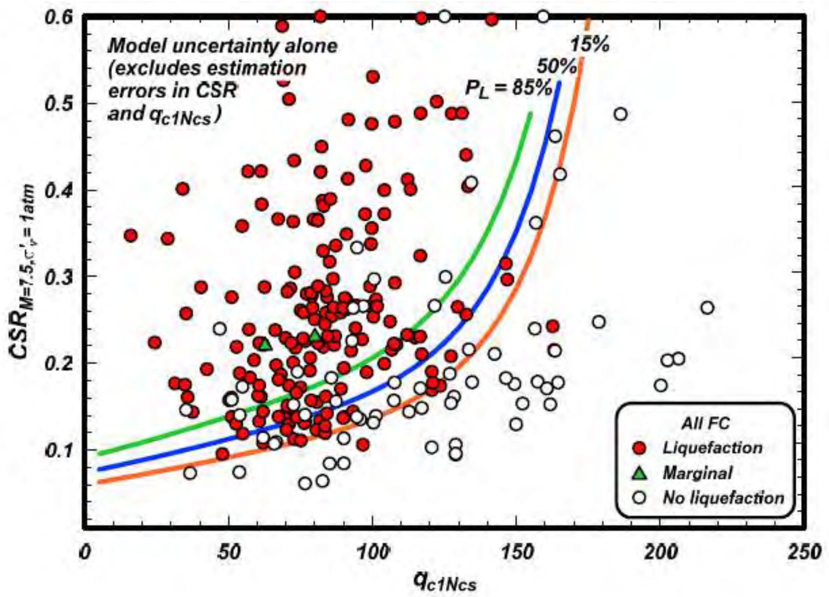
Comparison DPT & CPT Triggering Curves

DPT



Cao et al. (2013)

CPT



Boulanger & Idriss (2014)

Research Questions for DPT

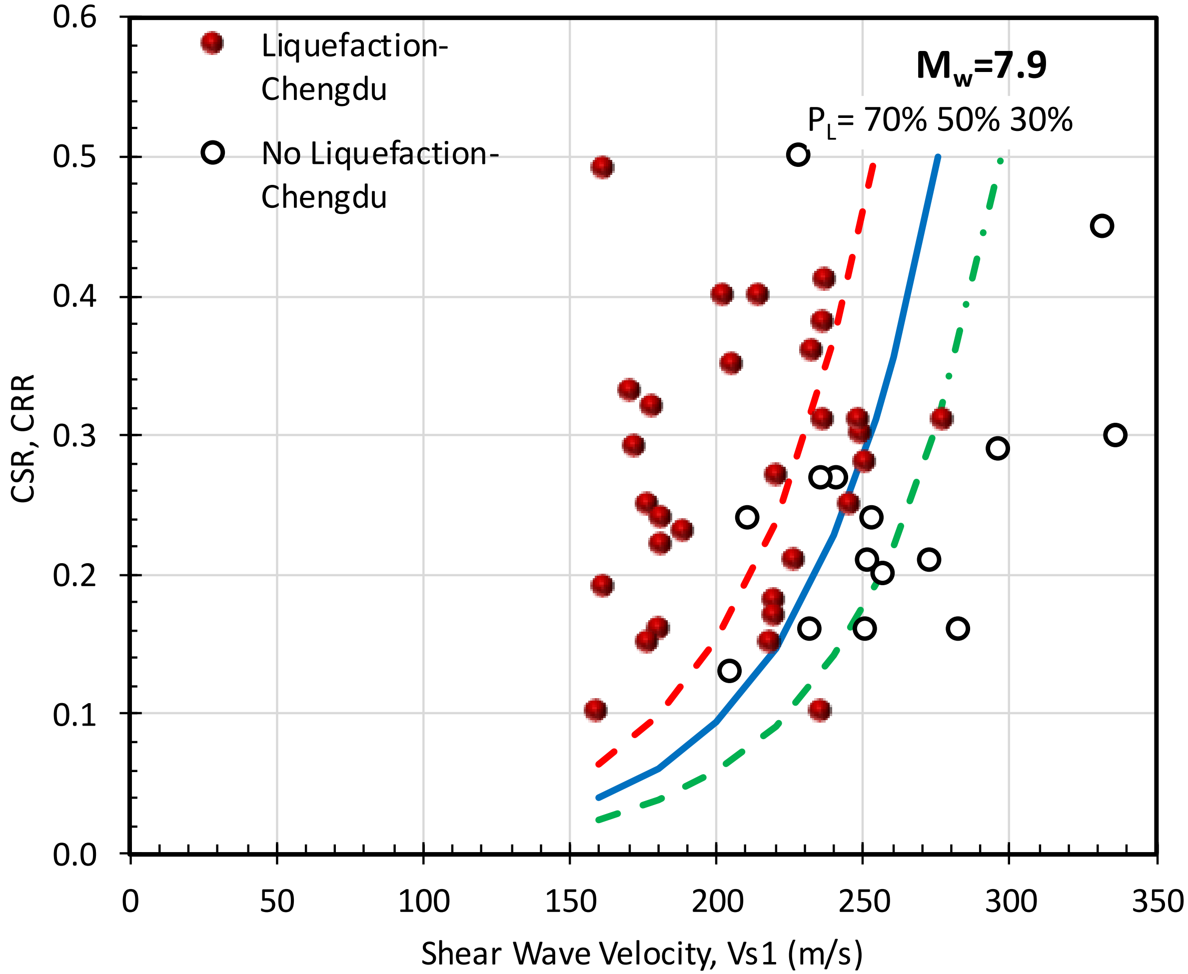
- Can we reduce the spread in DPT triggering curves with additional data points
- Will liquefaction Factor of Safety from DPT be similar to that from BPT?
- Can use of SPT hammer energy give acceptable results after energy correction?

Vs Measurements in Chengdu

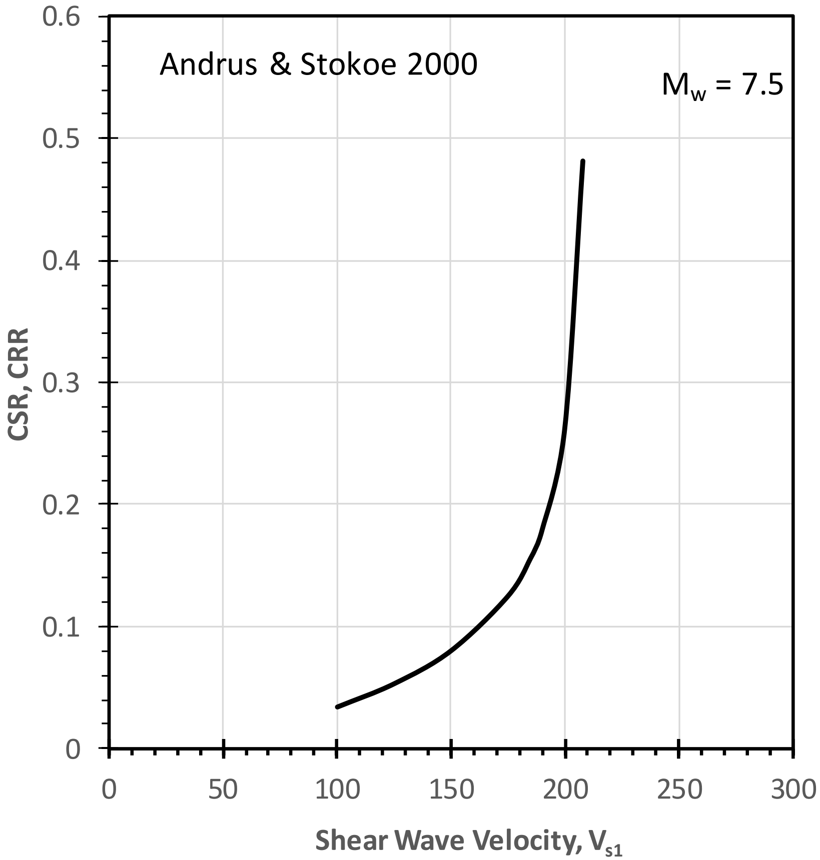
- MASW measurements performed & interpreted by Dr. Zhenzhong Cao
- 24 - 4.5 Hz receivers at 2 m spacing
- Source was hammer blows

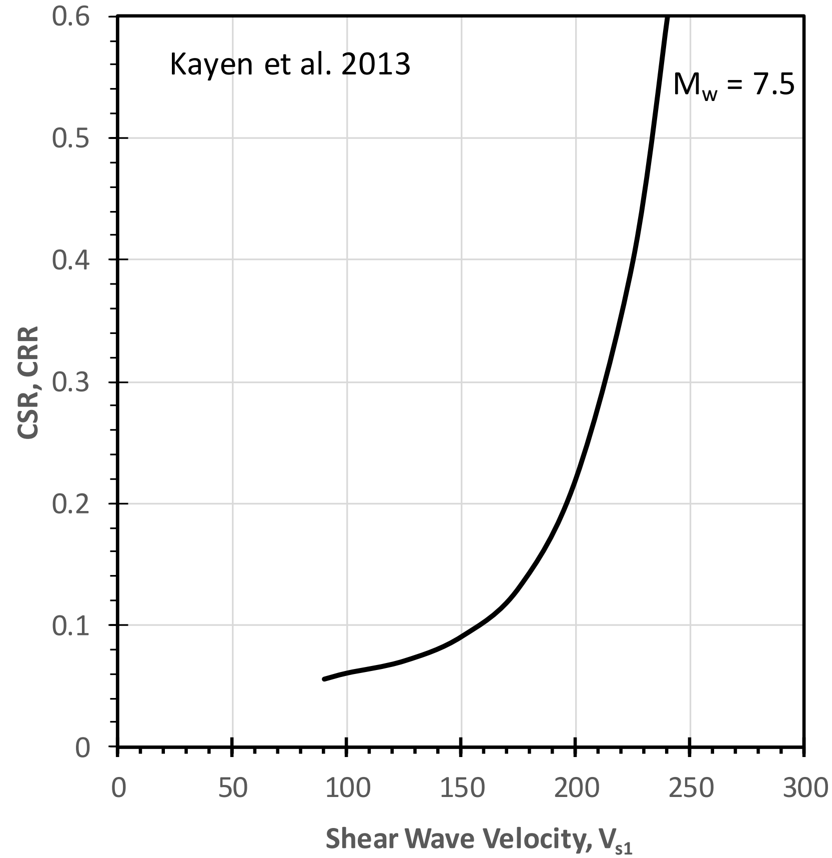
Vs Liquefaction Triggering Curve

Chengdu Plain Data – 47 Sites



Vs Triggering Curves for Sand

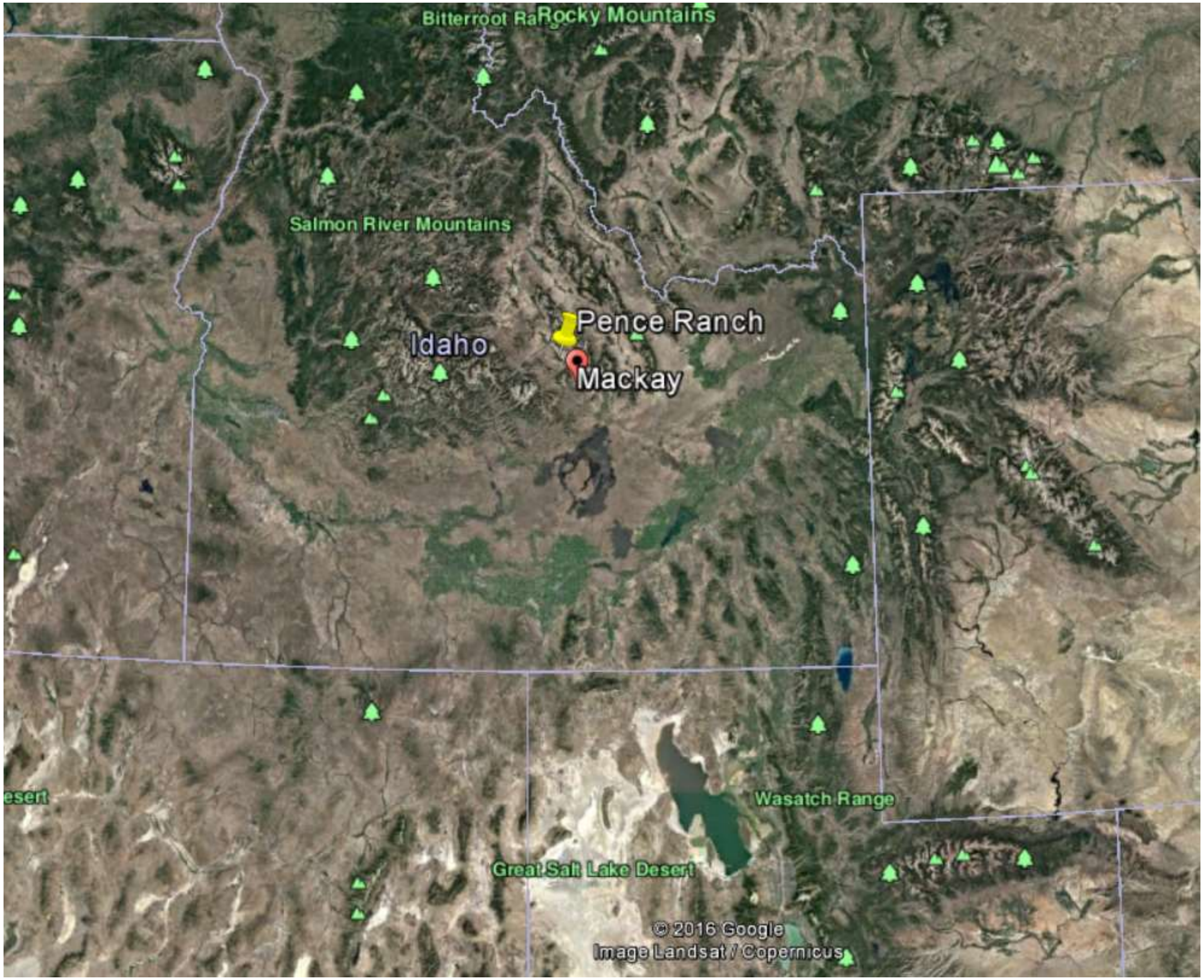




Possible Explanations

- Sediments may be older and have higher Vs for the same CRR
- Gravel content may increase the Vs for the same matrix relative density
- MASW may be averaging Vs and obscuring low velocity layers
- Errors in properly interpreting the Vs profile

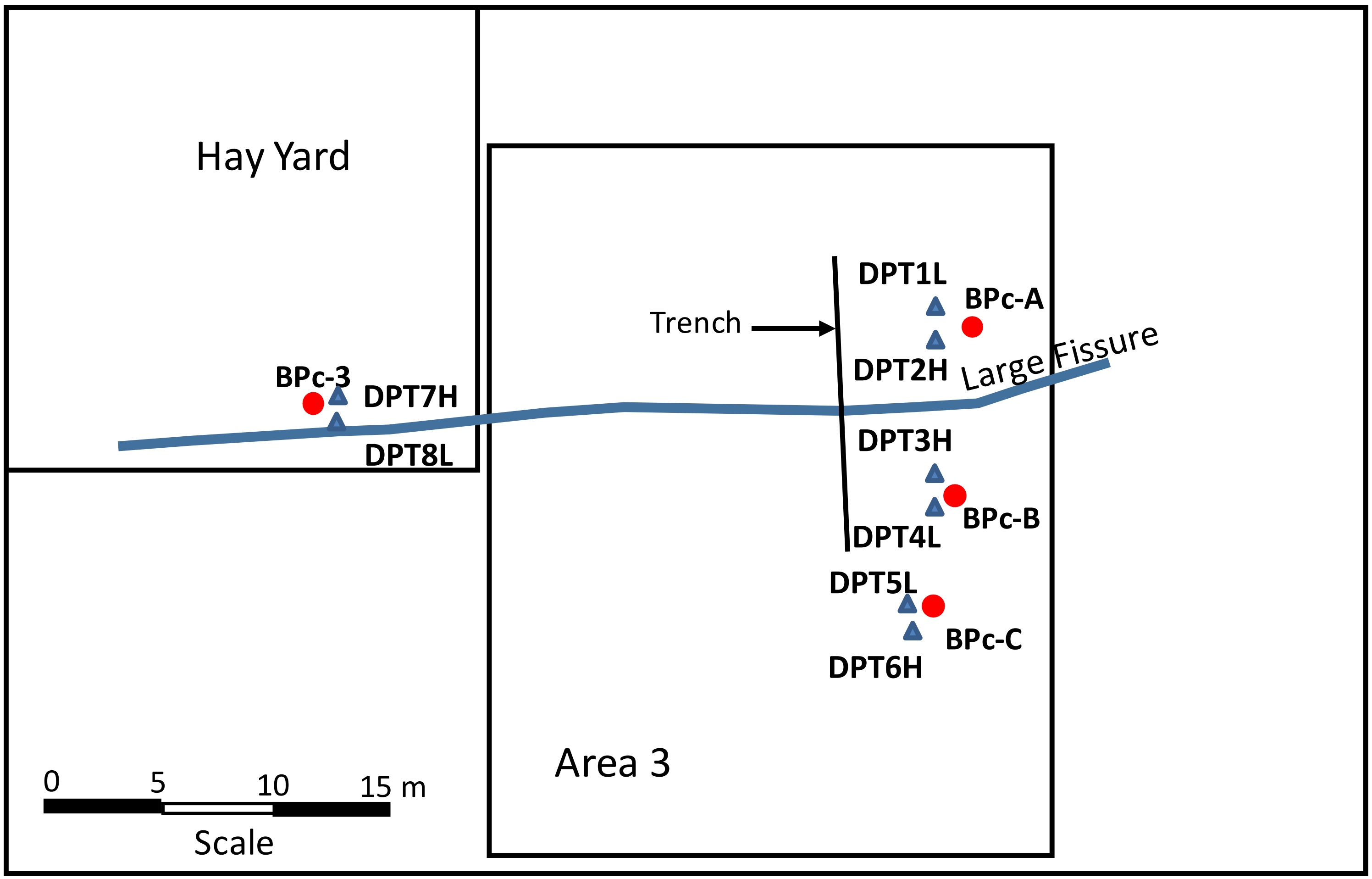
Pence Ranch Idaho, M_w6.9 Borah Peak EQ



Pence Ranch Idaho, Borah Peak EQ

- M_W6.9 with PGA of 0.39g
- 8 DPT holes (4 SPT and 4 DPT hammer energy)
- PDA Energy measurements
- Comparison with 4 BPT profiles (Andrus, 1986)

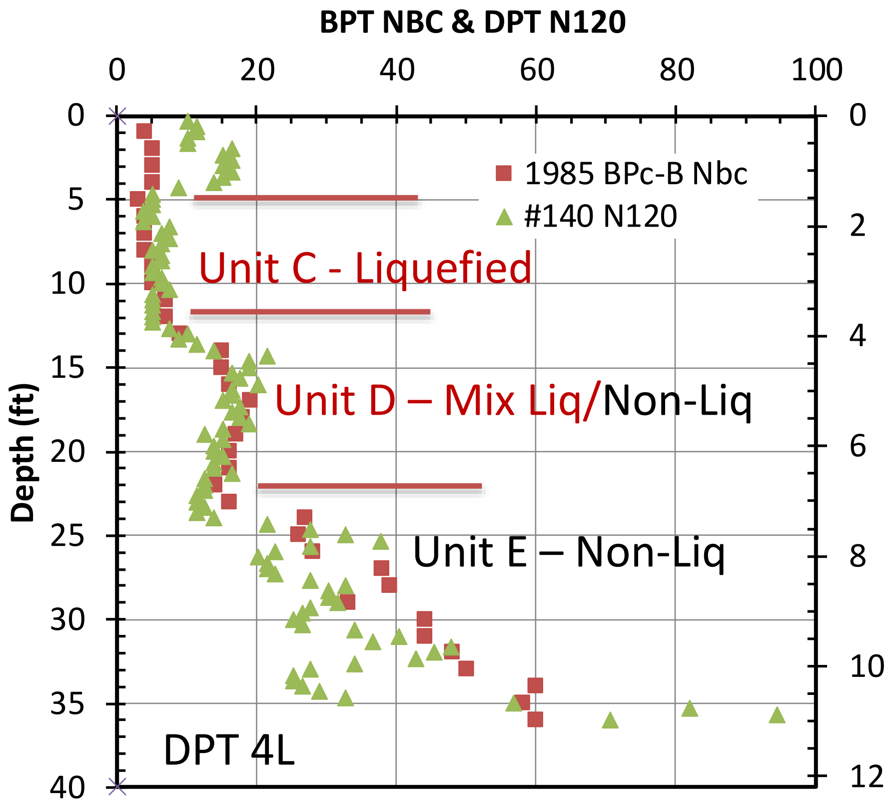
Layout of Test Holes Pence Ranch

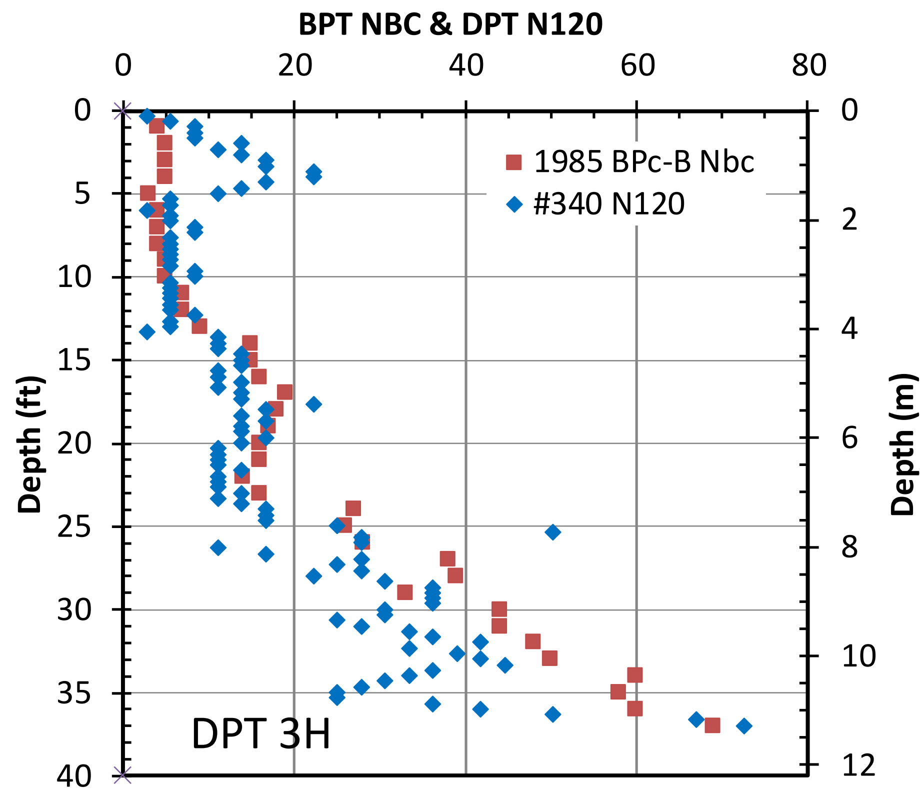


Simplified from Andrus (1986)

Drill Rig with Two Hammer Weights

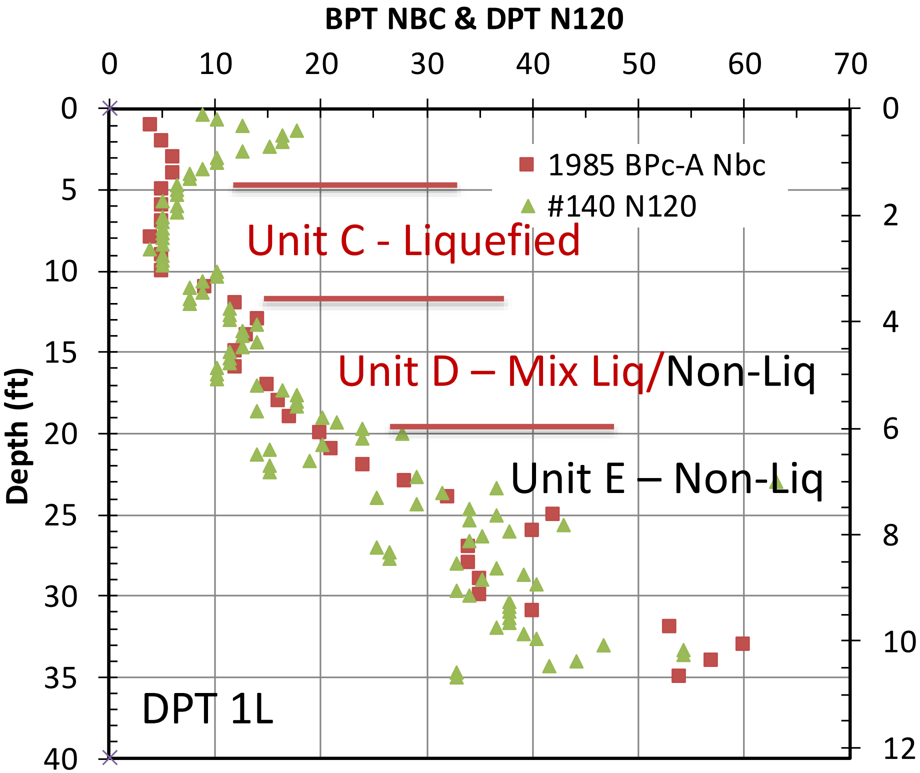
Comparison of BPT & DPT Holes

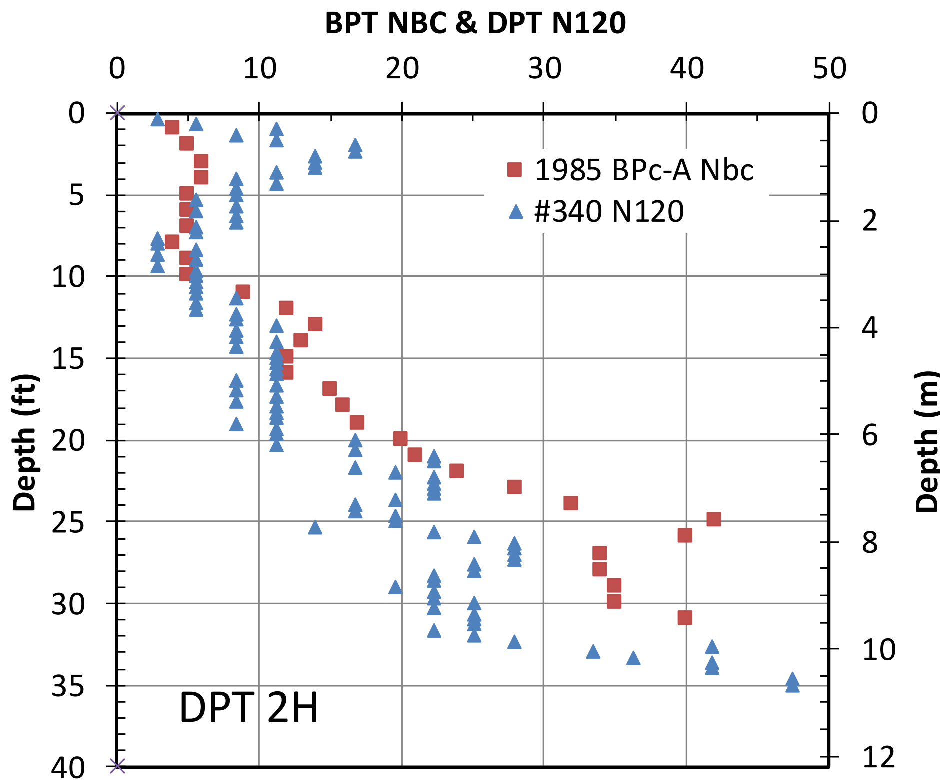




$$N_{120} = N_{measured}(E_{Delivered}/E_{Chinese\ DPT})$$

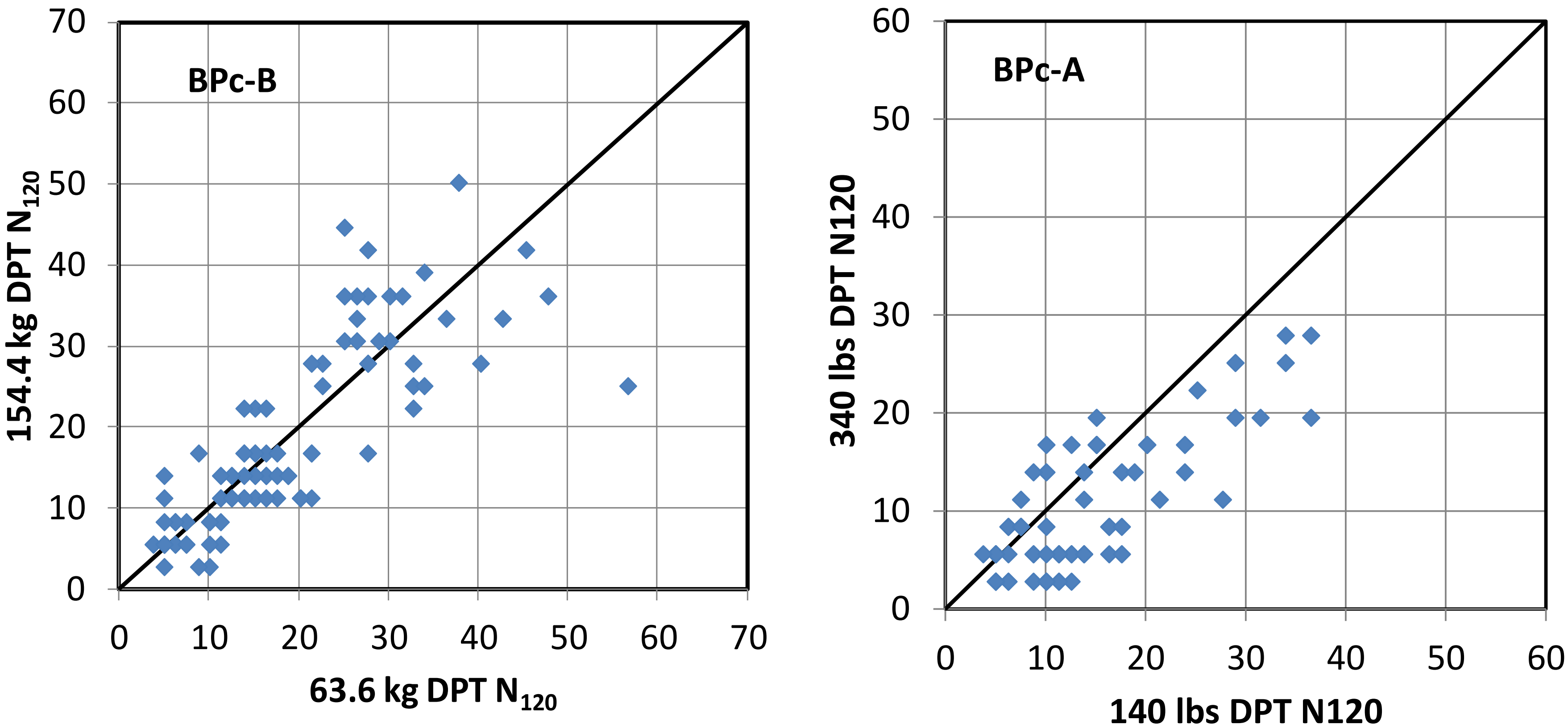
Comparison of BPT & DPT Holes





$$N_{120} = N_{measured}(E_{Delivered}/E_{Chinese\ DPT})$$

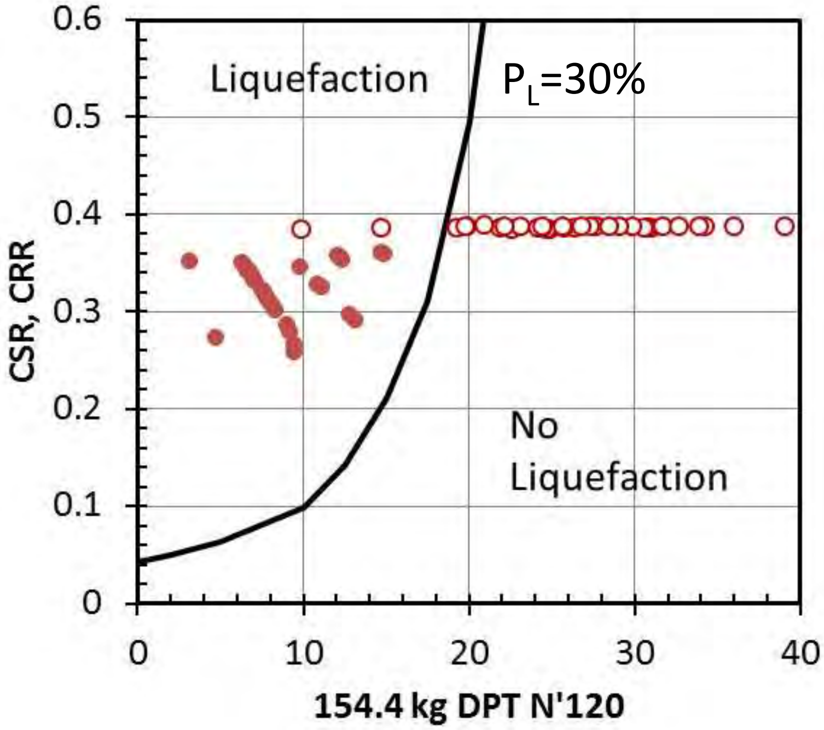
Comparison of N'_{120} with Two Hammer Energies



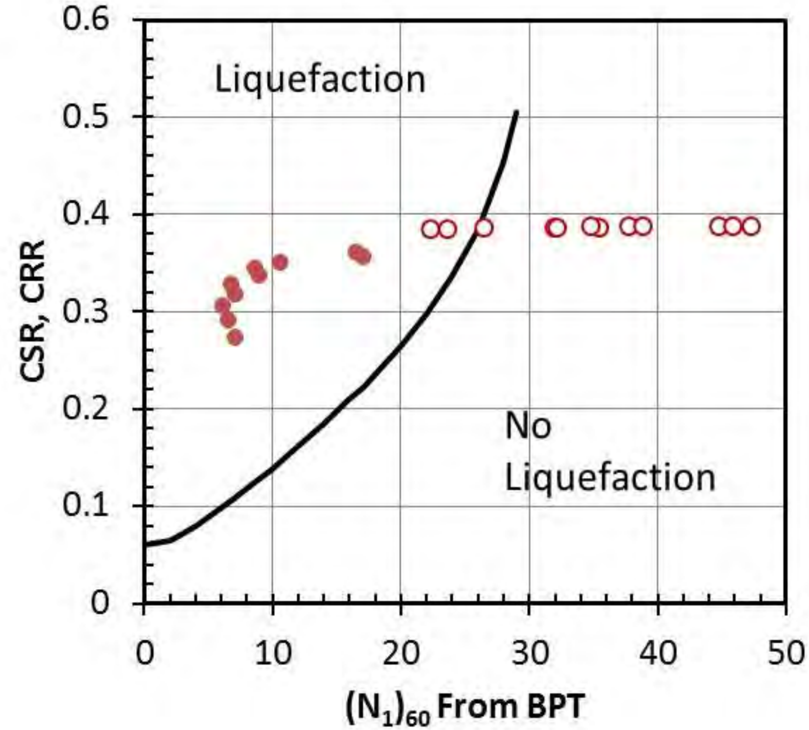
$$N_{120} = N_{measured}(E_{Delivered}/E_{Chinese\ DPT})$$

Comparison of BPT & DPT

Liquefaction Evaluation



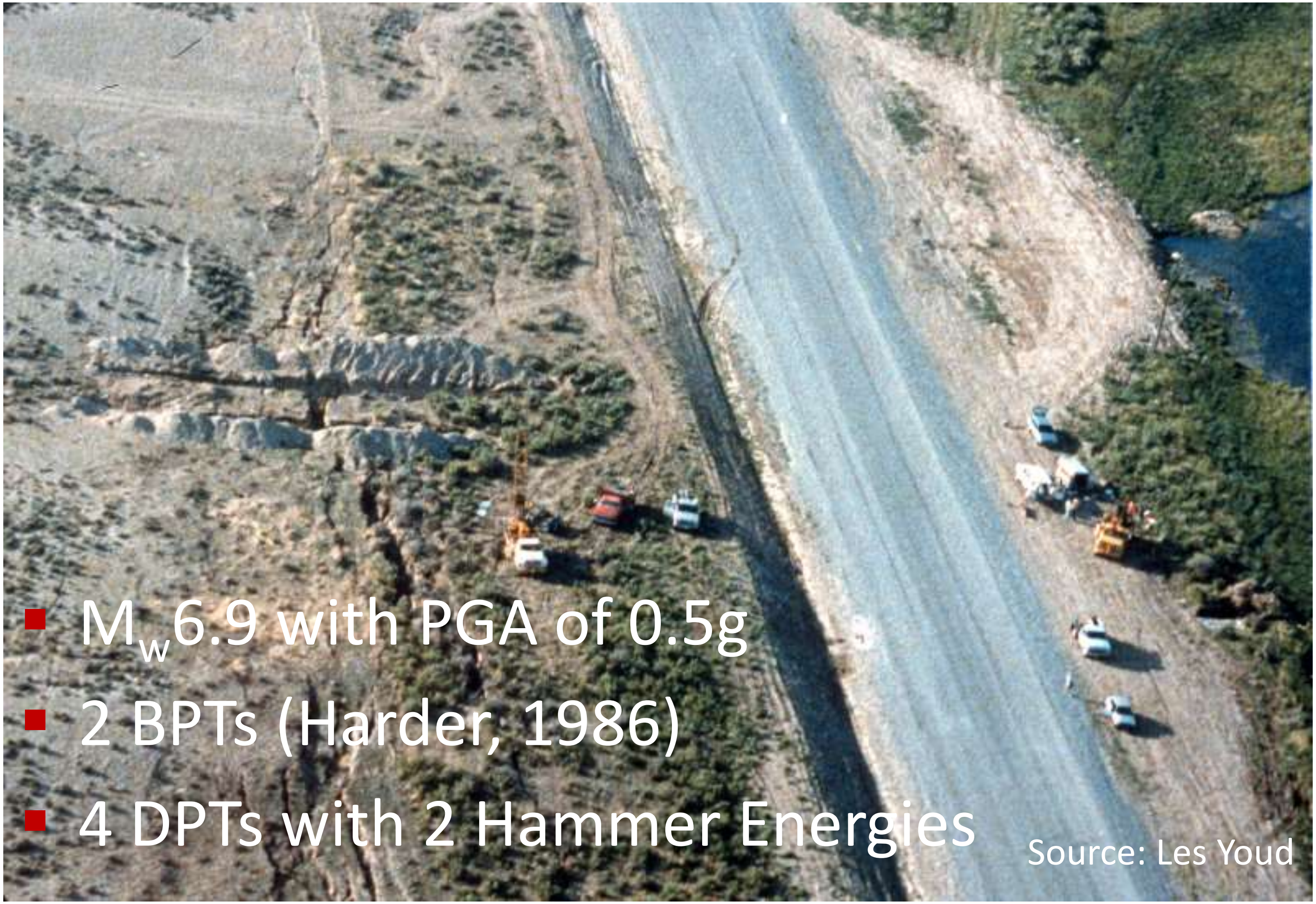
DPT Based Evaluation



BPT Based Evaluation

Used MSF = $10^{2.24}/M_w^{2.56}$

Whiskey Springs, M_W6.9 Borah Peak EQ

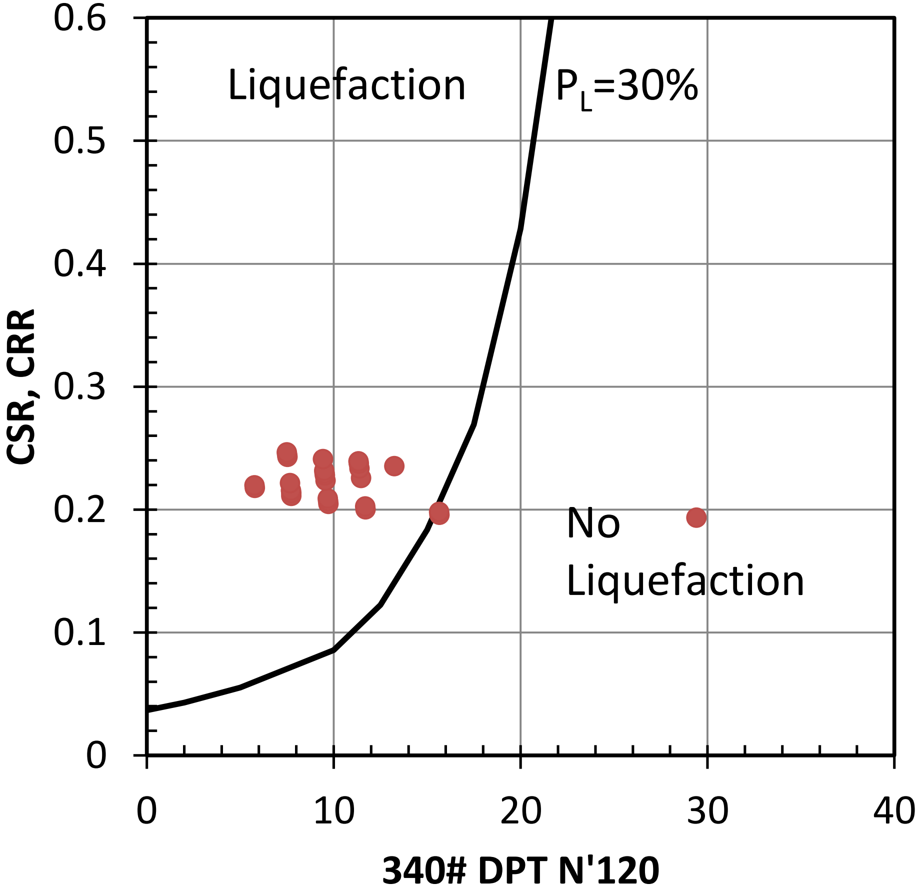


- M_w6.9 with PGA of 0.5g
- 2 BPTs (Harder, 1986)
- 4 DPTs with 2 Hammer Energies

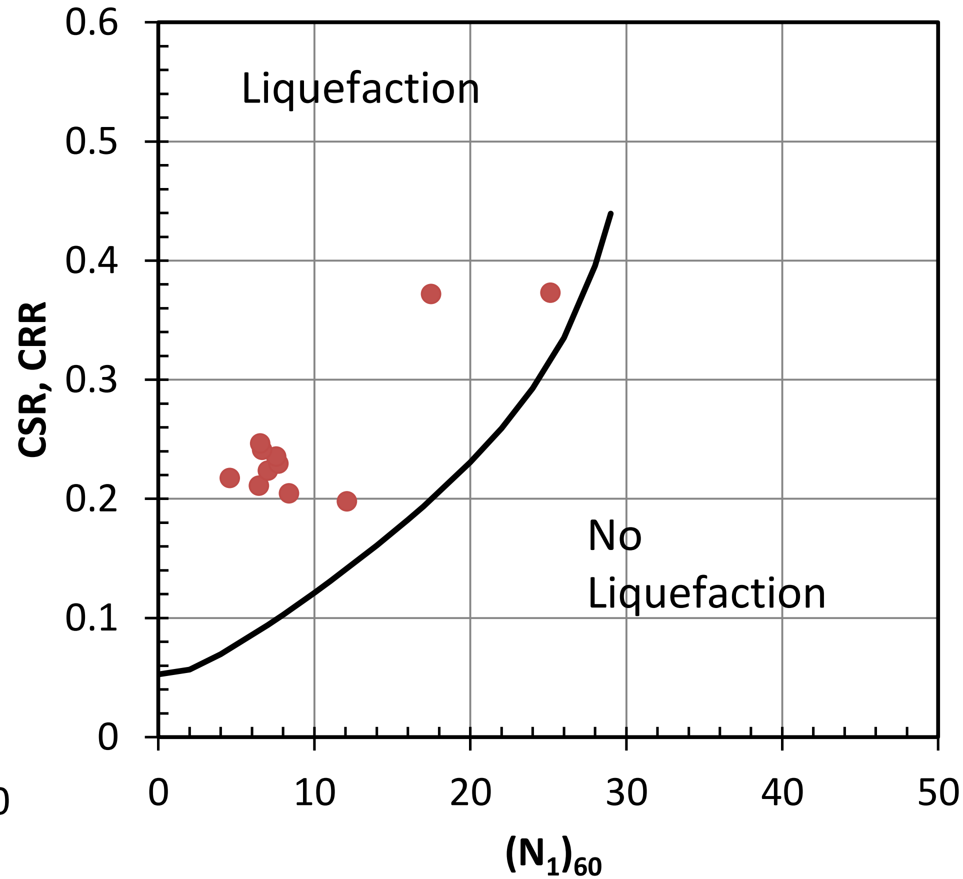
Source: Les Youd

Whiskey Springs, Borah Peak EQ

Liquefaction Evaluation



DPT Based Evaluation

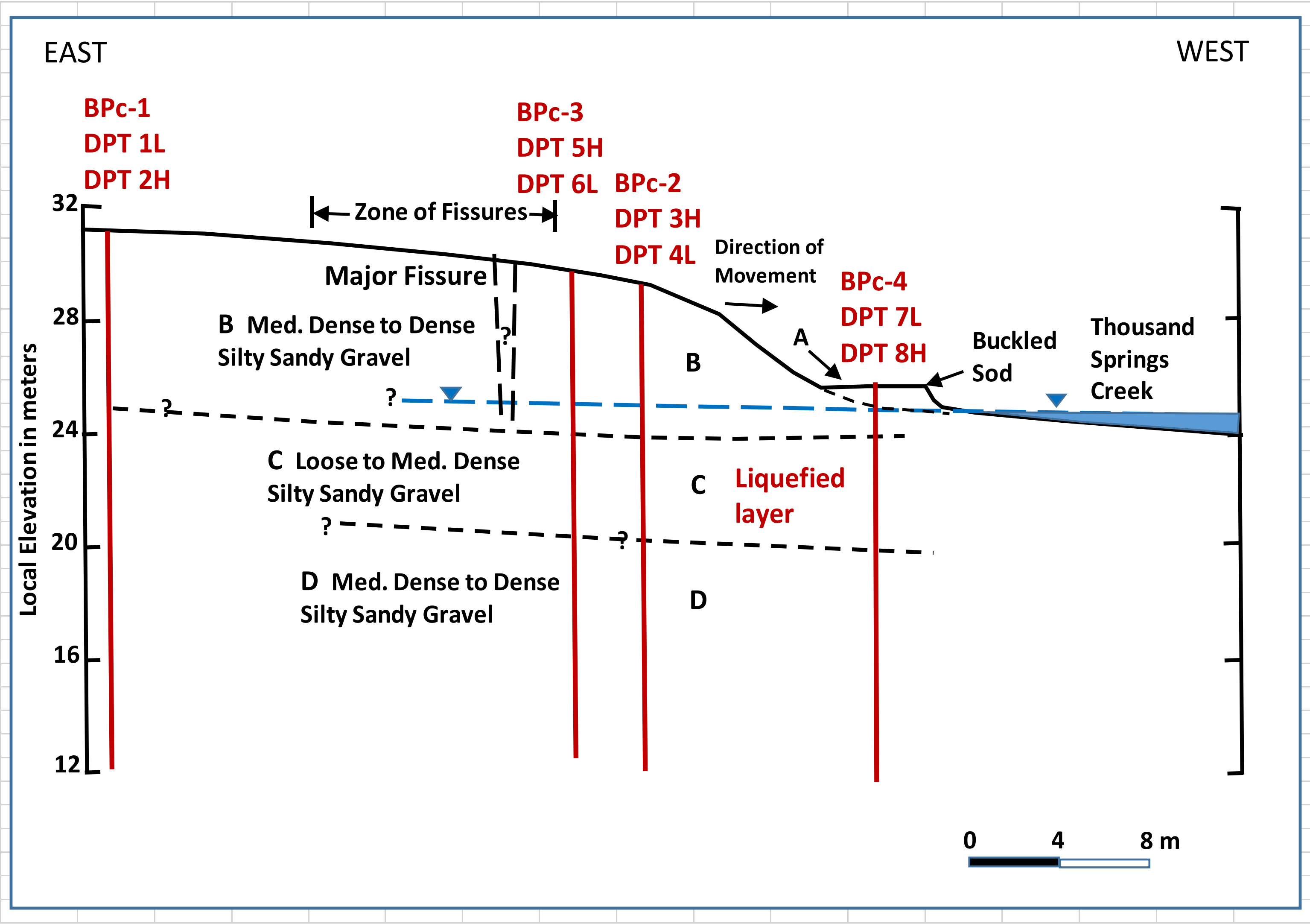


BPT Based Evaluation

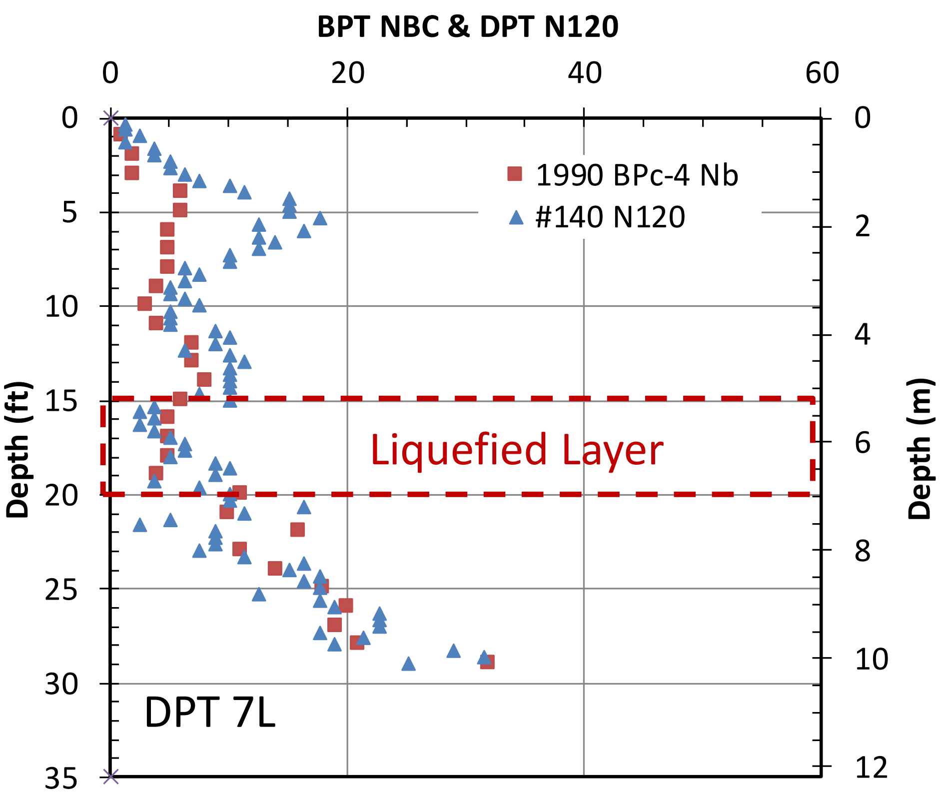
Larter Ranch, M_W6.9 Borah Peak EQ

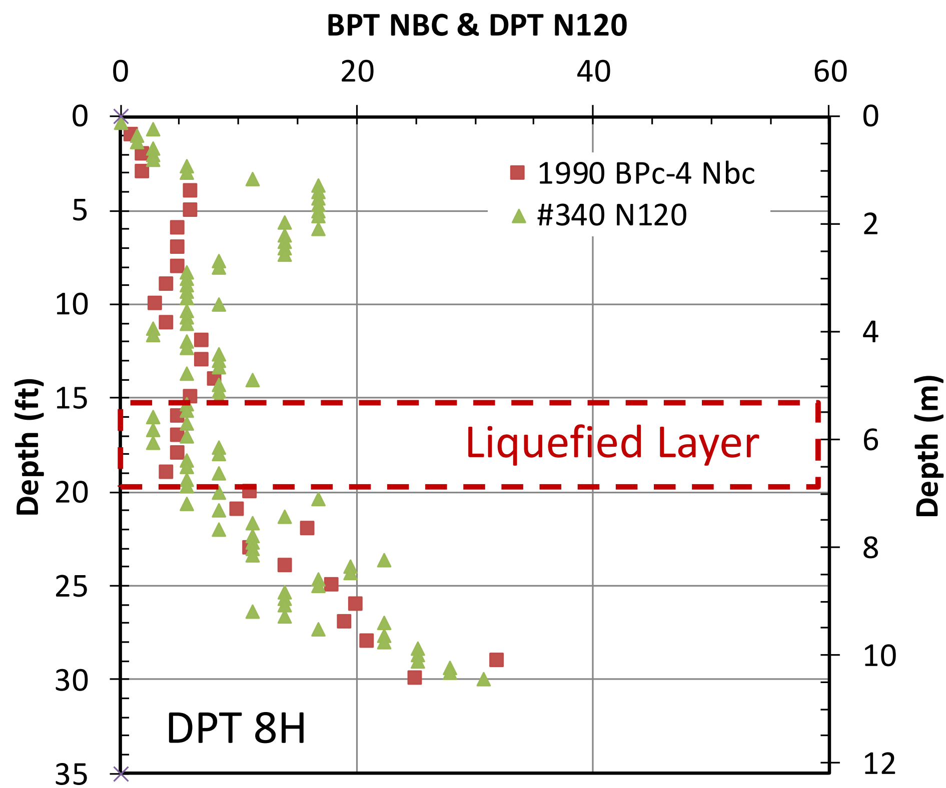
- M_w6.9 with PGA of 0.5g
- 4 BPTs (Andrus 1986)
- 8 DPTs with 2 Hammer Energies

Larter Ranch, Mw6.9 Borah Peak



Comparison of BPT & DPT Holes Larter Ranch, Idaho





$$N_{120} = N_{measured}(E_{Delivered}/E_{Chinese\ DPT})$$

Manta Port, 2016 M_W7.8 Ecuador EQ

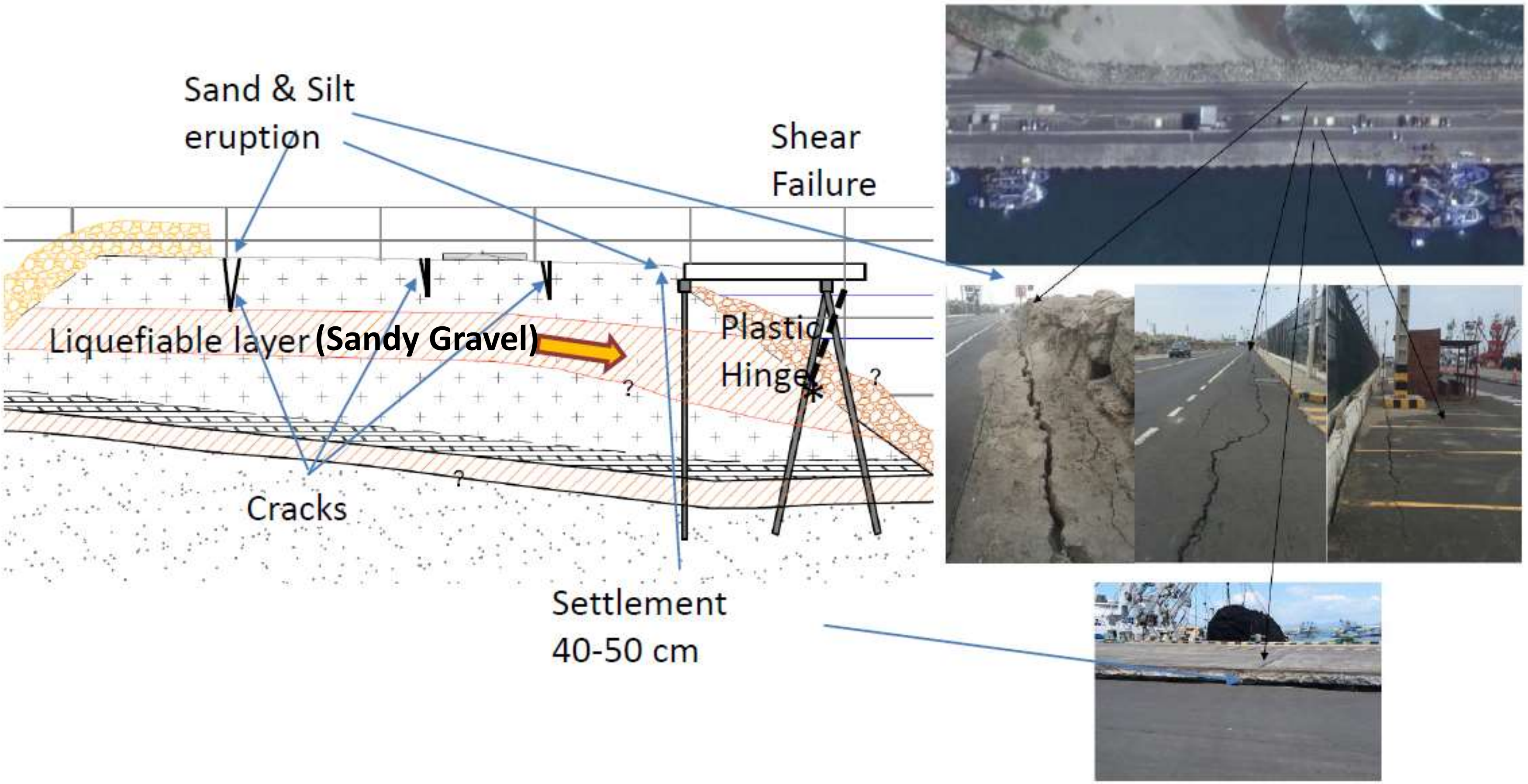
Manta Port, M_w7.8 Earthquake

Manta Port, M_w7.8 Earthquake

Damage to Piles from Lateral Spread

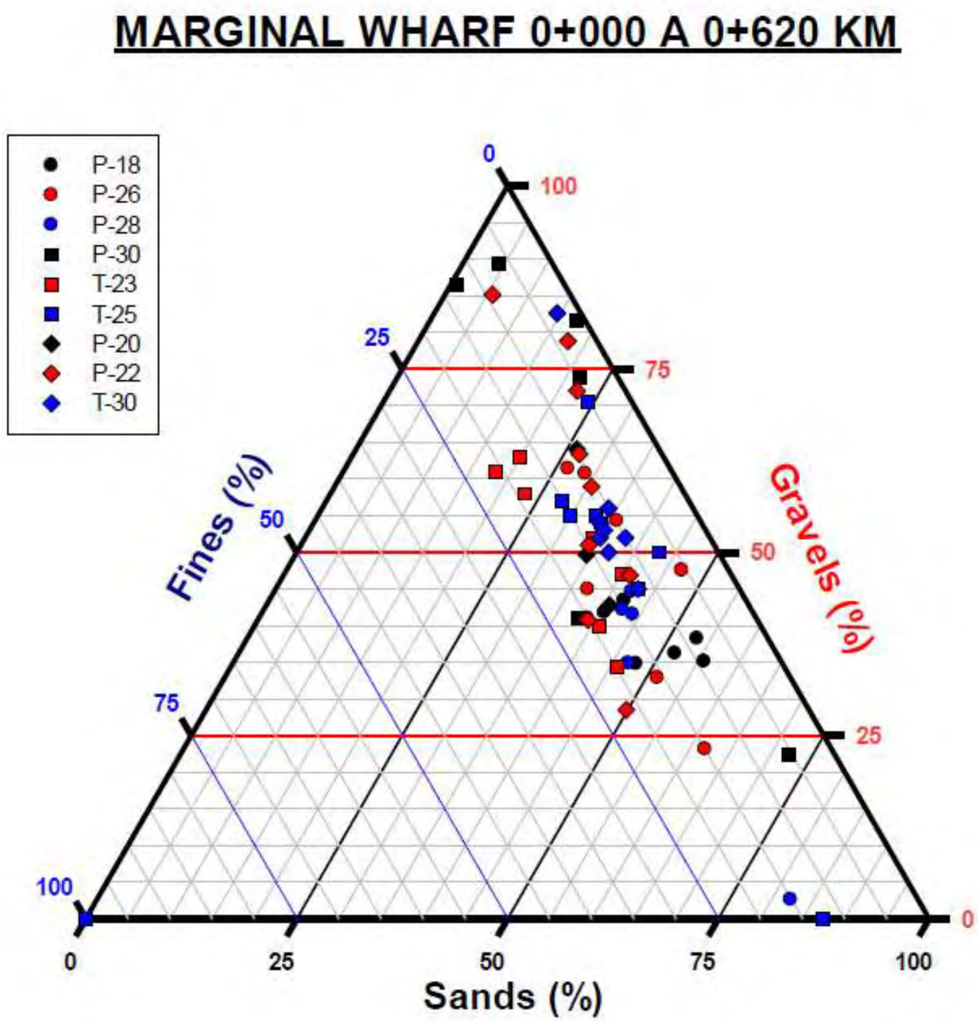
Damage to Battered Piles

Manta Port, M_W7.8 Ecuador EQ

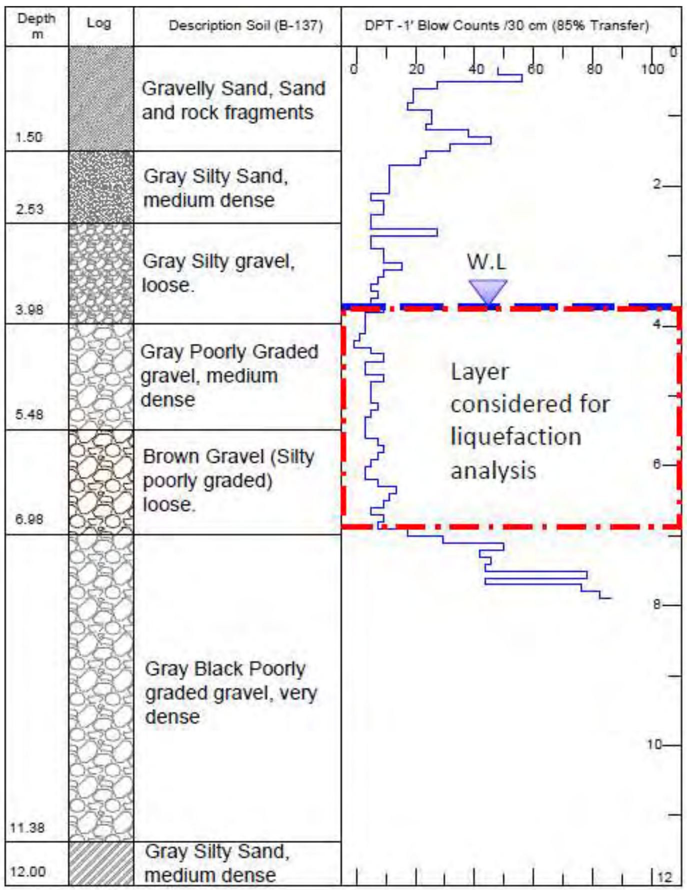


Courtesy GeoEStudios, Prof. Xavier Vera-Grunauer

Gradational Composition



Manta Port, M_W7.8 Ecuador EQ



Dynamic Penetration Test (DPT-1')

W.L: water level in the earthquake time (18h58).

The critical zones in the resistance profile were adopted for the liquefaction evaluation

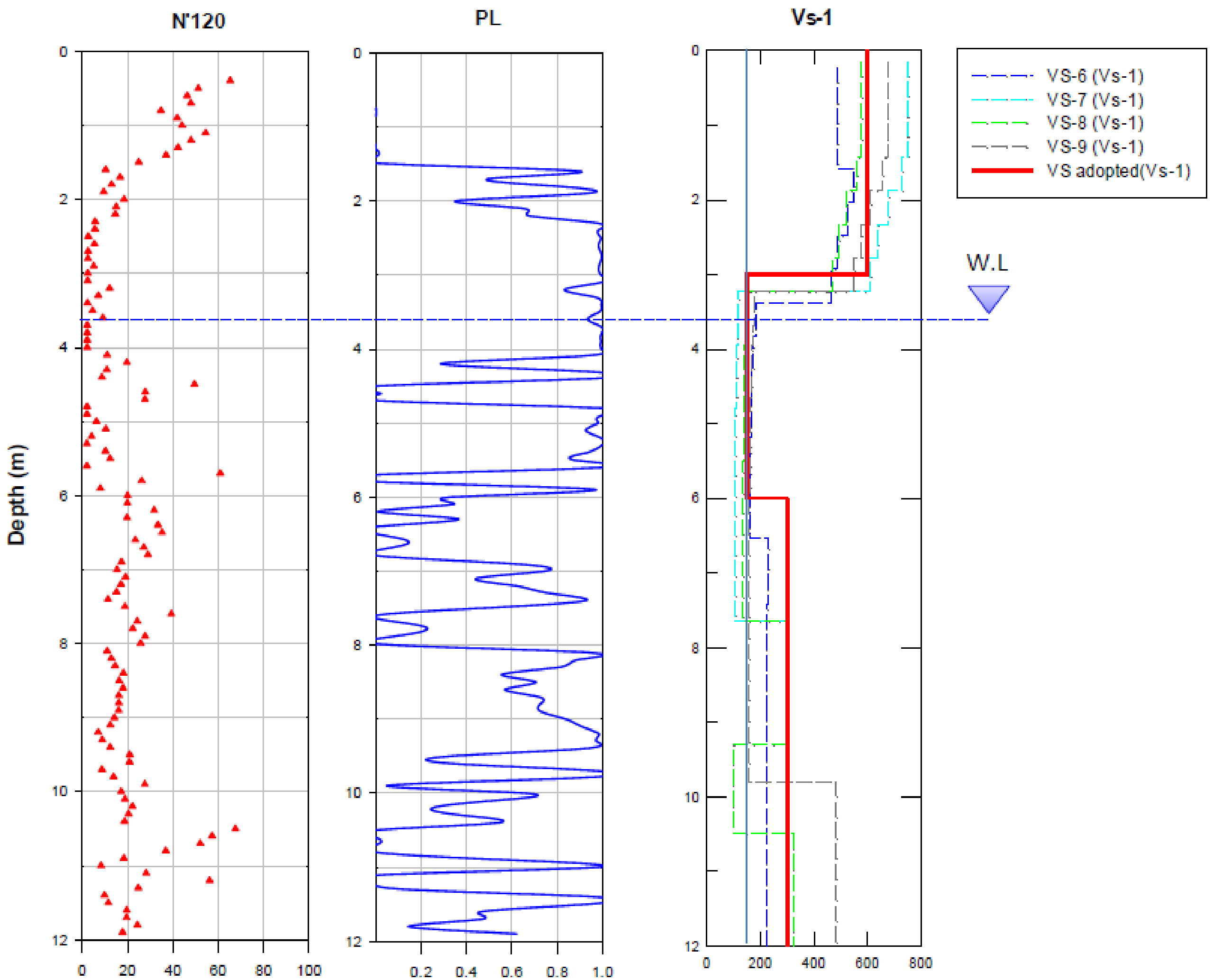
- PGA of 0.60 g
- 7 DPT soundings

(150 kg weight-0.67m)

- Energy Measurements
- 7 Vs profiles from MASW

Courtesy GeoEStudios, Prof. Xavier Vera-Grunauer

Manta Port, M_W7.8 Ecuador EQ



Courtesy GeoEStudios, Prof. Xavier Vera-Grunauer

Lixouri & Argostoli Ports, Cephalonia Earthquake

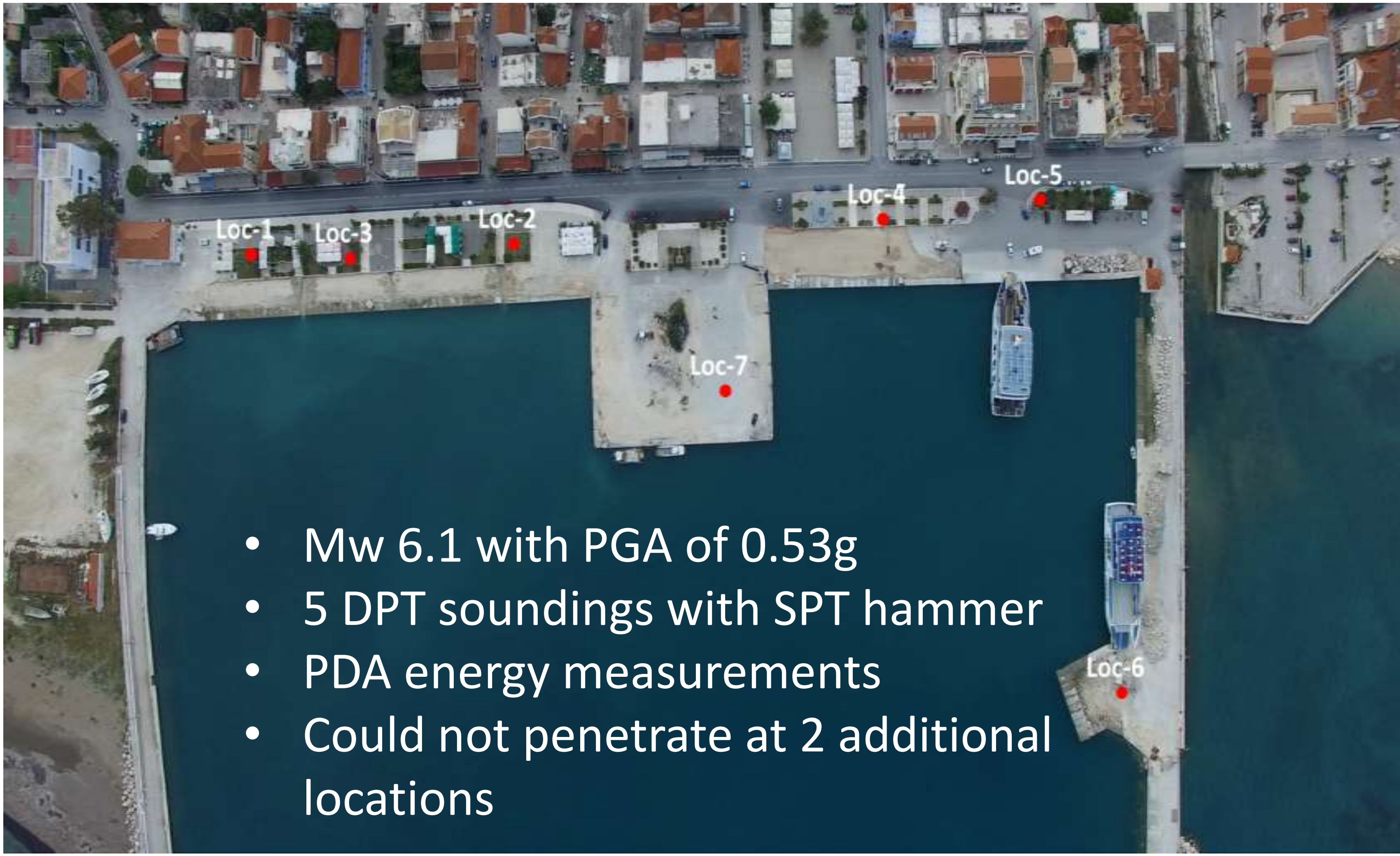
Lixouri & Argostoli Ports, Cephalonia Earthquake

2014 M6.1 Cephalonia Earthquake

Lateral Spreading at port

Sand and gravel ejecta

Lixouri Port, Cephalonia Earthquake



- Mw 6.1 with PGA of 0.53g
- 5 DPT soundings with SPT hammer
- PDA energy measurements
- Could not penetrate at 2 additional locations

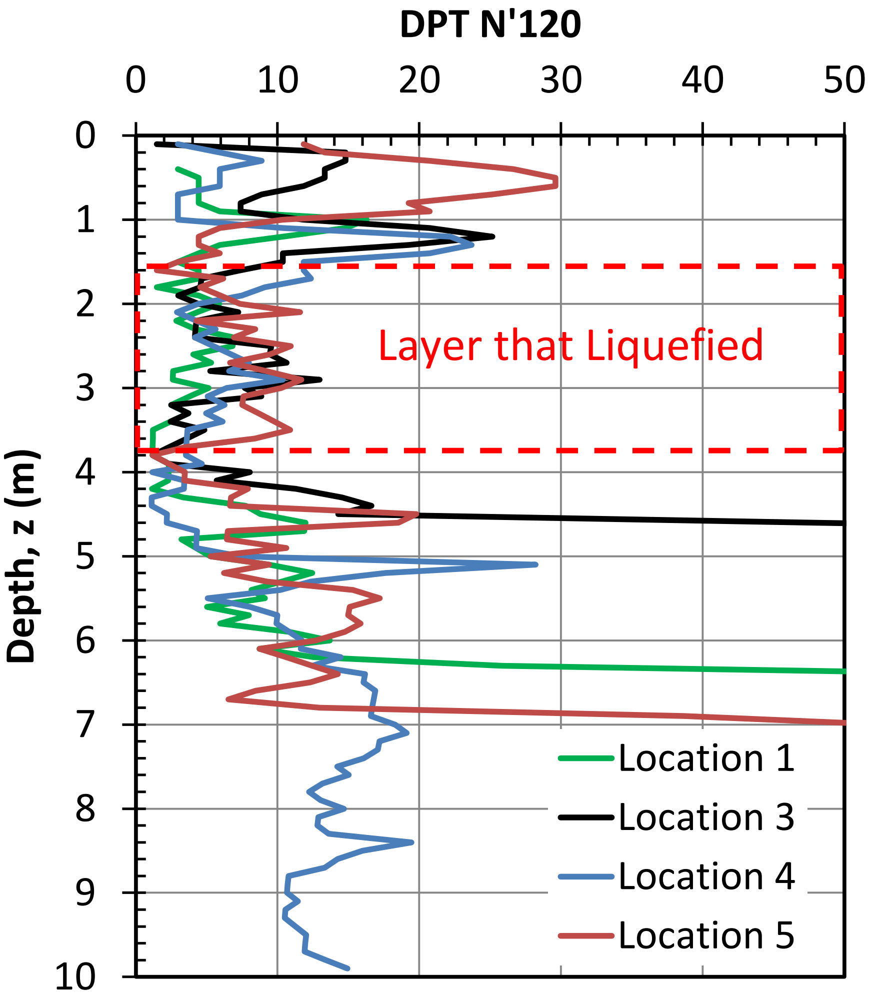
Collaboration with Profs. Adda and Dimitrios Zekkos, Univ. of Michigan

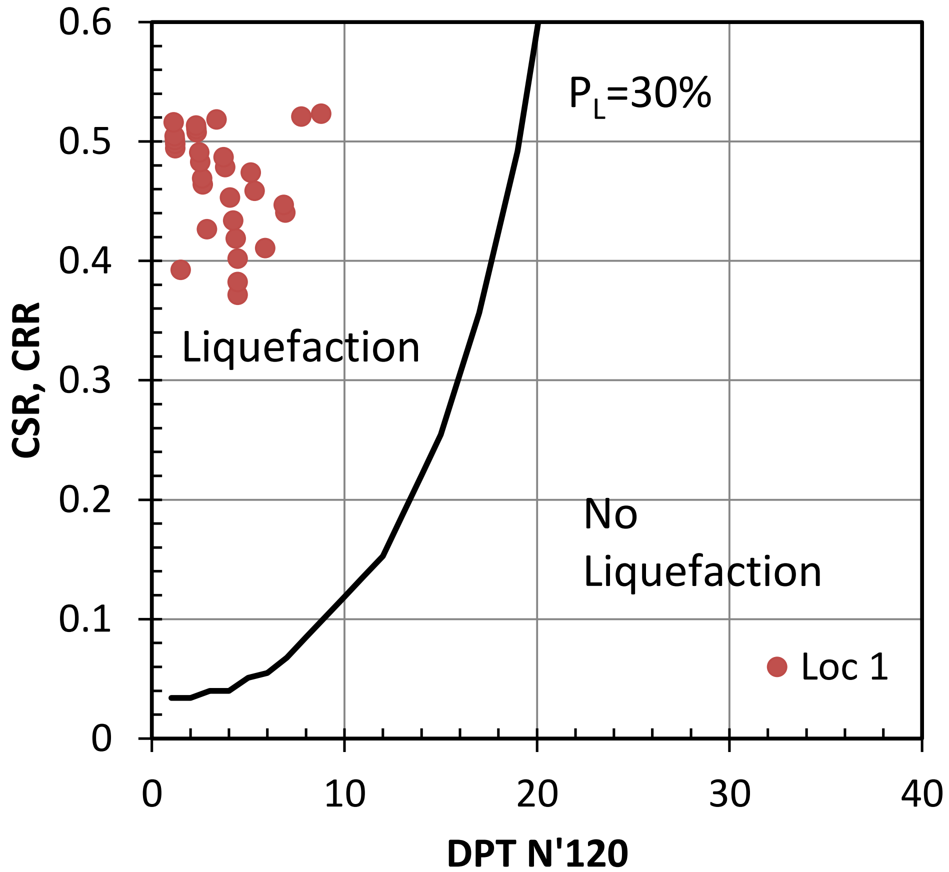
DPT Testing at Lixouri Port
Cephalonia Greece

Track-mounted penetrometer

PDA Energy Measurement

Results from DPT at Lixouri Port

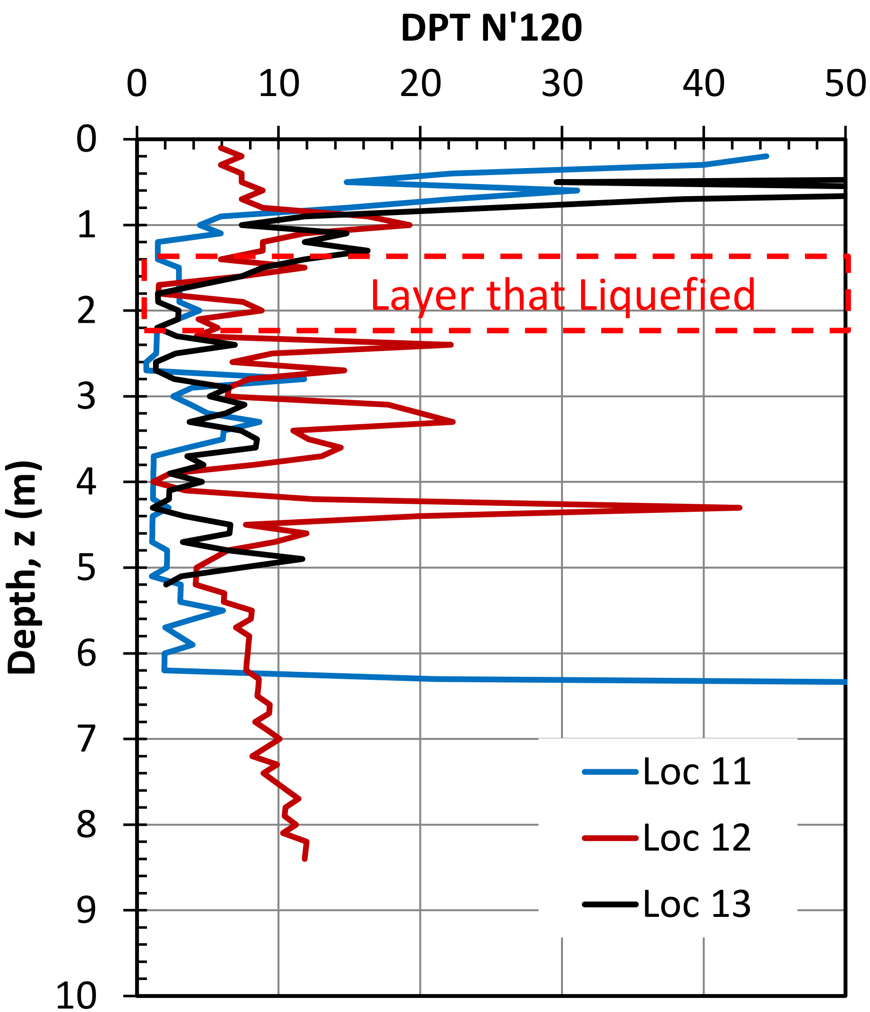


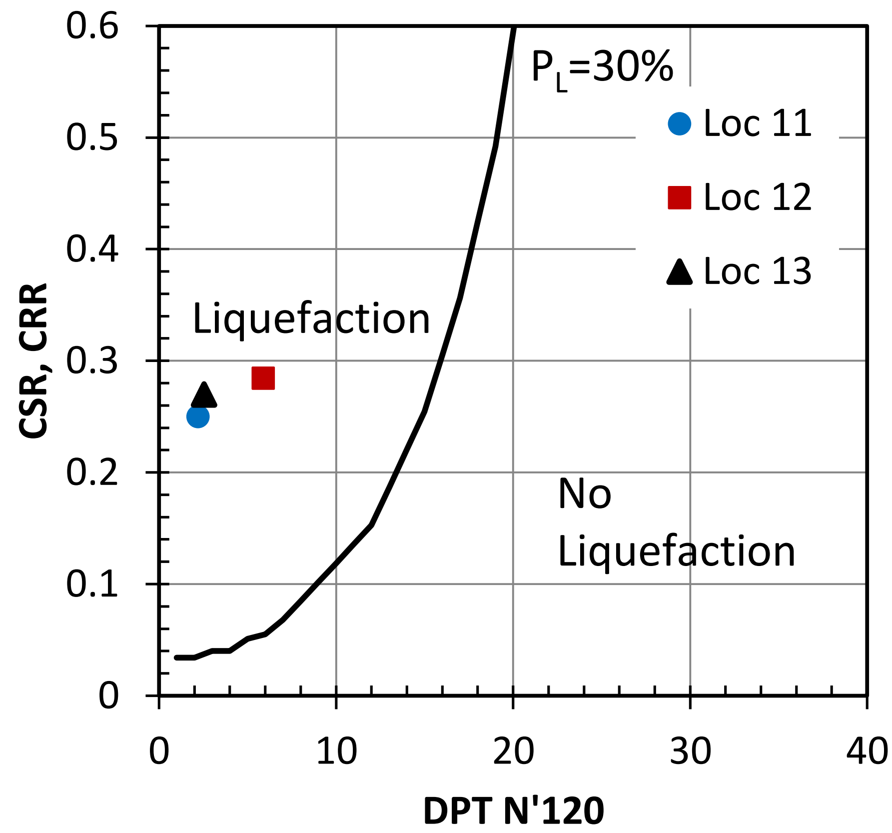


Argostoli Port, Cephalonia Earthquake

- M_W6.1 with PGA = 0.35g
- 4 DPT holes at 3 sites
- PDA measurements

Results from DPT at Argostoli Port

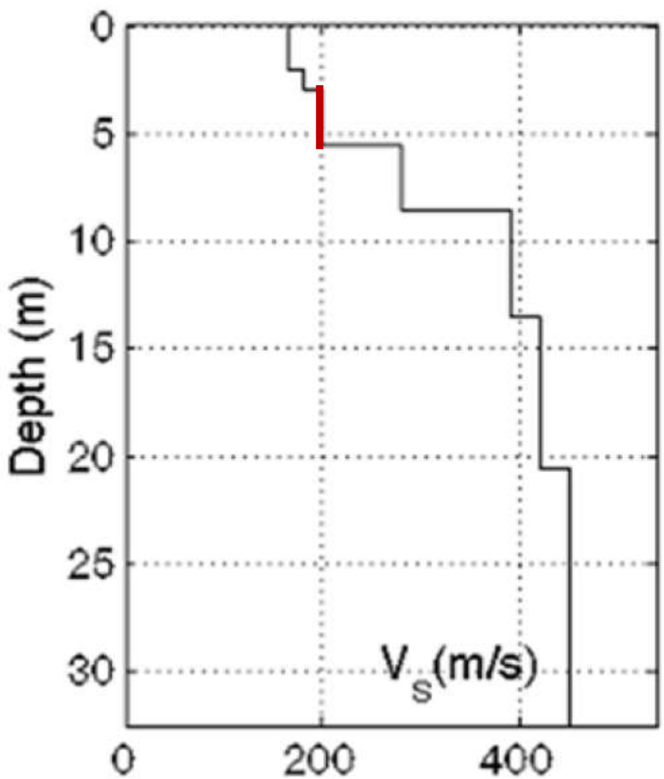




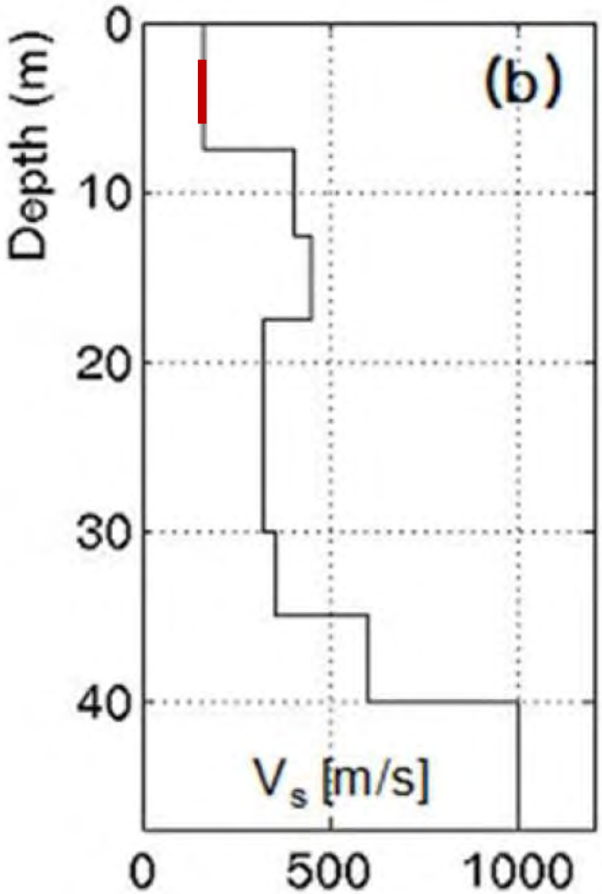
MASW Shear Wave Testing

Prof. Dimitrios Zekkos, Univ. of Michigan

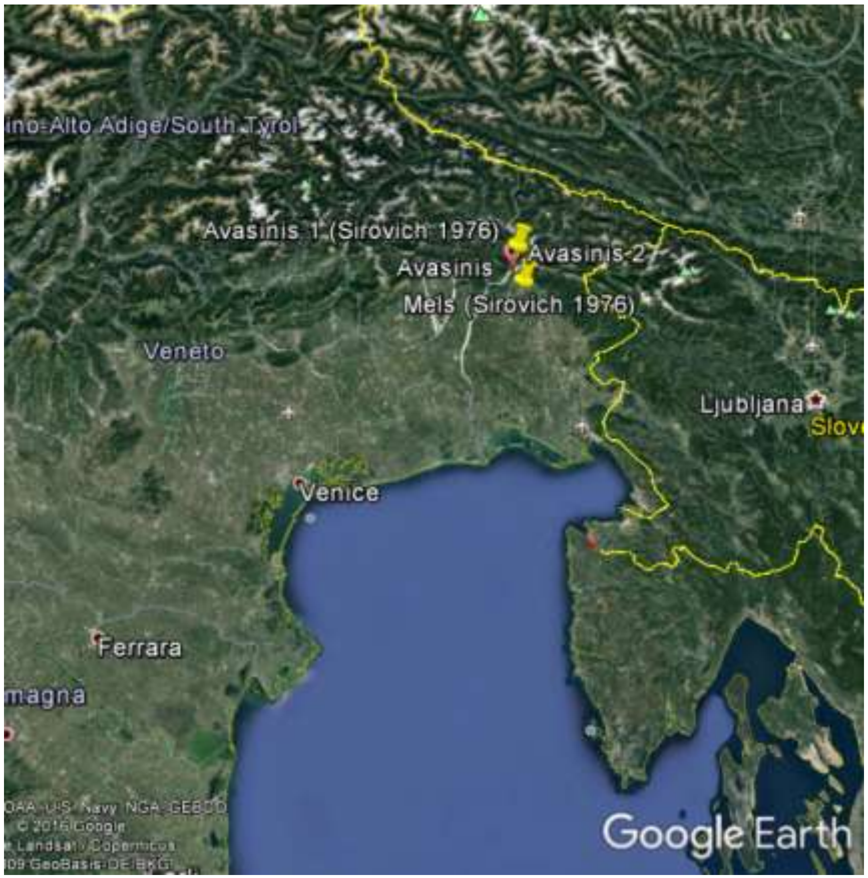
Lixouri Port, Cephalonia Earthquake

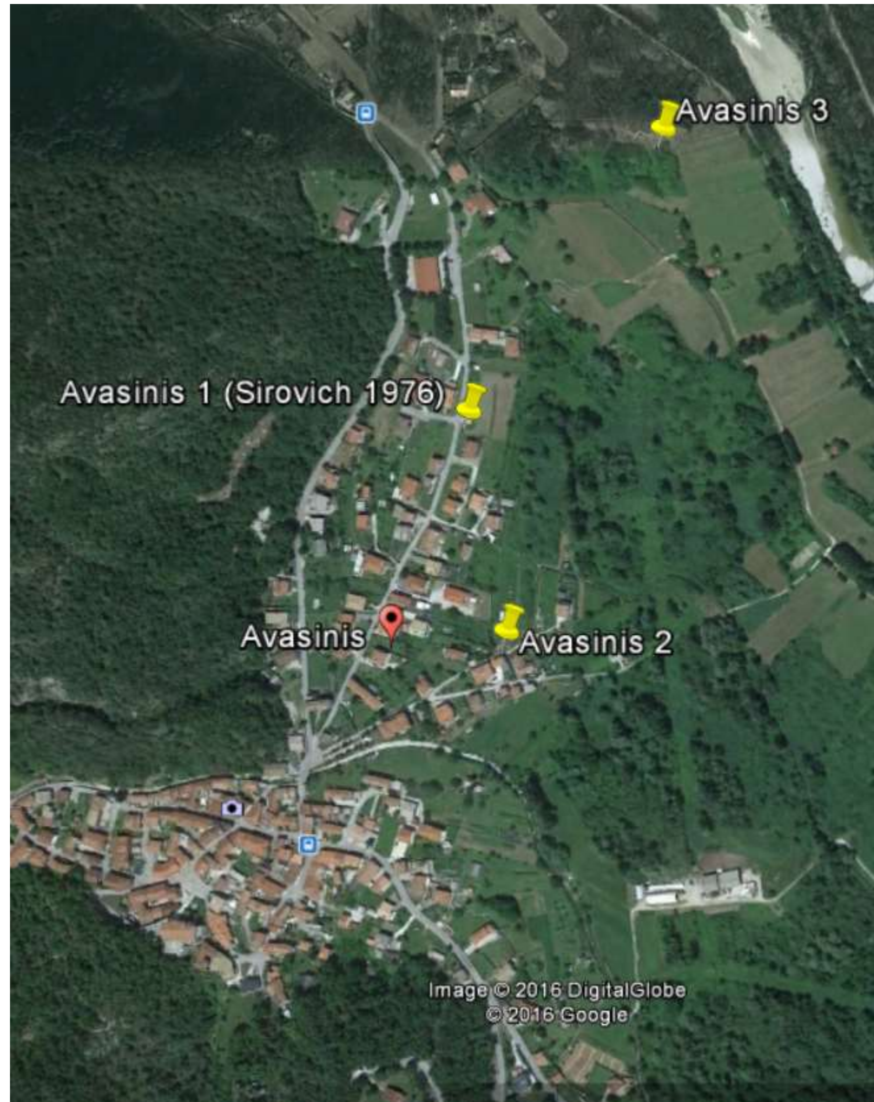


Argostoli Port, Cephalonia Earthquake

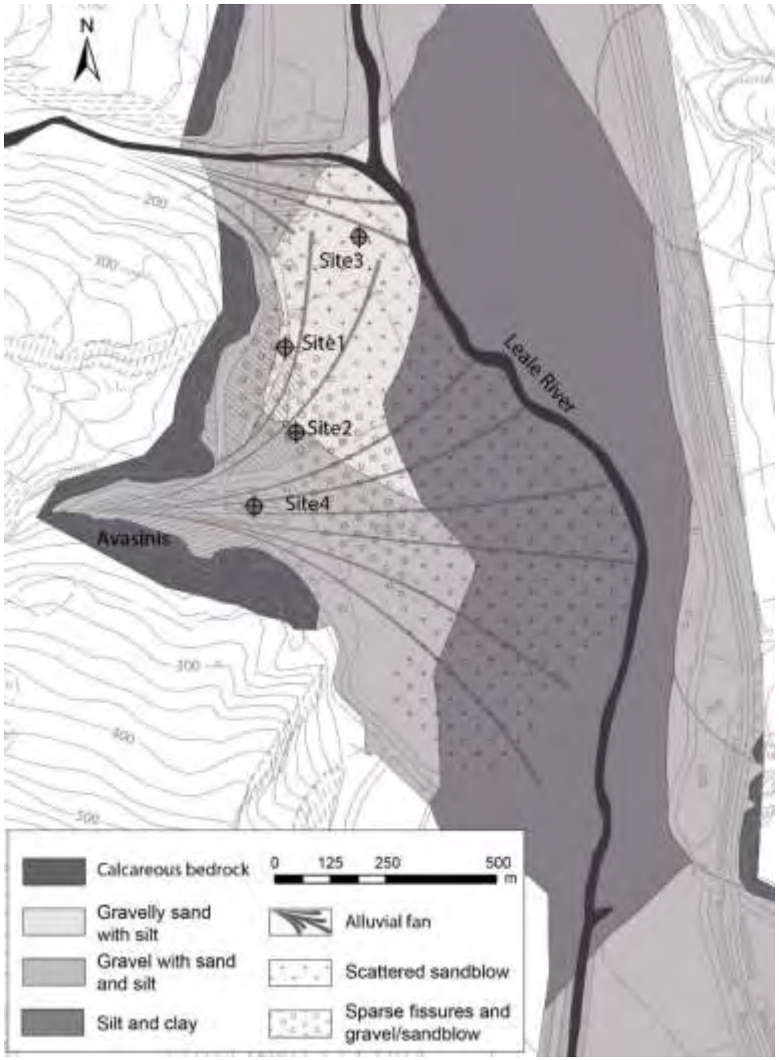


Avasinis, Italy (1976 Friuli Earthquake)





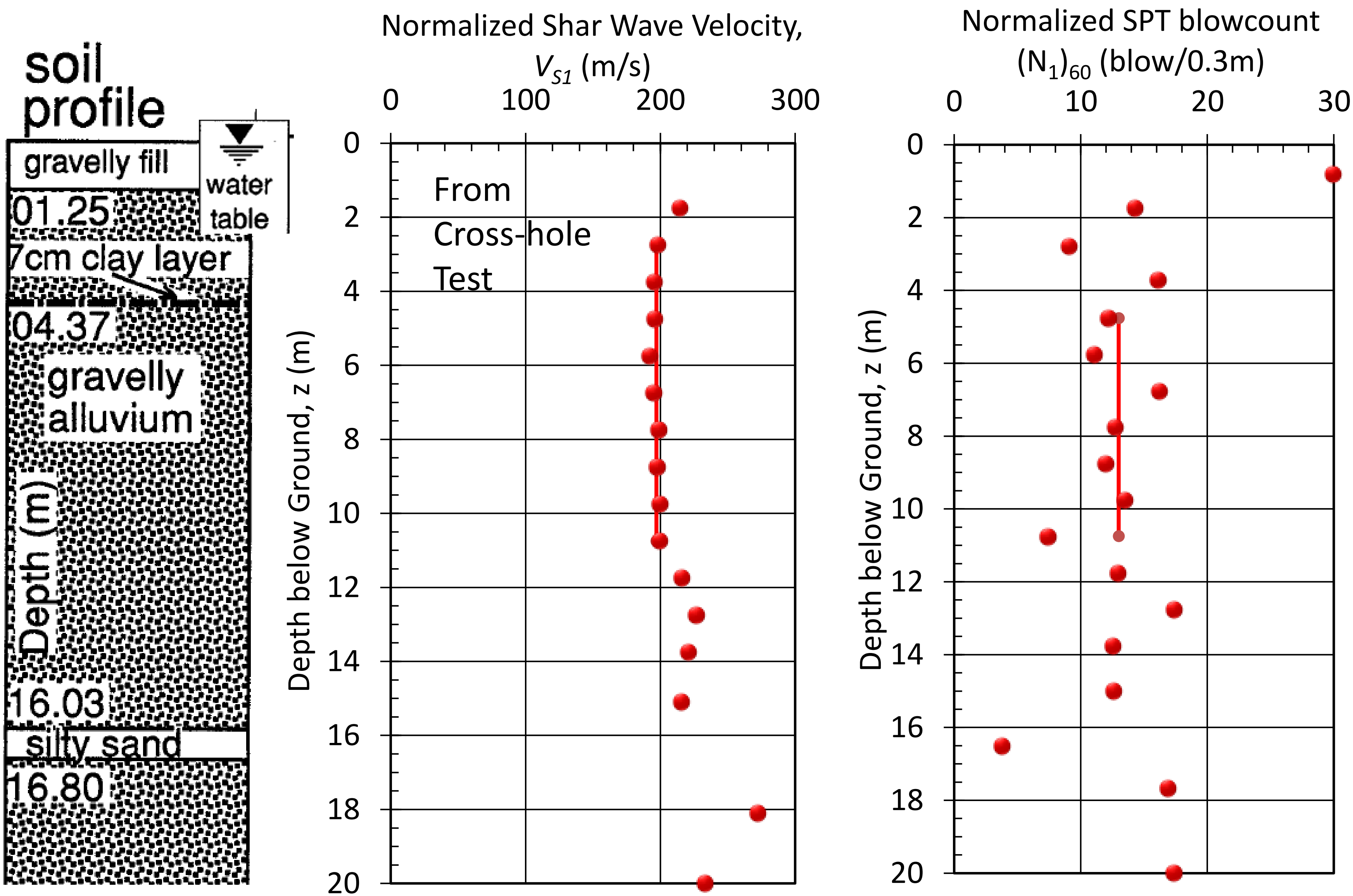
Avasinis, Italy (Friuli Earthquake)



- Gravel liquefied in
  Mw 6.5 (May 1976)
  Mw 6.0 (Sept 1976)
  Mw 5.6 (Sept 1977)
- Three test sites liquefied and one site did not.
- DPTs at two hammer energies per site

Gravelly Sand Ejecta (Friuli Earthquake)

Avasinis, Italy (Friuli Earthquake)



Range of Grain Size Distribution Curves

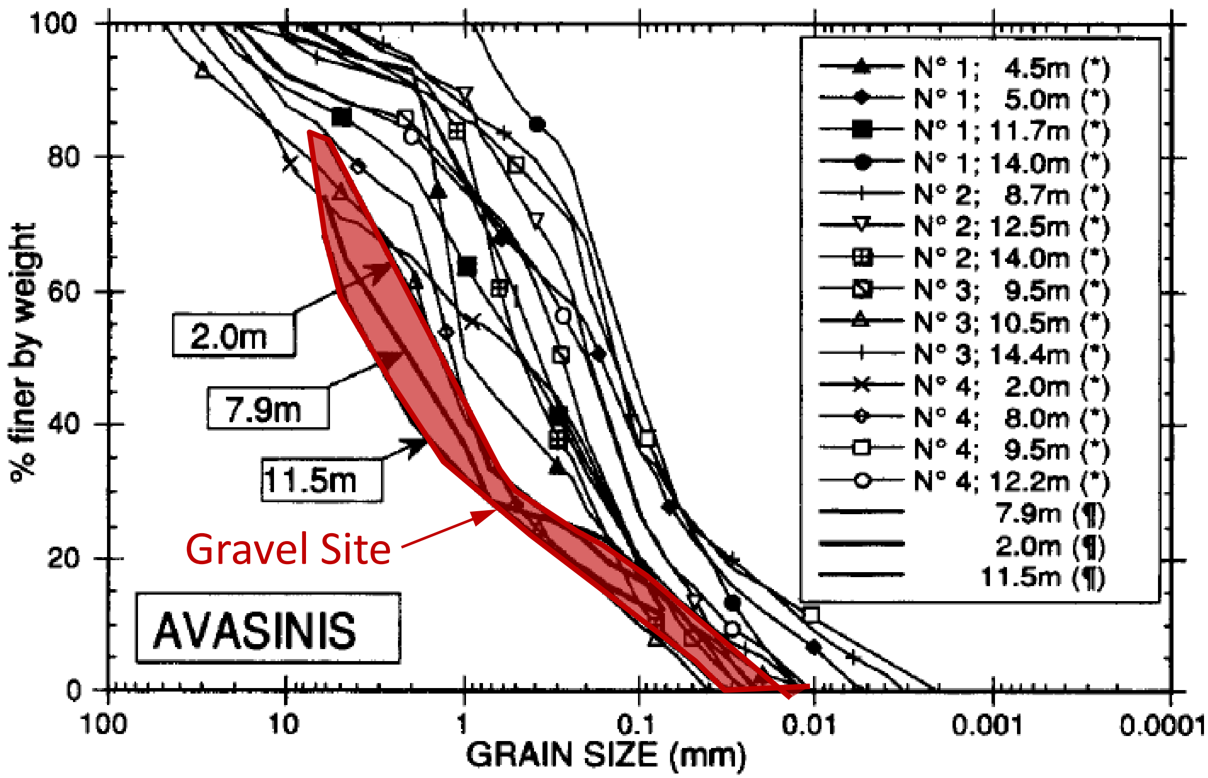


Fig. 5. Grain size distributions of Avasinis sediments: (*): four sites from F. Sgobino (private communication), liquefied or suspected of liquefaction. (¶): from the site investigated in the present study, extensive liquefaction

Photo of Core Samples

DPT Testing at Avasinis

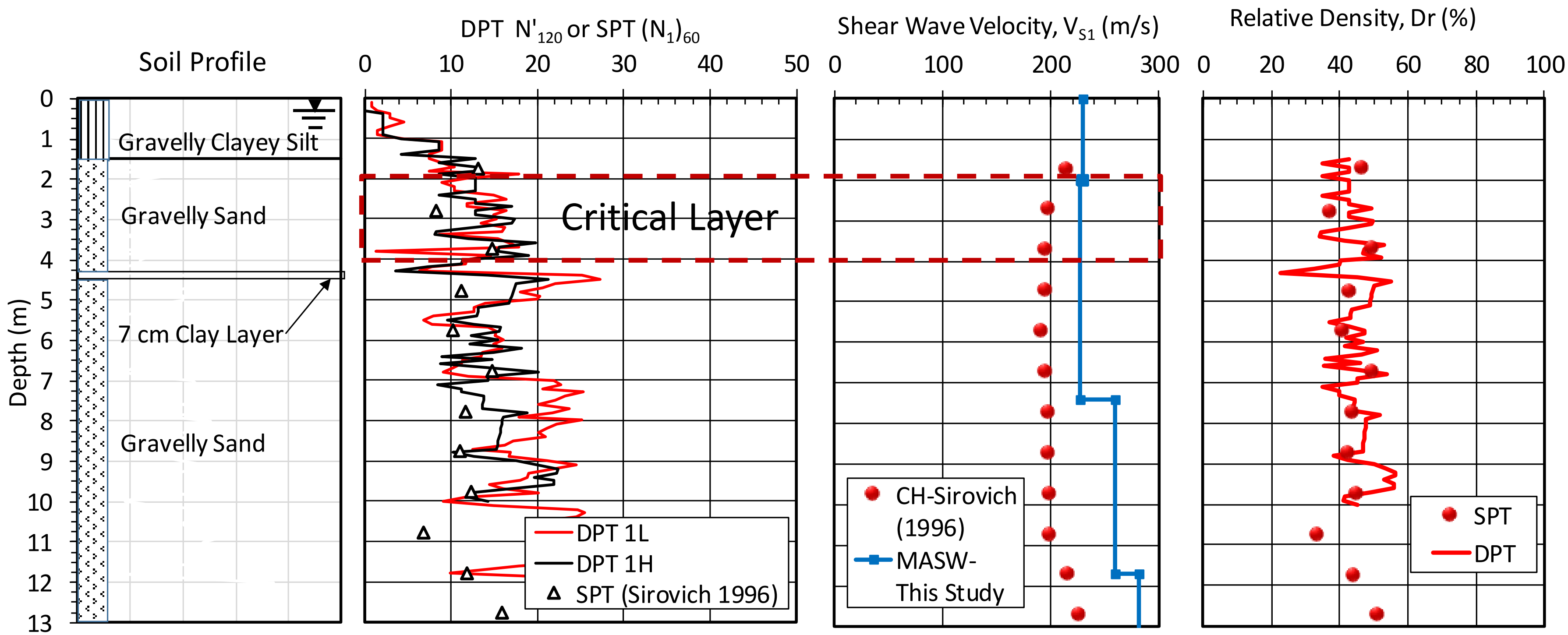
Testing with 154 kg Hammer-0.67 m drop

PDA Testing – 75% energy transfer

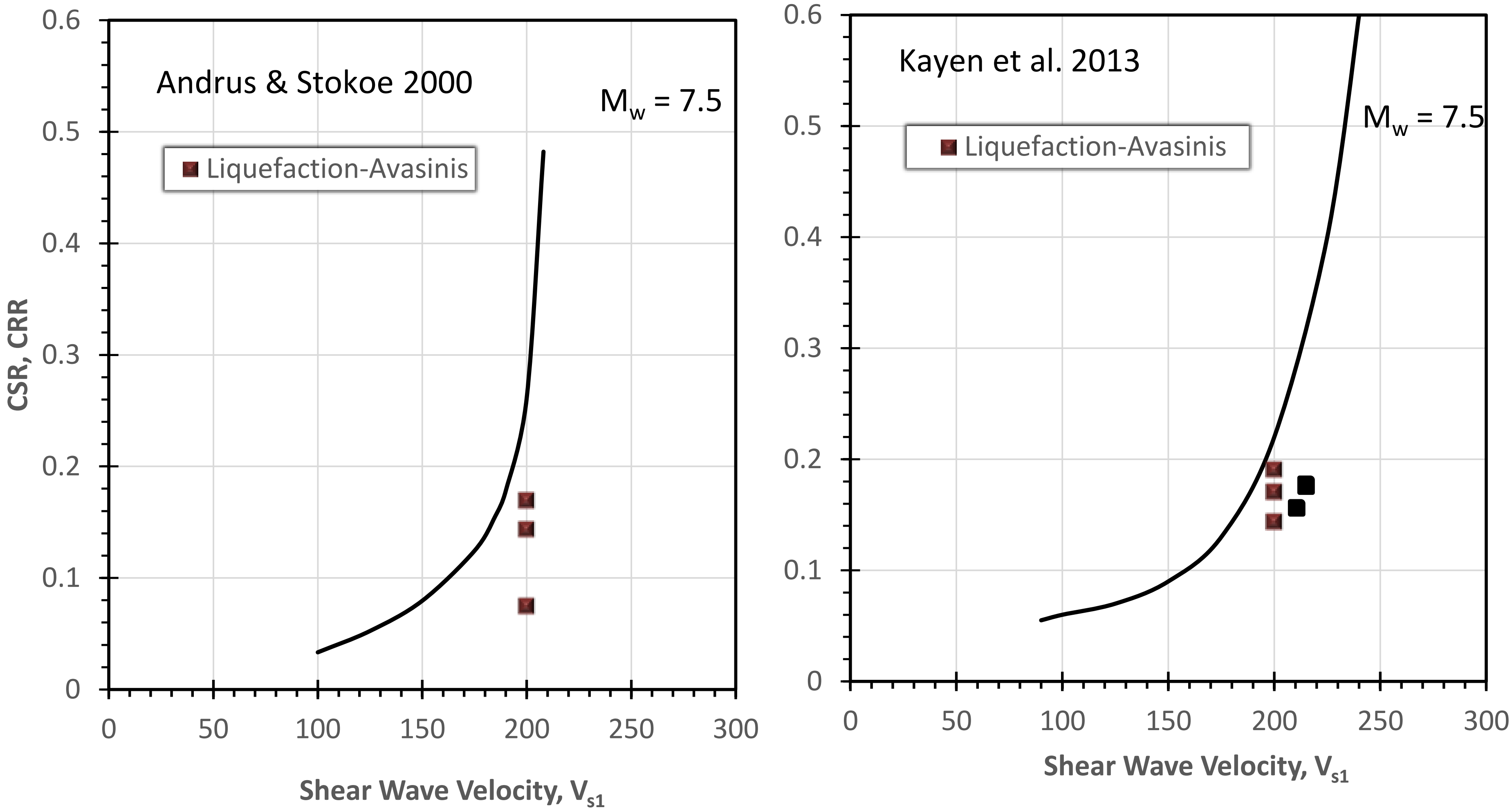
MASW Testing Friuli Earthquake

Collaboration with INGV (Italian Institute for Geophysics and Volcanology)

Avasinis, Italy M_w6.1 Friuli Earthquake

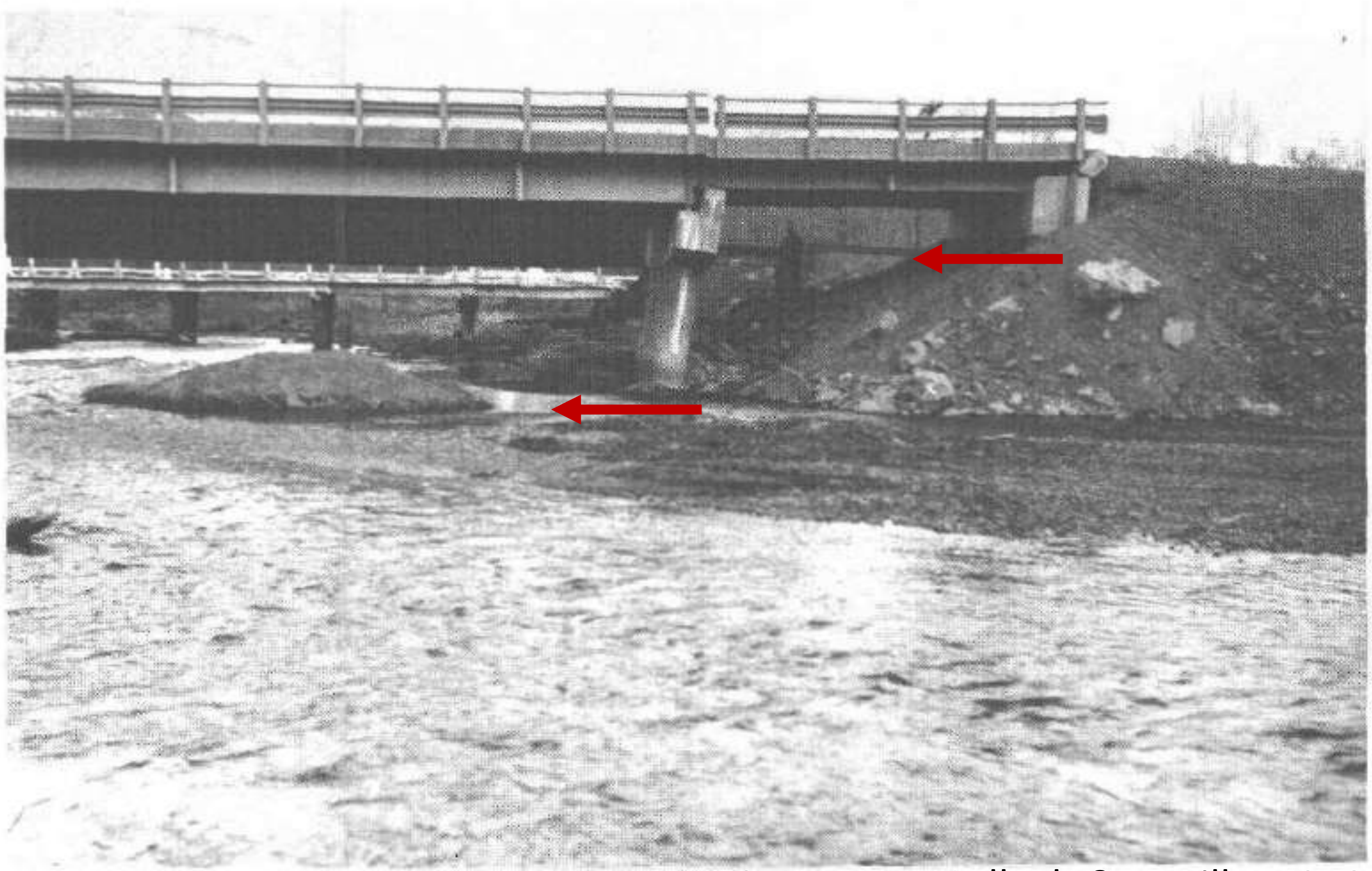


Avasinis, Italy Vs Triggering Curves



Seward, Alaska (1964 Alaska Earthquake)

Seward, Alaska (1964 Alaska Earthquake)



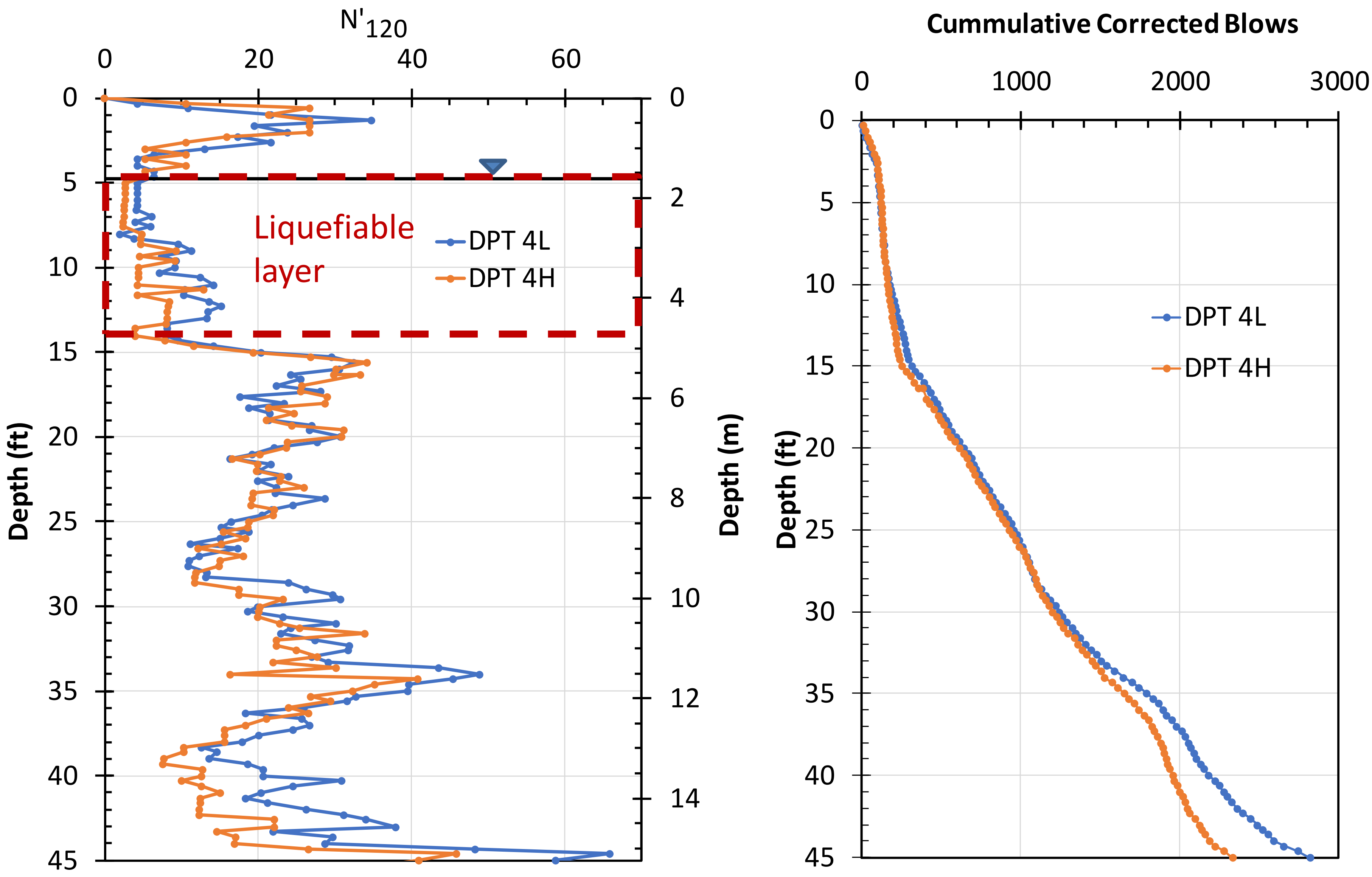
Source: McCulloch & Bonilla, 1970

Lateral spreading compressed the deck and displaced bent towards river

Seward, Alaska M_w9.2 Earthquake

- 8 DPT holes to 50 ft in less than 2 days
- PDA Energy measurements
- 2 hammer energies at each of four sites
- Nearby cross-hole V_s measurements

Seward, Alaska Resurrection River



Seward Alaska Resurrection River

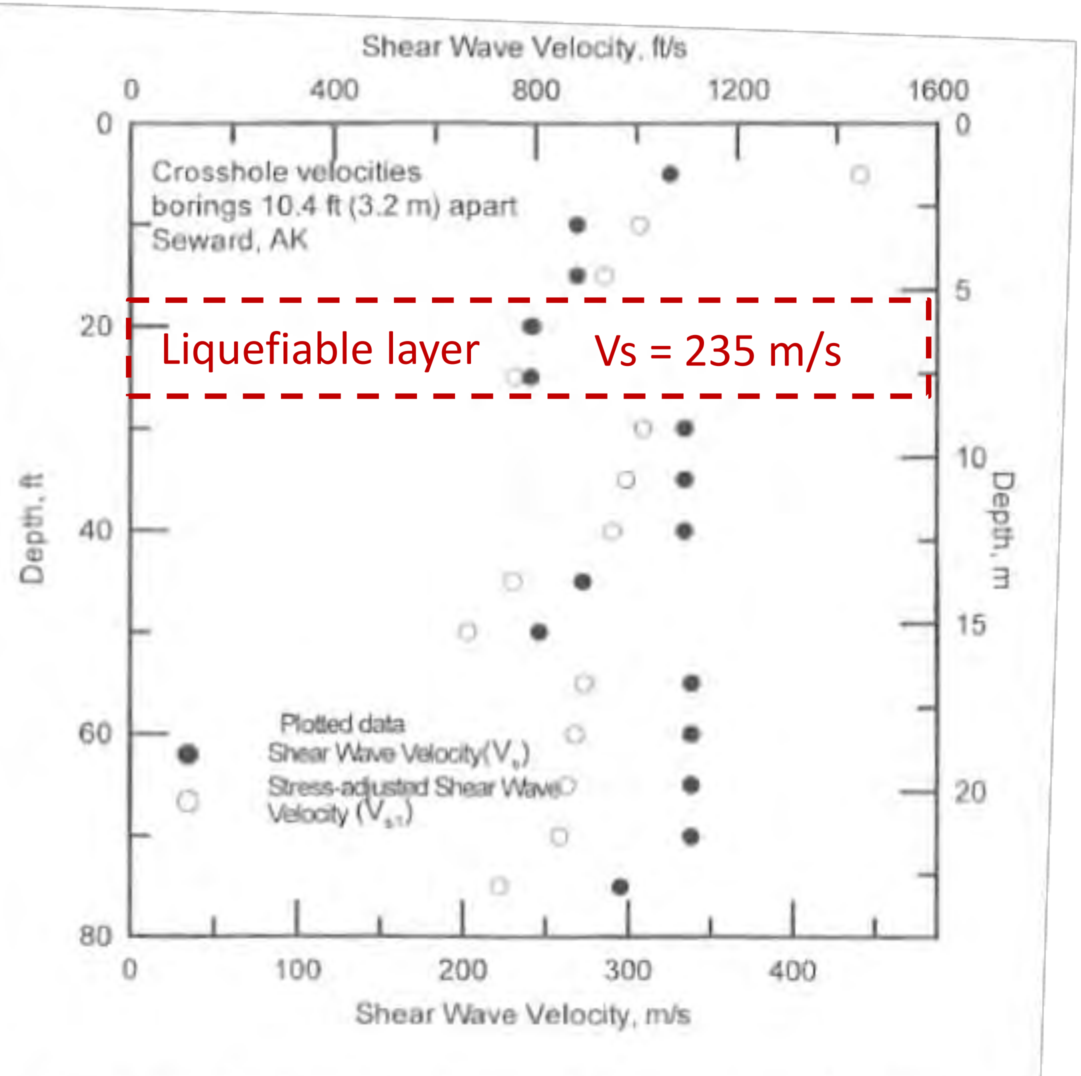
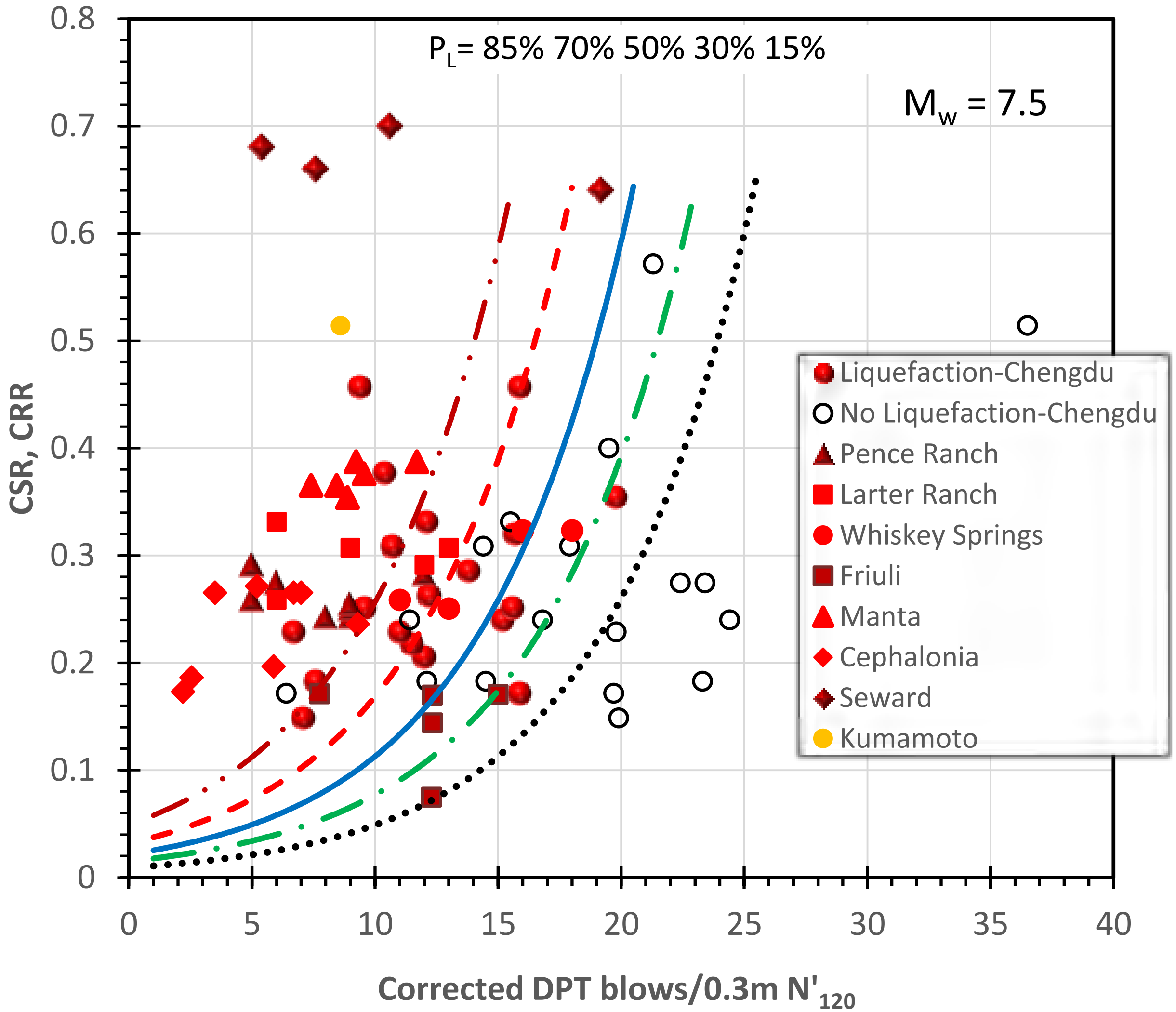
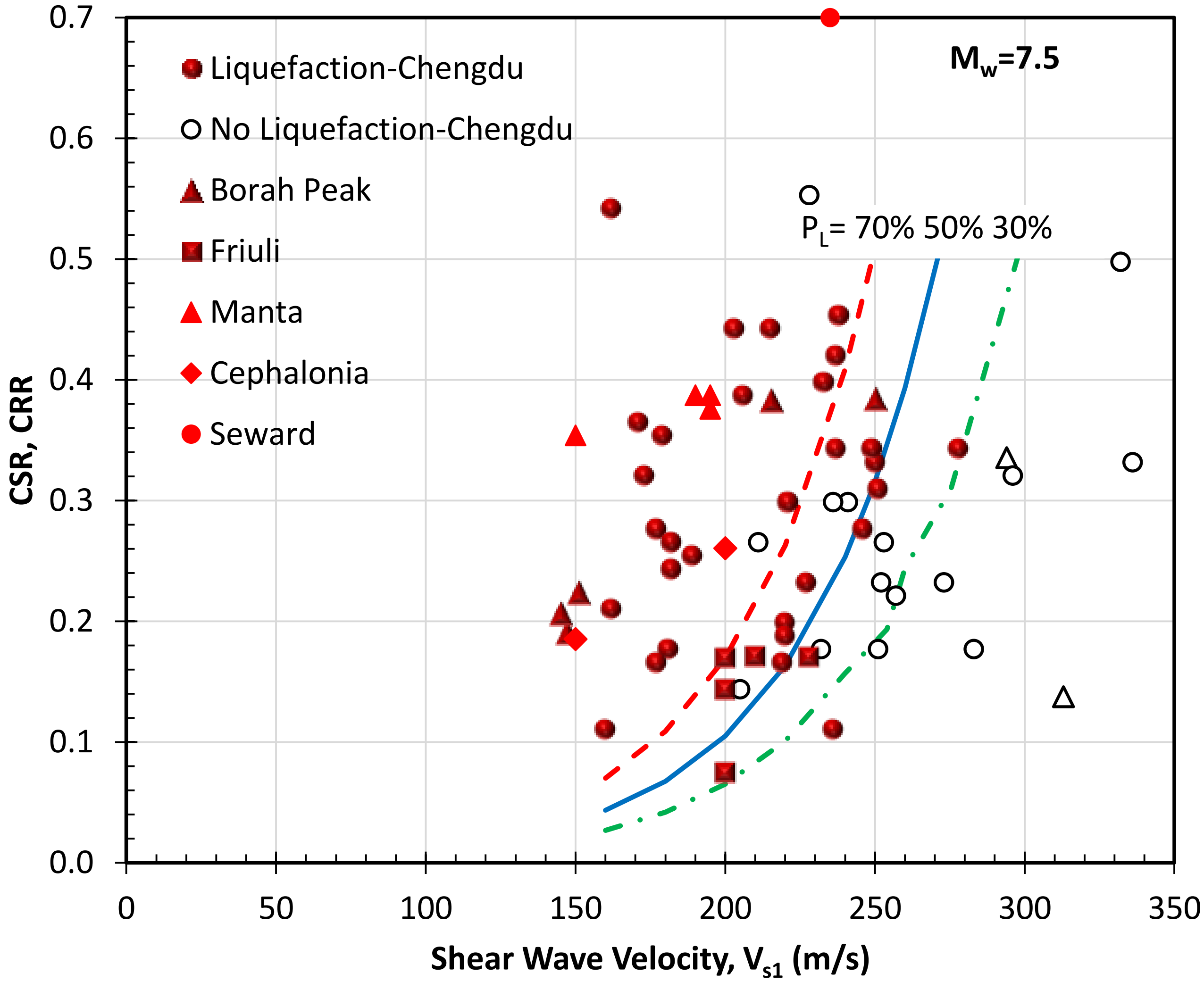


Figure 7. Crosshole Shear Wave Velocities Measured at Seward Test Site 1

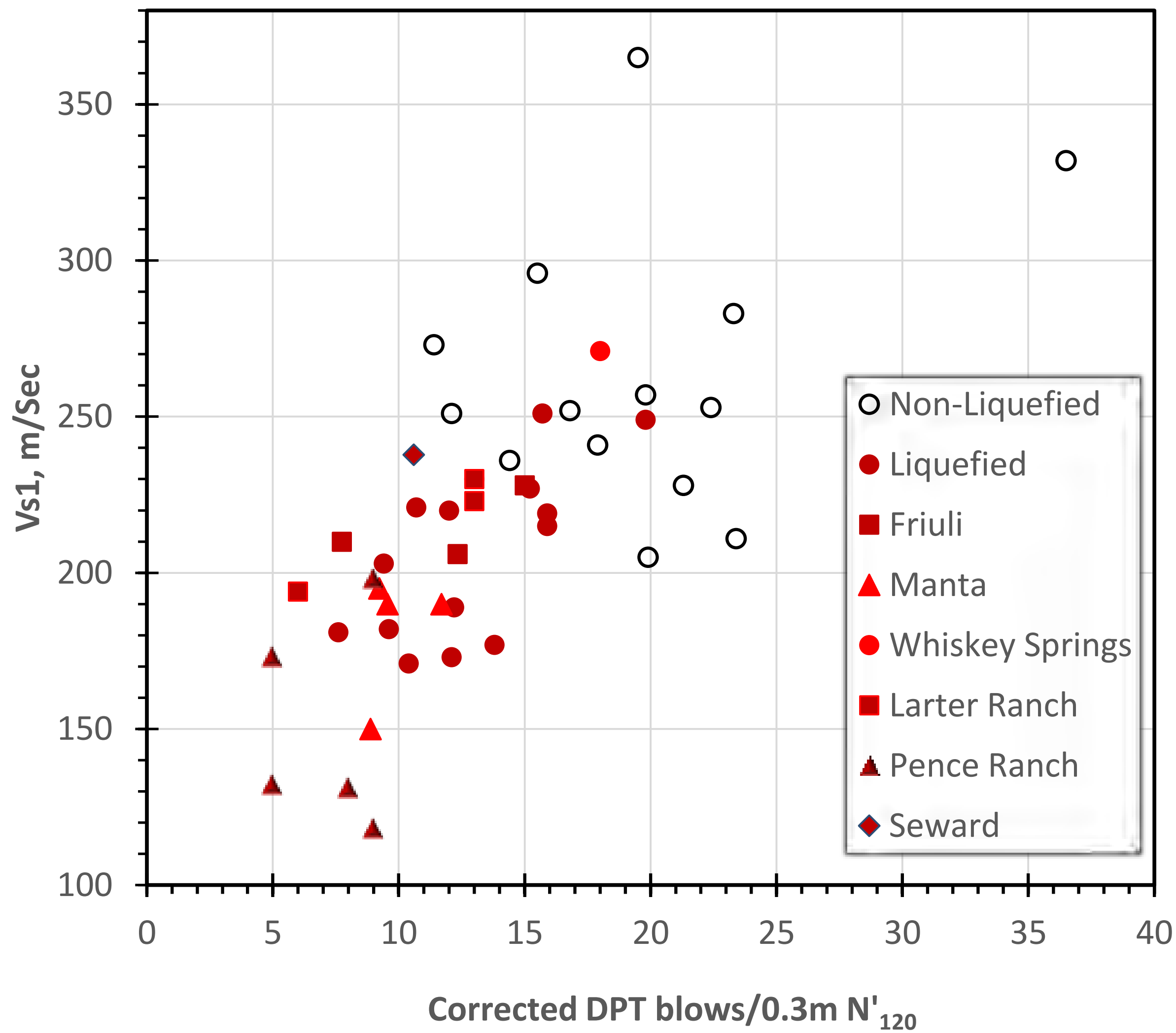
Summary of DPT Results All Sites



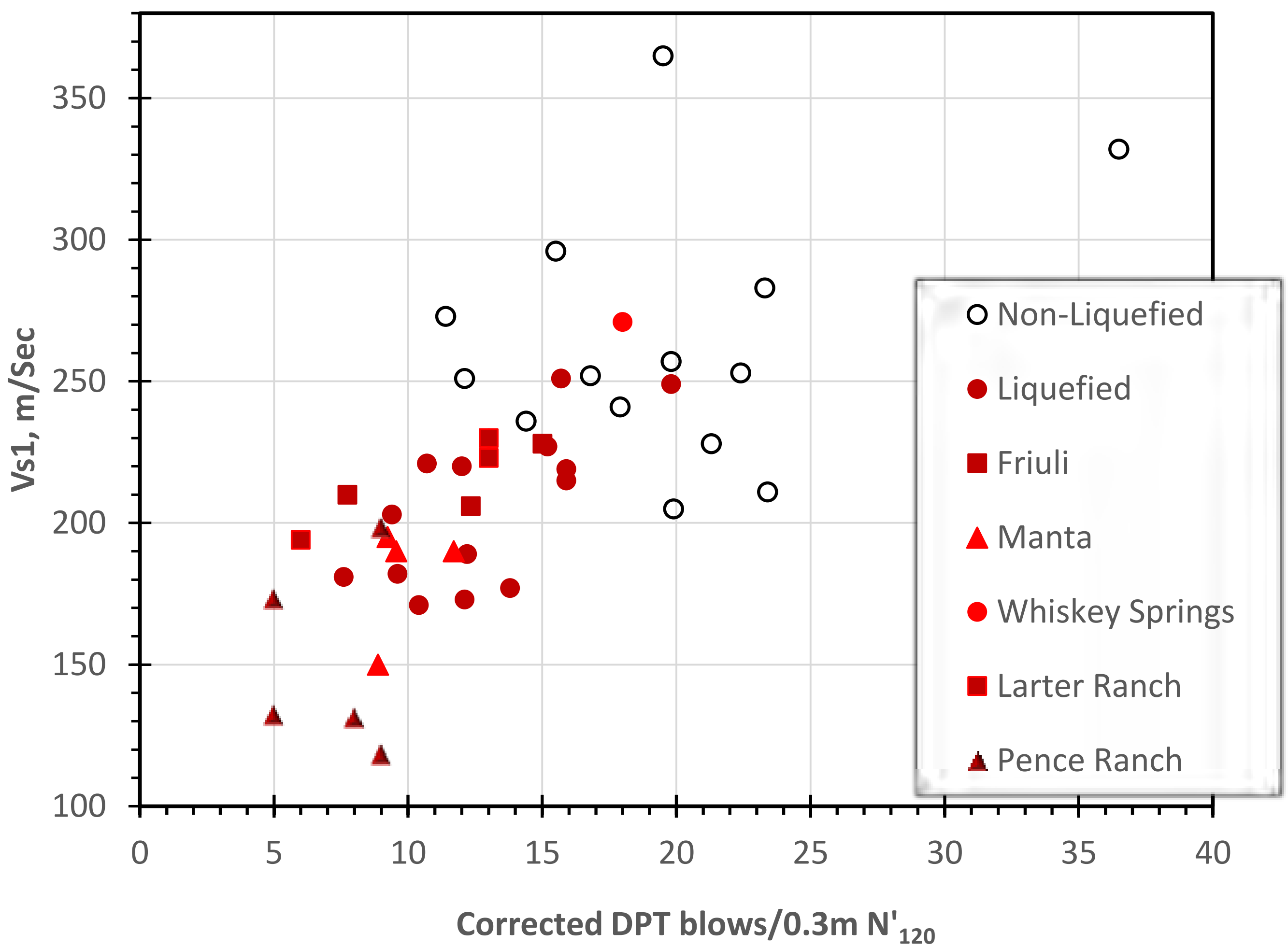
Summary of V_{s1} Results All Sites



V_{s1} vs DPT N'_{120} For all Data



V_{s1} vs DPT N'_{120} For all Data



Preliminary Conclusions

- With energy and magnitude corrections, DPT yields liquefaction factors of safety comparable to BPT.
- DPT results to date correctly estimate liquefaction triggering at sites where gravels have liquefied.
- DPT can generally penetrate gravels with lower SPT hammer energy, but correlations less reliable for higher density and larger gravel particle size
- Chinese DPT can provide a simpler, more economical, approach for evaluating liquefaction in gravel relative to the Becker penetration test (BPT).

Questions?

Hazard Mapping Update

Ben Erickson

February 12, 2018

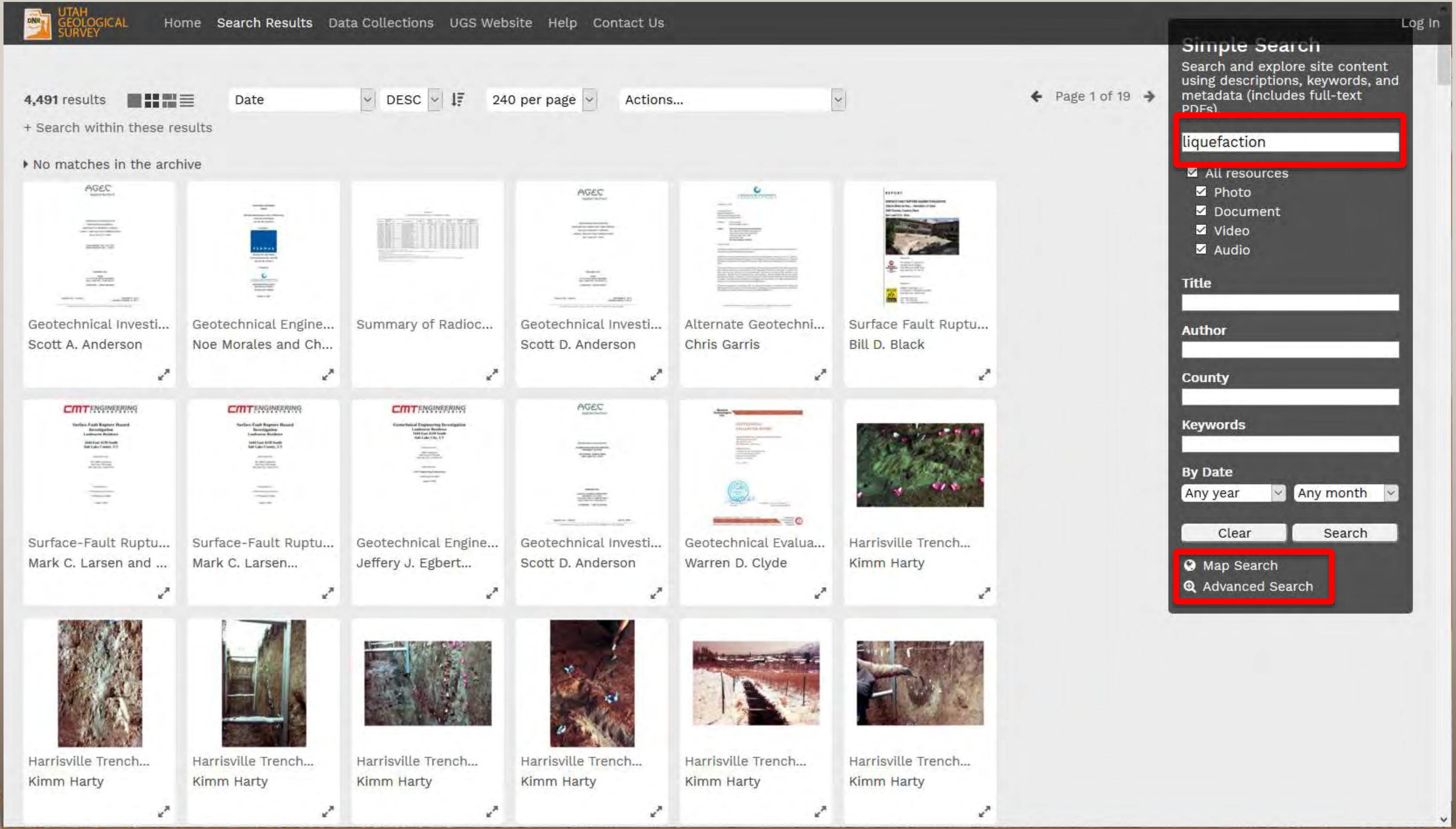
Hazard Mapping Overview

- Gather Area Data
  - Geologic Maps
  - Historic Records
  - Available GIS
  - Review Our Archives
  - Available State Data

- Build Relationships with local government
- Collect Report from local government
- Review federal data (FEMA, NRCS, Etc)

UGS Archive

https://geodata.geology.utah.gov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Chris Garris
Surface Fault Ruptu...
Bill D. Black
Surface-Fault Ruptu...
Mark C. Larsen and ...
Surface-Fault Ruptu...
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Geotechnical Engine...
Jeffery J. Egbert...
Geotechnical Investi...
Scott D. Anderson
Geotechnical Evalua...
Warren D. Clyde
Harrisville Trench...
Kimm Harty
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liquefaction
All resources
Photo
Document
Video
Audio
Title
Author
County
Keywords
By Date
Any year
Any month
Clear
Search
Map Search
Advanced Search

Geotechnical Database

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	GEOTECH	PROJ_NO	DATE	NAME_OR_AD	Quad	LATITUDE	LONGITUDE	MAX_DEP	No_Explo	GEOLOGIC	POINT_ID	SMPL_DP	USCS	GW_dept	LL	PI	DD	MOISTURE	SCT	Bedrock/	Sulfate	pH	NOTES
9036	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Na	40.390143	-111.88851	5	13	Qaly	TP-2	1	CL	4.5									
9037	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Na	40.390082	-111.890741	8.5	13	Qlmp	TP-3	5	CL	7.5									
9038	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Narrows			8.5	13	Qlmp	TP-3	6.5	SM	7.5	21			14					
9039	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Na	40.390703	-111.887176	6.5	13	Qlmp	TP-4	1.5	CL	5									
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9051	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Na	40.394611	-111.892626	9	13	Qlmp	TP-10	1.5	CL	8.5									
9052	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Narrows			9	13	Qlmp	TP-10	2	CL	8.5	35	16		12					
9053	Earthtec	140491	6/9/2014	GEOTECHNICAL STUDY '	Jordan Na	40.394162	-111.890527	8.5	13	Qlmp	TP-11	1.5	CL	8									
9054	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Na	40.438248	-111.884909	11	22	Qlsb	TP-1	0.5	CL/ML	NGWE									
9055	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			11	22	Qlsb	TP-1	2	CL/ML	NGWE			102	19					
9056	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			11	22	Qlsb	TP-1	6	GM	NGWE									
9057	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Na	40.437311	-111.884931	12	22	Qlsb	TP-2	0.5	CL/ML	NGWE									
9058	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			12	22	Qlsb	TP-2	4	GM	NGWE									
9059	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			12	22	Qlsb	TP-2	6	CL	NGWE									
9060	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Na	40.437976	-111.883773	10	22	Qlsb	TP-3	0.5	CL	NGWE									
9061	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			10	22	Qlsb	TP-3	1.5	GP	NGWE									
9062	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Na	40.436944	-111.884122	12	22	Qlsb	TP-4	0.5	CL/ML	NGWE									
9063	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			12	22	Qlsb	TP-4	7	CL/ML	NGWE			86	5					
9064	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Na	40.437189	-111.88314	11.5	22	Qlsb	TP-5	0.5	CL/ML	NGWE									
9065	AGEC	1010173	3/30/2001	GEOTECHNICAL INVEST	Jordan Narrows			11.5	22	Qlsb	TP-5	1.5	GP	NGWE									

Database Expansion

- Partnering with Weber State University
- Gain Experience
  - GIS
  - Database entry
  - Geologic data
  - Engineering reports
- Expedite entry time

WEBER STATE UNIVERSITY

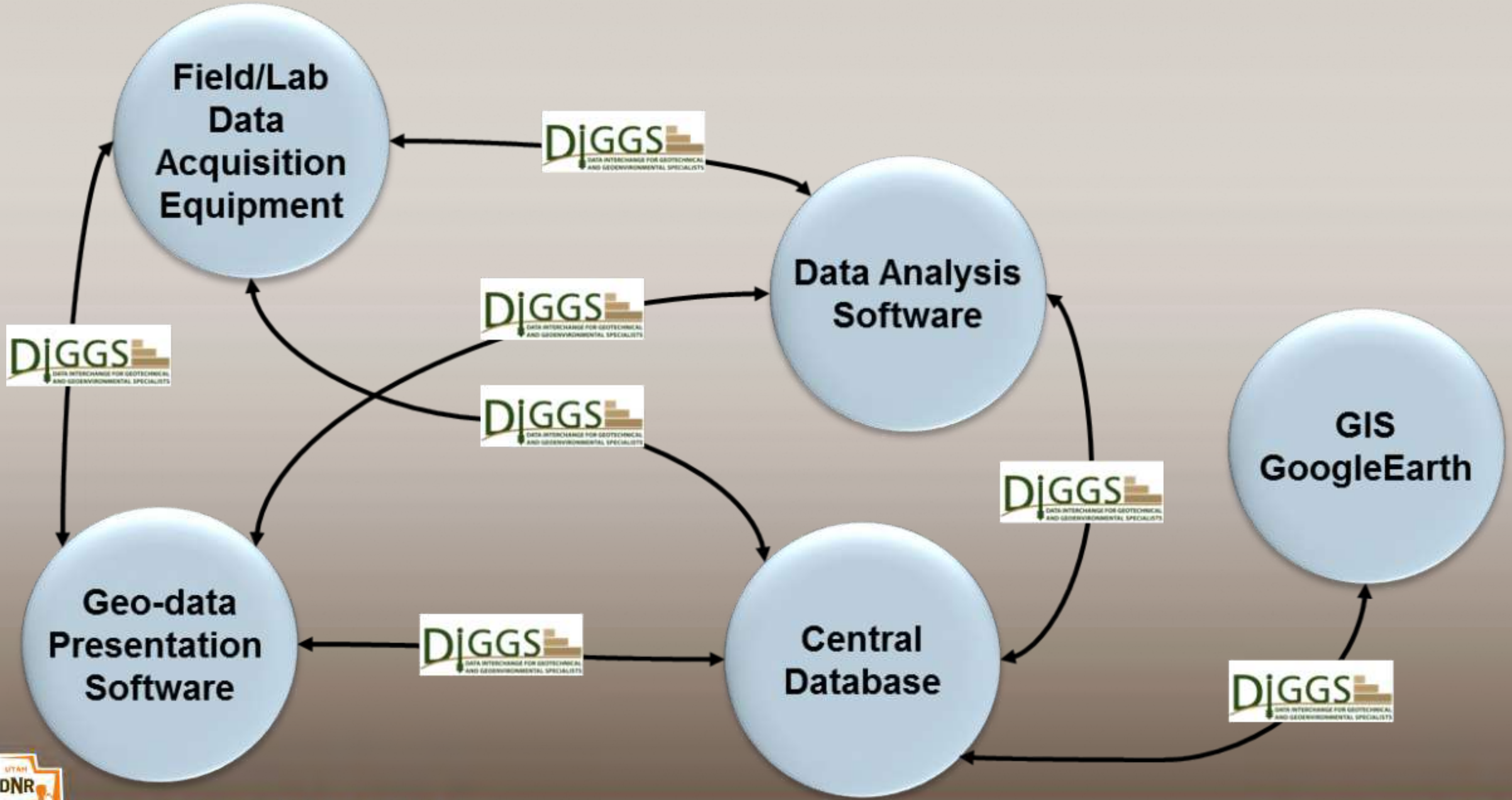
UDOT Partnership

- Pilot project to extract subsurface data from boring and test pits
  - Soil/Rock units & classification
  - Groundwater depth
  - SPT Counts
  - Laboratory Data (Atterberg limits, consolidation/expansion, shear strength)
- A selected area to develop a process of data entry

DIGGS Format

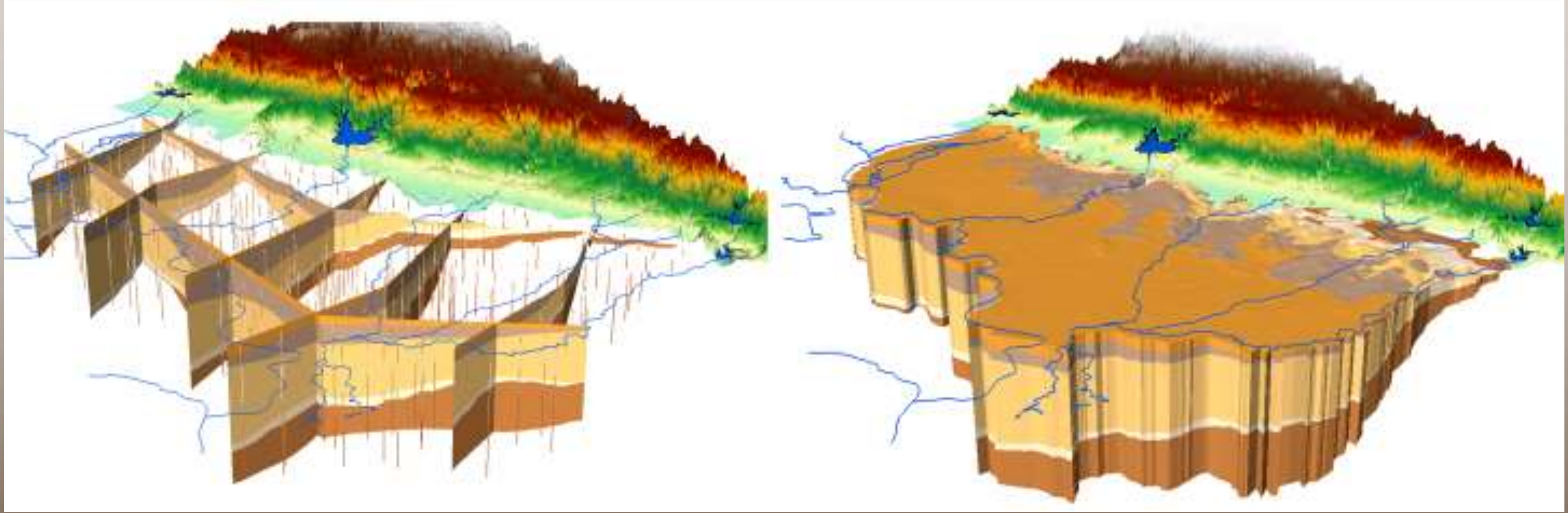
- Data Interchange for Geotechnical and Geoenvironmental Specialists Format
- An effort to standardize geotechnical data
  - Developed by government and private organizations
    - United States Federal Highway Administration (FHWA)
    - United Kingdom Highways Agency (UKHA)
    - Eleven United States Departments of Transportation
    - United States Geological Survey (USGS)
    - United States Army Corps of Engineers (USACE)
    - United States Environmental Protection Agency (US EPA)
    - United States Navy (USN)
    - Construction Industry Research and Information Association (CIRIA)
    - United Kingdom Association of Geotechnical and Geoenvironmental Specialists (AGS)
    - Consortium of Organizations for Strong-Motion Observation Systems (COSMOS)
    - The University of Florida
    - The University of New Hampshire
    - Petrochemical Open Standards Consortium (POSC)
    - Major software vendors including Keynetix, gINT, and EarthSoft

- DIGGS is designed to assist anyone who wants to send or receive geotechnical or geoenvironmental information such as owner agencies, companies associated with software and databases, academic institutions, industry organizations
- DIGGS is an electronic data transfer format. It is not:
  - A software product
  - A database structure


Field/Lab Data Acquisition Equipment
Data Analysis Software
GIS GoogleEarth
Geo-data Presentation Software
Central Database
DIGGS

- Converting data to DIGGS
  - Excel plugin tool, Keynetix contact required to obtain the tool (http://www.keynetix.com/diggs/)
  - Website zipped csv files to xml (http://diggsml.org/diggs/)
- Diggs to GIS
  - ArcMap/Pro
  - GoogleEarth

Subsurface Mapping



Summary

- Archive Public Access – More data available to the public
- UDOT – Continuing partnership to increase database
- Better Mapping – The scope and detail of the data will allow for increased understanding of the subsurface

Questions?