MAPPING OF LATERAL SPREAD DISPLACEMENT HAZARD, WEBER COUNTY, UTAH

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THE UNIVERSITY OF UTAH

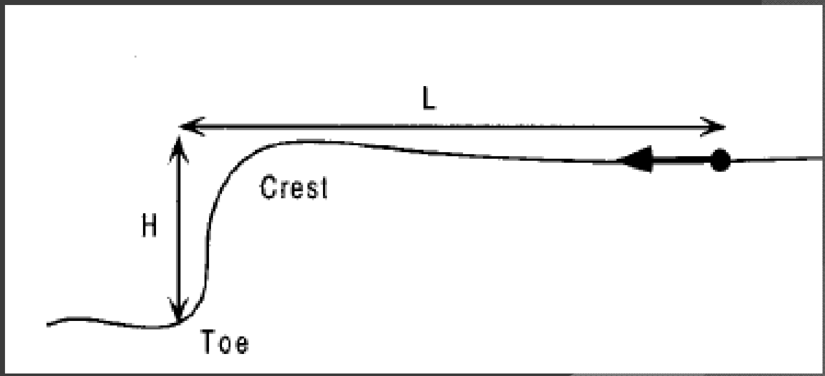
Outline

- Modification to Lateral Spread Model
- Interpreting and Use CPT Data in Revised Model
- Monte Carlo Method
- Mapping Inputs
- Map Examples

Youd et al. (2002) Empirical Model

$$LogD_H = \frac{b_o + b_{off}\alpha + b_1 M + b_2 LogR^* + b_3 R + b_4 LogW + b_5 LogS + b_6 LogT_{15} +}{+ b_7 Log(100 - F_{15}) + b_8 Log(D50_{15} + 0.1 \text{ mm})}$$

- Seismic Factors
  - *M*, *R*
- Topographic Factors
  - *W*, *S*
- Geotechnical Factors
  - T_{15}, F_{15}, $D50_{15}$



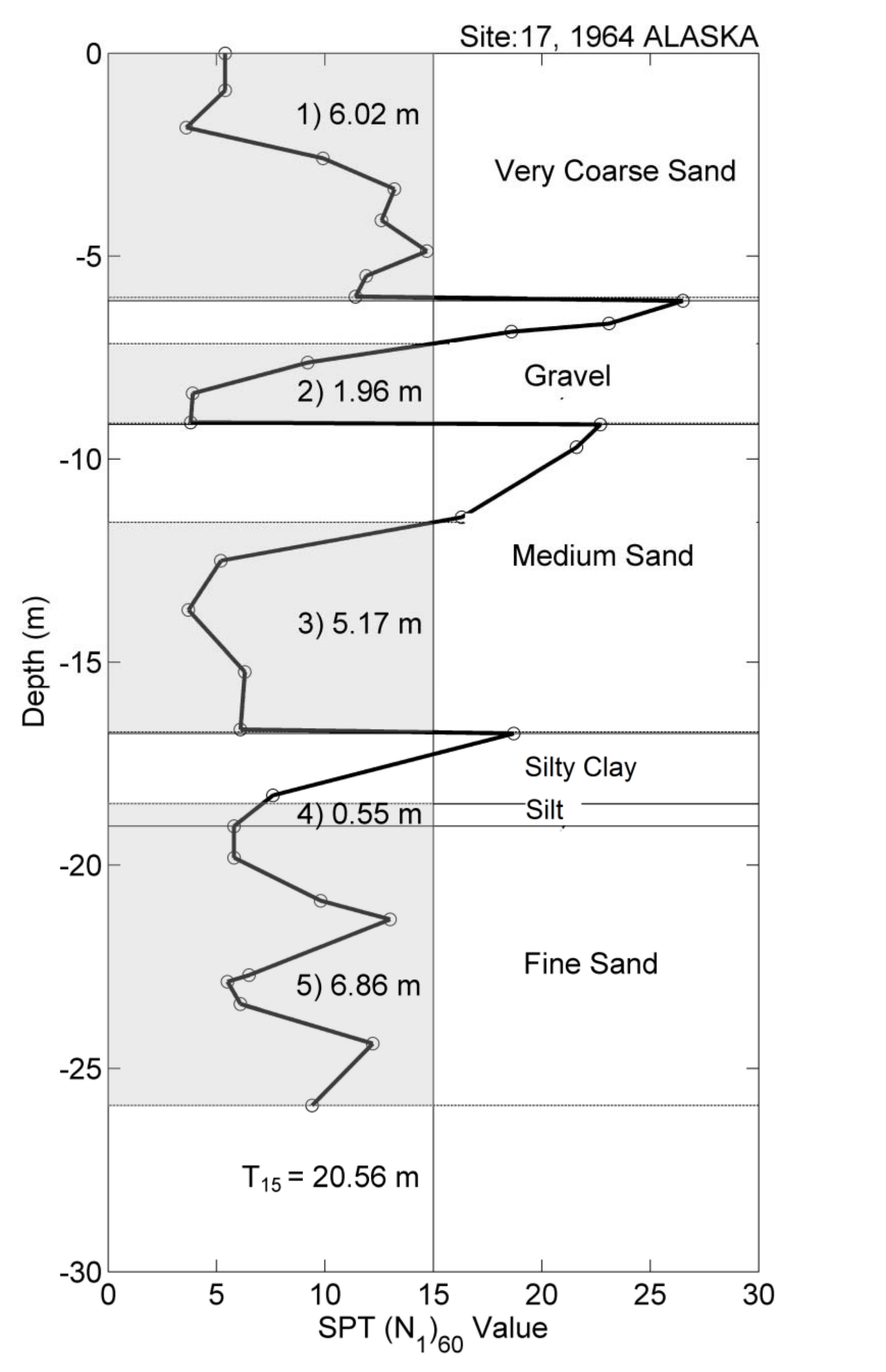
Free-face ratio: *W (%) = H / L * 100*

New Empirical Model

$$LogD_H = \begin{array}{c} b_o + b_{off}\alpha + b_1 M + b_2 LogR^* + b_3 R + b_4 LogW + b_5 LogS + \\ + b_6 LogT_{15} + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 \end{array}$$

x_i *= the portion (decimal fraction) of* T_{15} *in a borehole that has a soil index corresponding to the table below*

Soil Index *(SI)*	Typical Soil Description in Case History Database	General USCS Symbol
1	Silty gravel, fine gravel	GM
2	Coarse sand, sand and gravel	GM-SP
3	Medium to fine sand, sand with some silt	SP-SM
4	Fine to very fine sand, silty sand	SM
5	Low plasticity silt, sandy silt	ML
6	Clay (not liquefiable)	CL-CH



sented as a decimal. For example, the borehole plotted in Fig. 2 has $x_1 = 1.96/20.6 = 0.10$, $x_2 = 6.02/20.6 = 0.29$, $x_3 = 0.25$, $x_4 = 0.33$, and $x_5 = 0.03$. Of course, the sum of all values of x in the borehole equals 1.

Comparing the Models

Model	*R^2* **(%)**	***MSE***	σ_{logDH}	P-Value
Full: Youd et al. (2002)	83.6	0.0388	0.1970	0.000
Reduced: no F_{15} or $D50_{15}$	66.6	0.0785	0.2802	0.000
New: with soil type terms	80.0	0.0476	0.2182	0.000

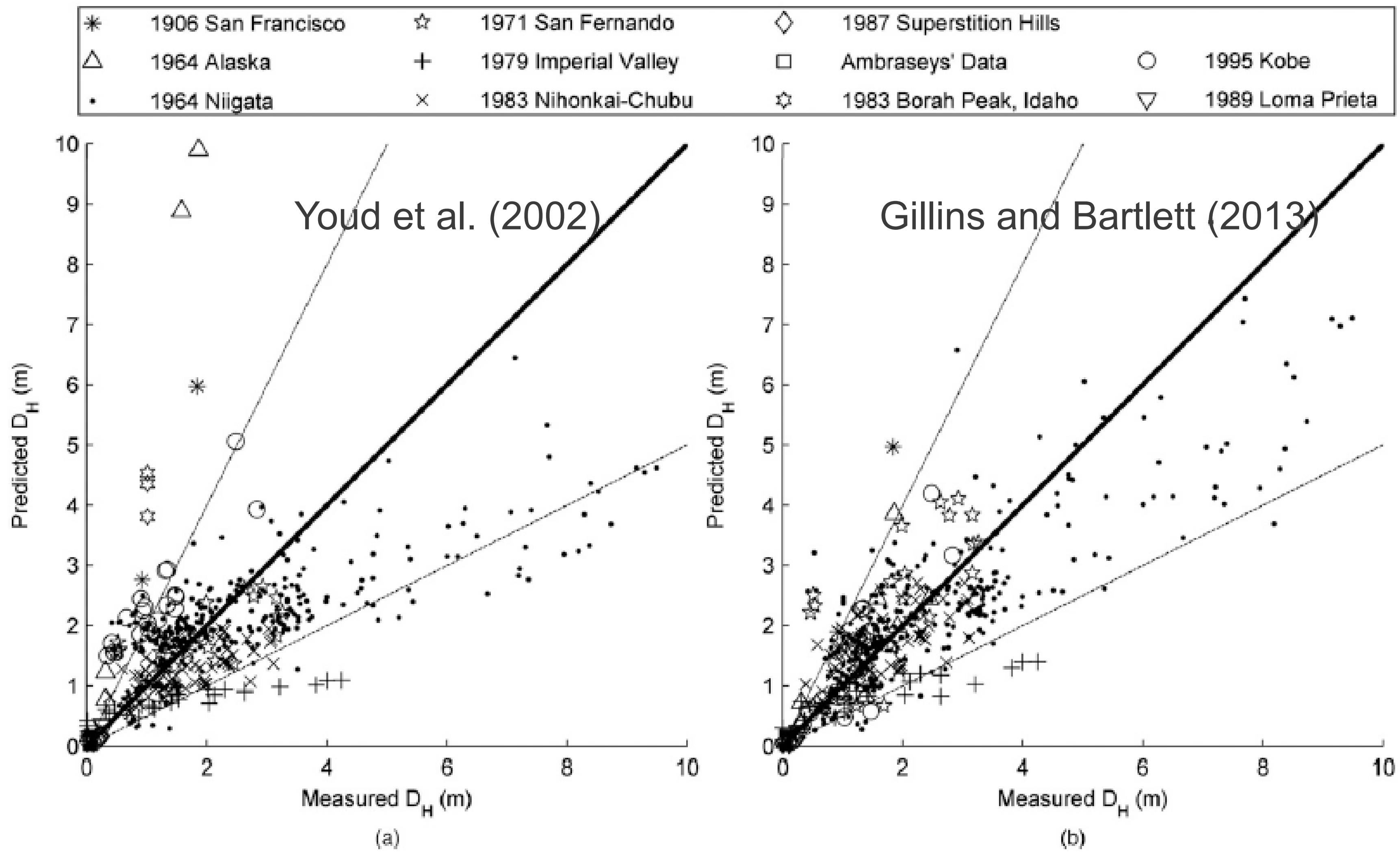
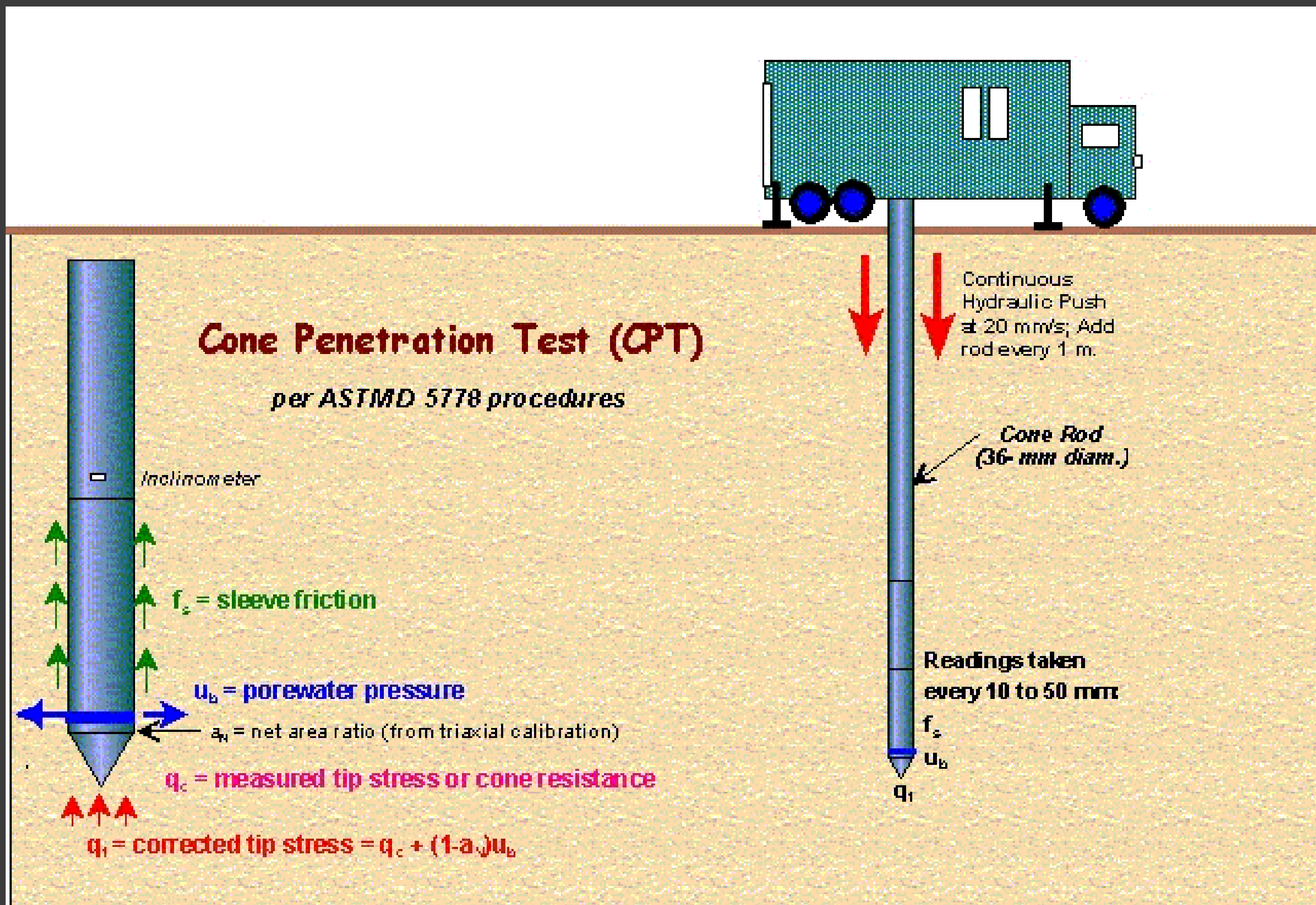
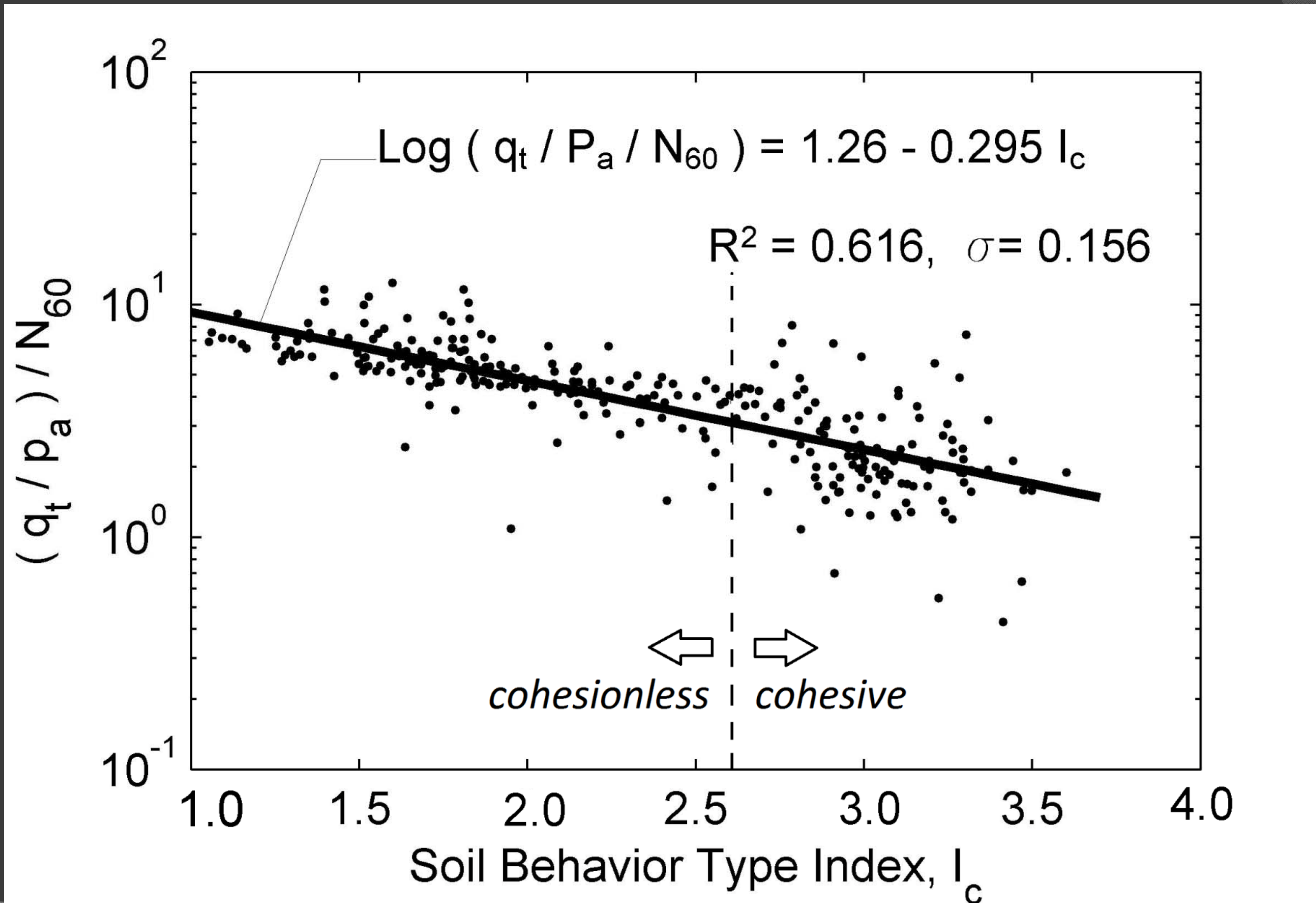


Fig. 1. Predicted lateral spread displacement using (a) Eq. (3) or (b) Eq. (4), versus measured lateral spread displacement from the case history database of Youd et al. (2002)

Cone Penetrometer Test (CPT)



Estimating $N_{1,60}$ from CPT Data

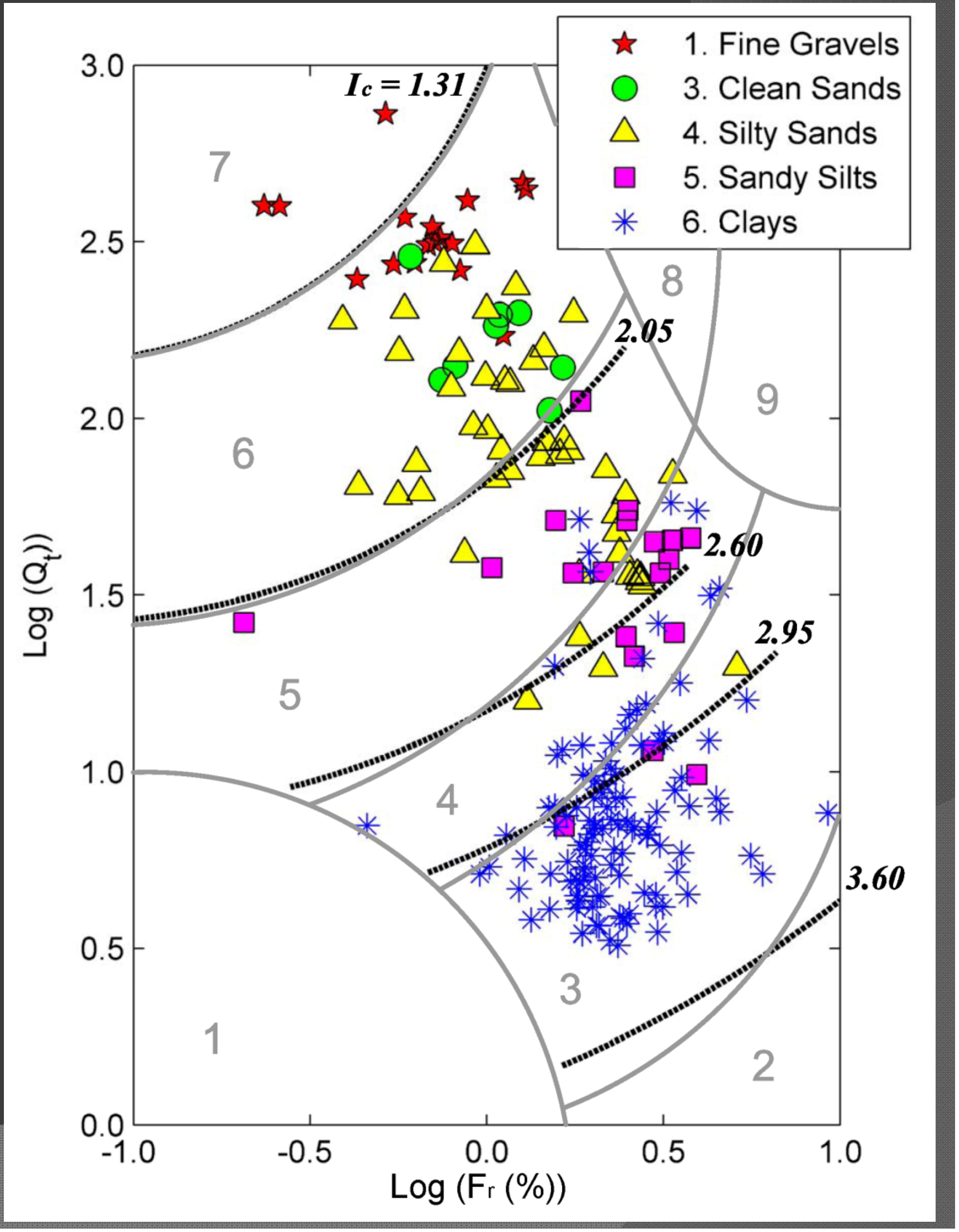


Estimating x_i Variables with CPT

Zone	Soil Behaviour Type (SBT)
1	*Sensitive fine-grained*
2	*Clay - organic soil*
3	*Clays: clay to silty clay*
4	*Silt mixtures: clayey silt & silty clay*
5	*Sand mixtures: silty sand to sandy silt*
6	*Sands: clean sands to silty sands*
7	*Dense sand to gravelly sand*
8	*Stiff sand to clayey sand**
9	*Stiff fine-grained**

** Overconsolidated or cemented*

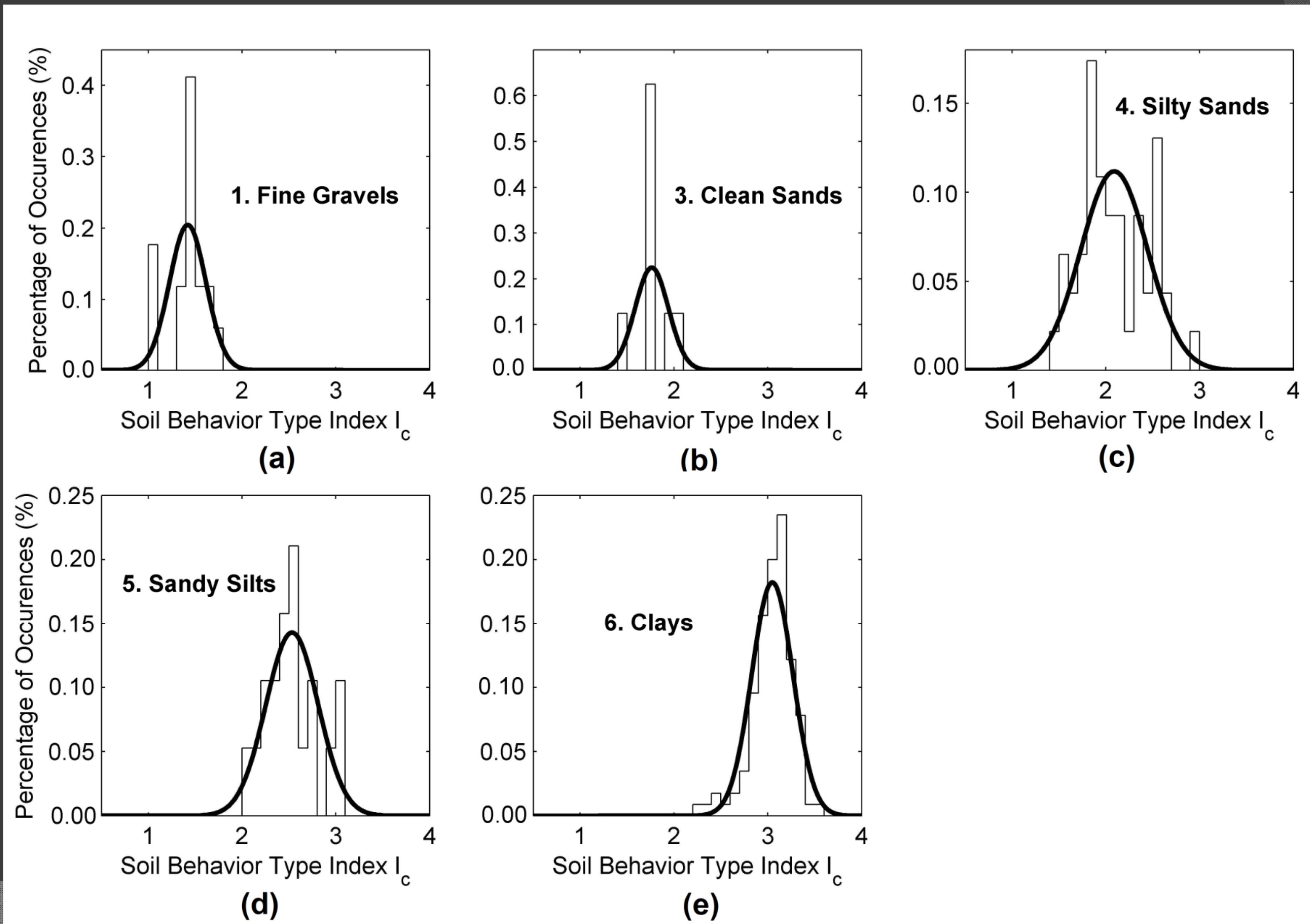
$$I_c = [(3.47 - LogQ_{tn})^2 + (LogF_r + 1.22)^2]^{0.5}$$



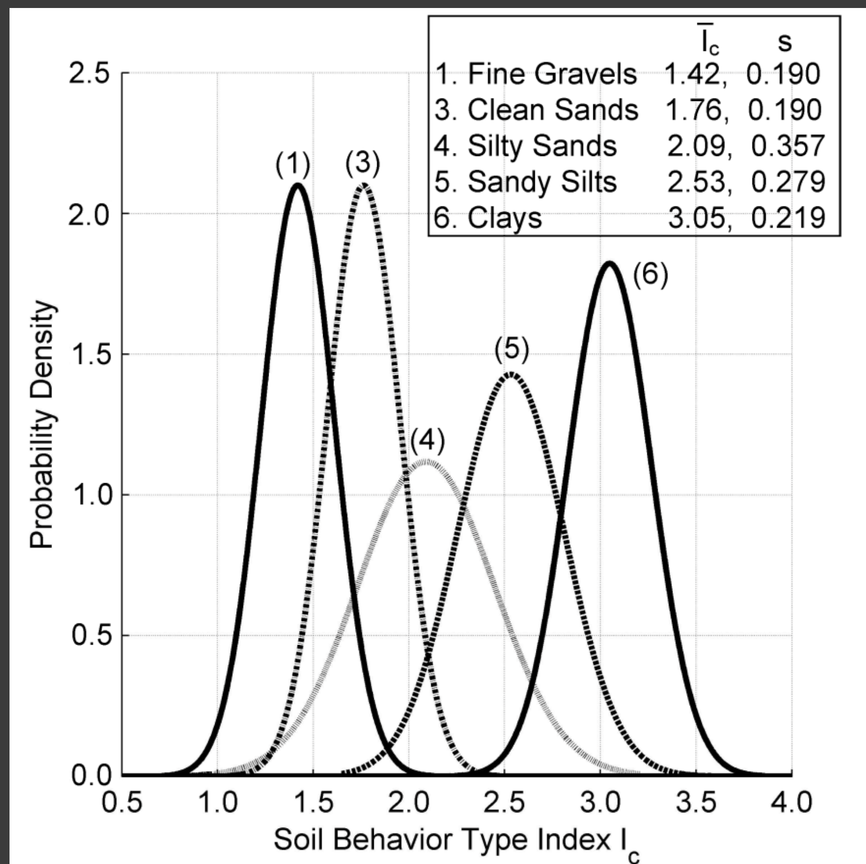
Robertson (1990) Soil Behavior Type Chart

- Boundaries of each zone estimated by circles with radius = I_c

Histograms of I_c for each *SI*



Charts to Estimate *SI* given I_c



Recommended normal probability density functions; Weber County

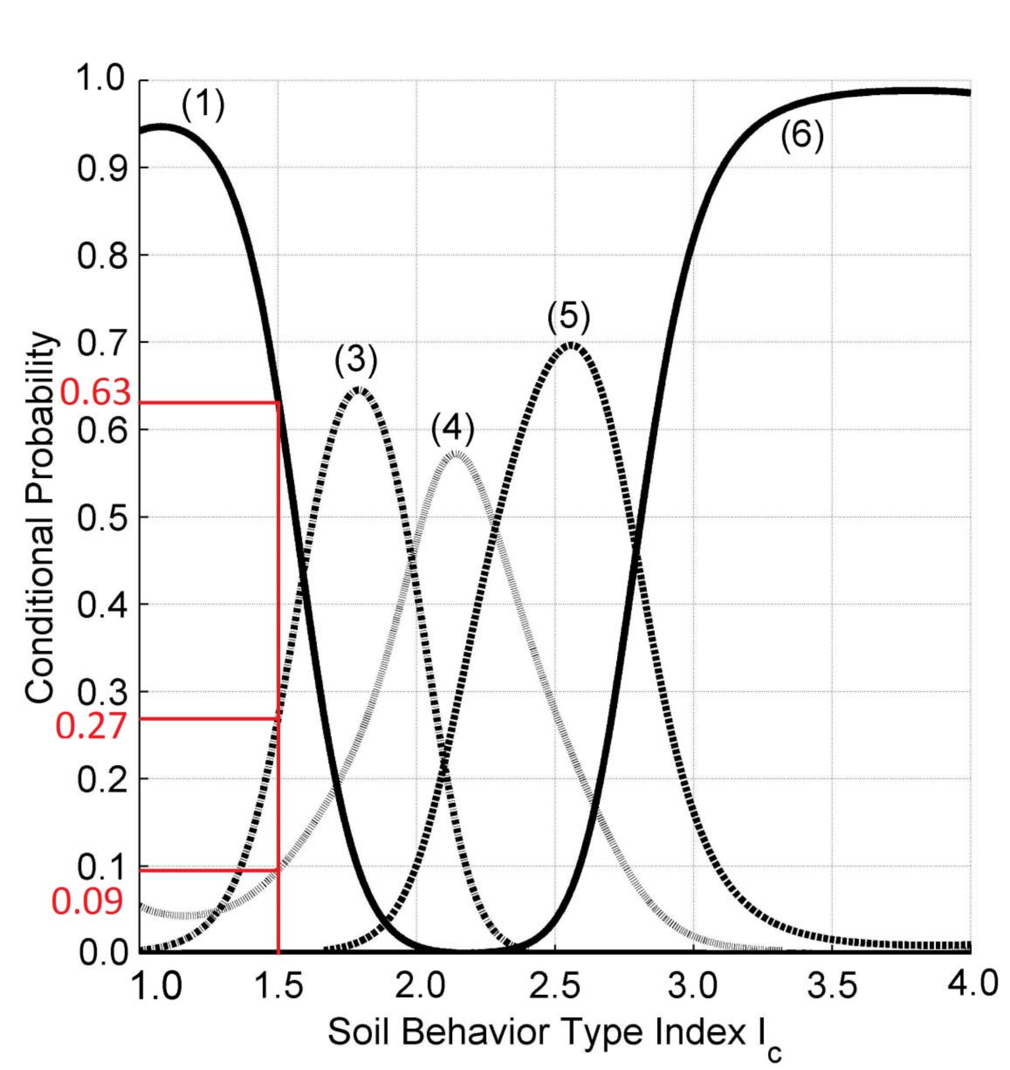
Example 1

Find probability that:

SI = 1 (i.e., fine gravel)
given I_c = 1.5

$P\ (SI = i \mid I_c = 1.5\ )$:

i	*P*
1. Fine Gravels	0.63
3. Clean Sands	0.27
4. Silty Sands	0.09
5. Sandy Silts	0.00
6. Clays	0.00

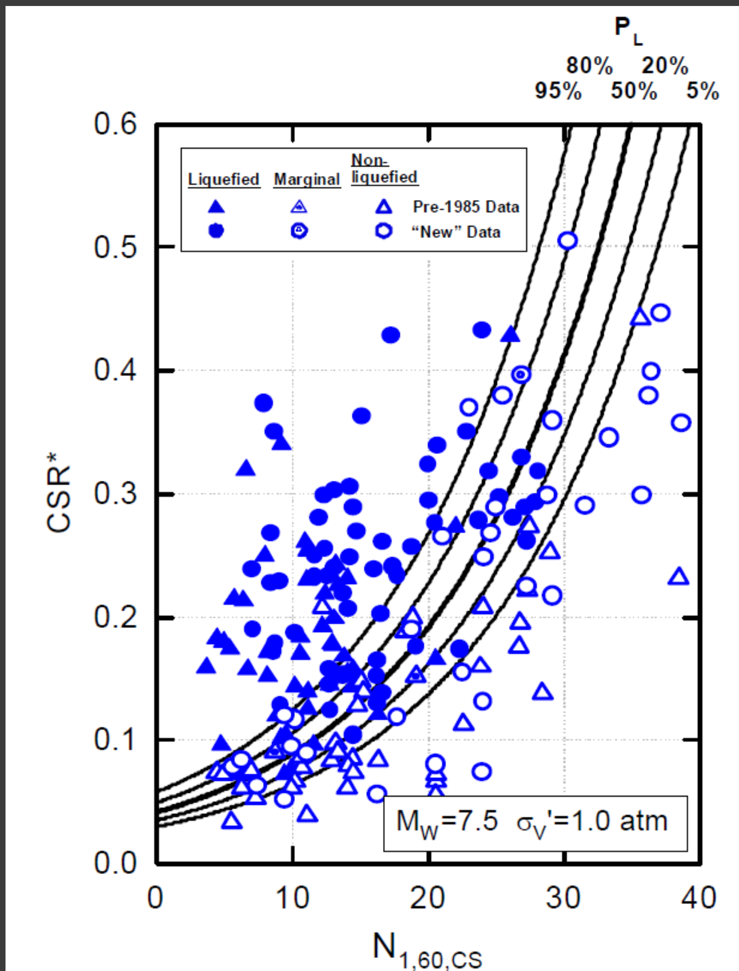


Probabilistic Framework

$$P[D_H > y] = P[D_H > y \mid L] \cdot P_L$$

1. Select a threshold distance, *y*
2. Find $P[D_H > y \mid L]$ using new empirical model
3. Find P_L from liquefaction potential curves of Cetin et al. (2004) and Moss et al. (2006)

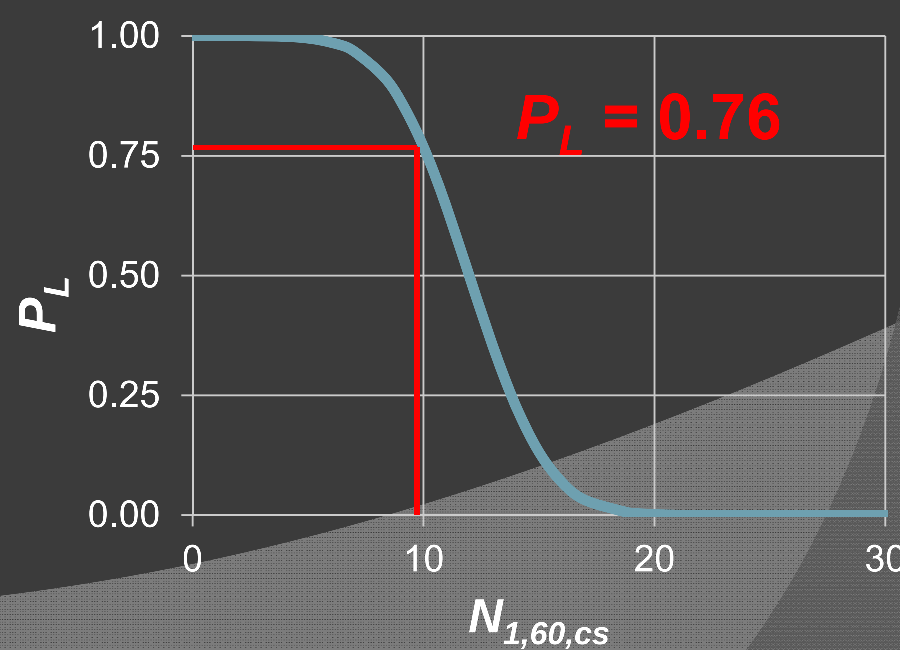
Example 2



SPT-based Liquefaction Potential Curves (Cetin et al., 2004)

Find P [D_H > 1 m] given:

- $CSR = 0.1$; $N_{1,60,cs} = 10$
- $M = 7.5$; $R = 20$ km
- $S = 0.5$ %
- $T_{15,cs} = 1$ m; $\sigma'_v = 1$ atm

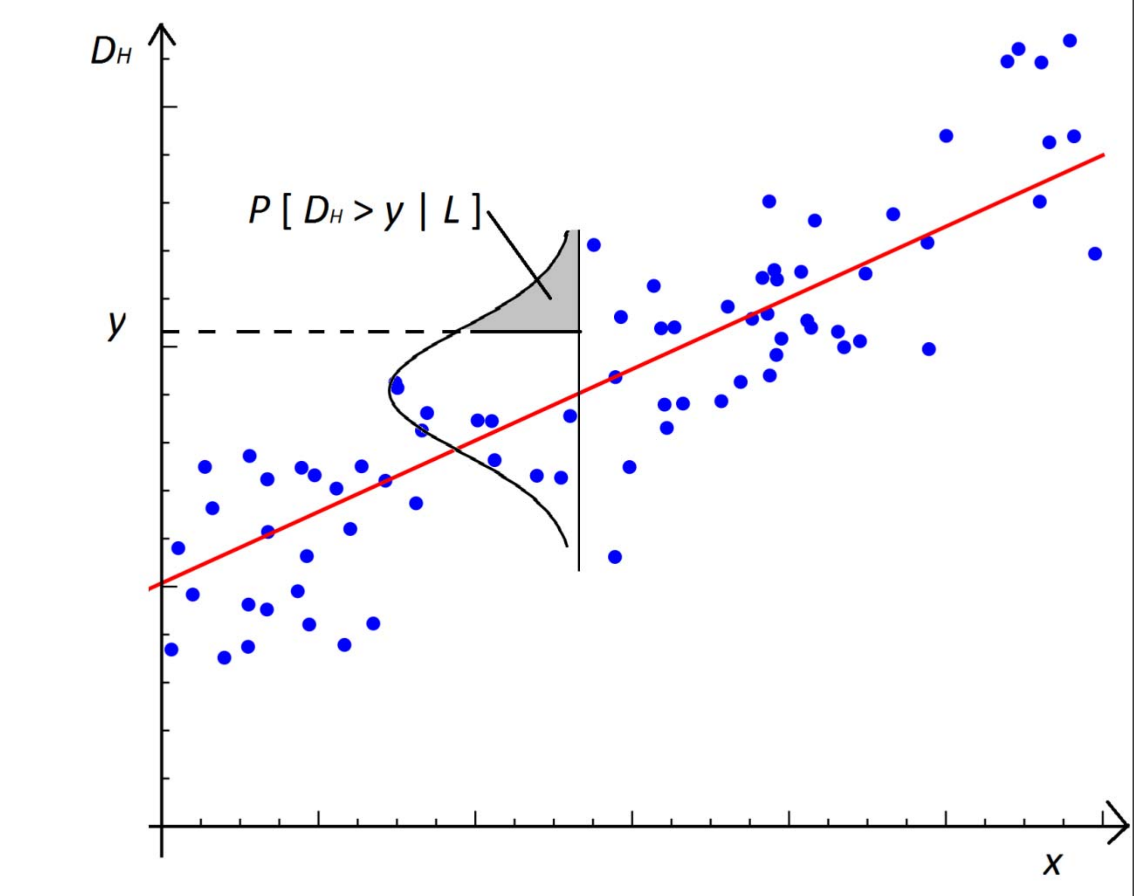


Example 2 (cont.)

$$P[D_H > y \mid L] = \Phi\left(-\frac{Log(y) - \overline{Log(D_H)}}{\sigma_{Log(D_H)}}\right)$$

= Φ (- *z*)

= <u>0.33</u>



***P* [D_H > *y*] = (0.33)*(0.76) = <u>0.25</u>**

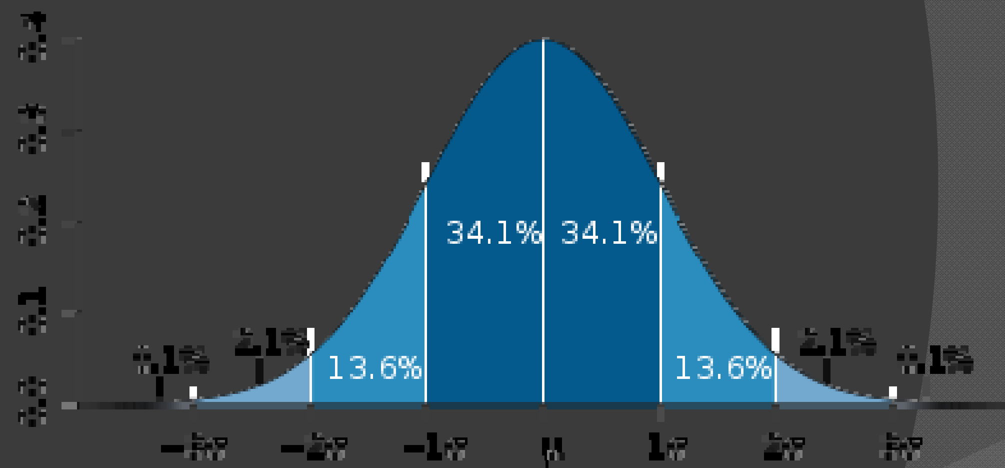
“Simple calculations based on a range of variables are better than elaborate ones based on limited input.”

-Ralph B. Peck

Monte Carlo Technique

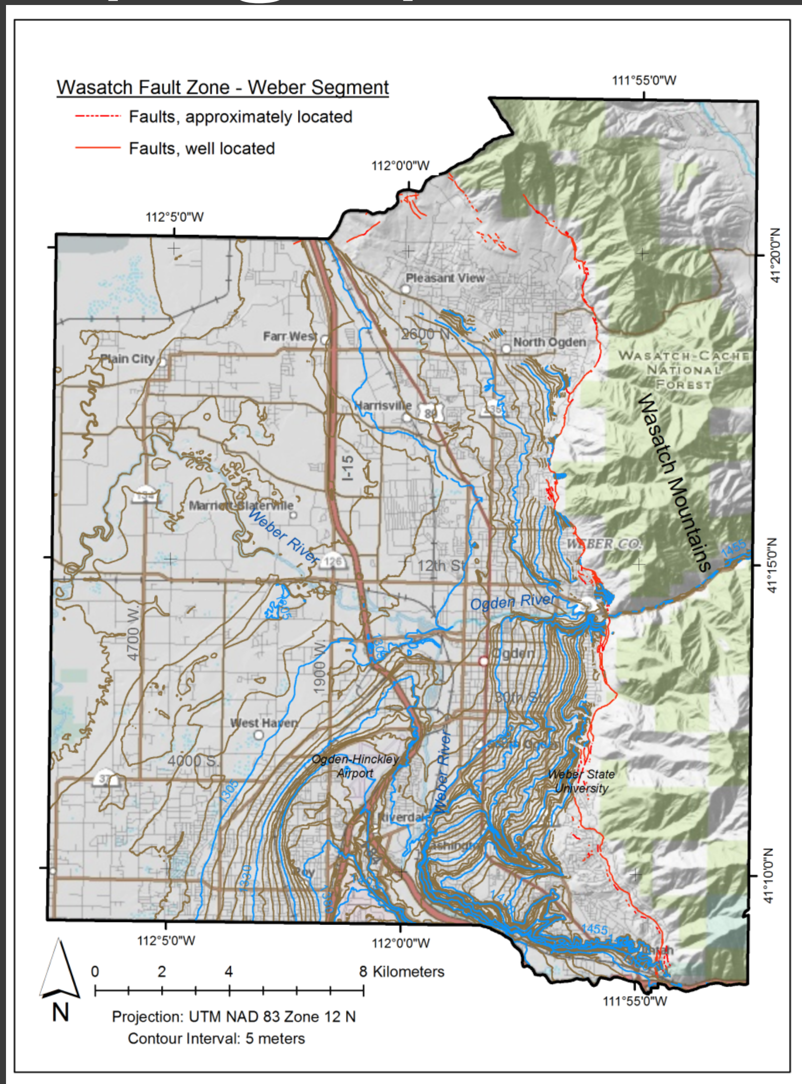
- Used when:
  - Unable to compute results deterministically
  - Systems have many degrees of freedom
  - Modeling phenomena with significant uncertainty

1) Define a domain of inputs
2) Generate inputs randomly from a probability distribution over the domain;
3) Perform a deterministic computation on the inputs;
4) Aggregate the results to define the median values and their uncertainty

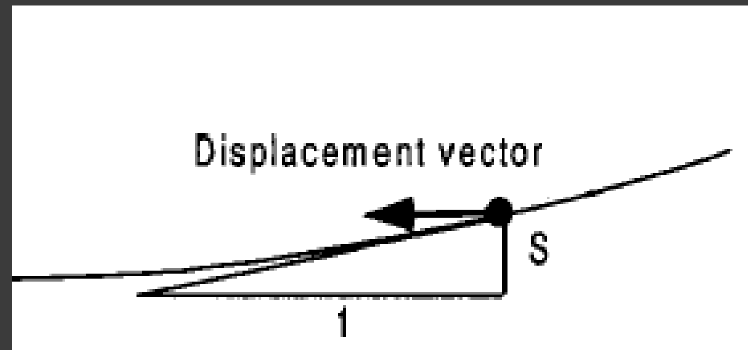


The Normal Distribution

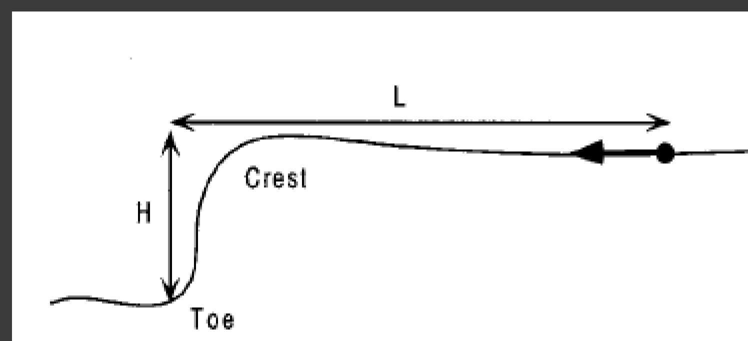
Topographic Variations



Contours Based on Digital Elevation Model (DEM) from USGS National Elevation Dataset



Percent ground slope: *S (%)*

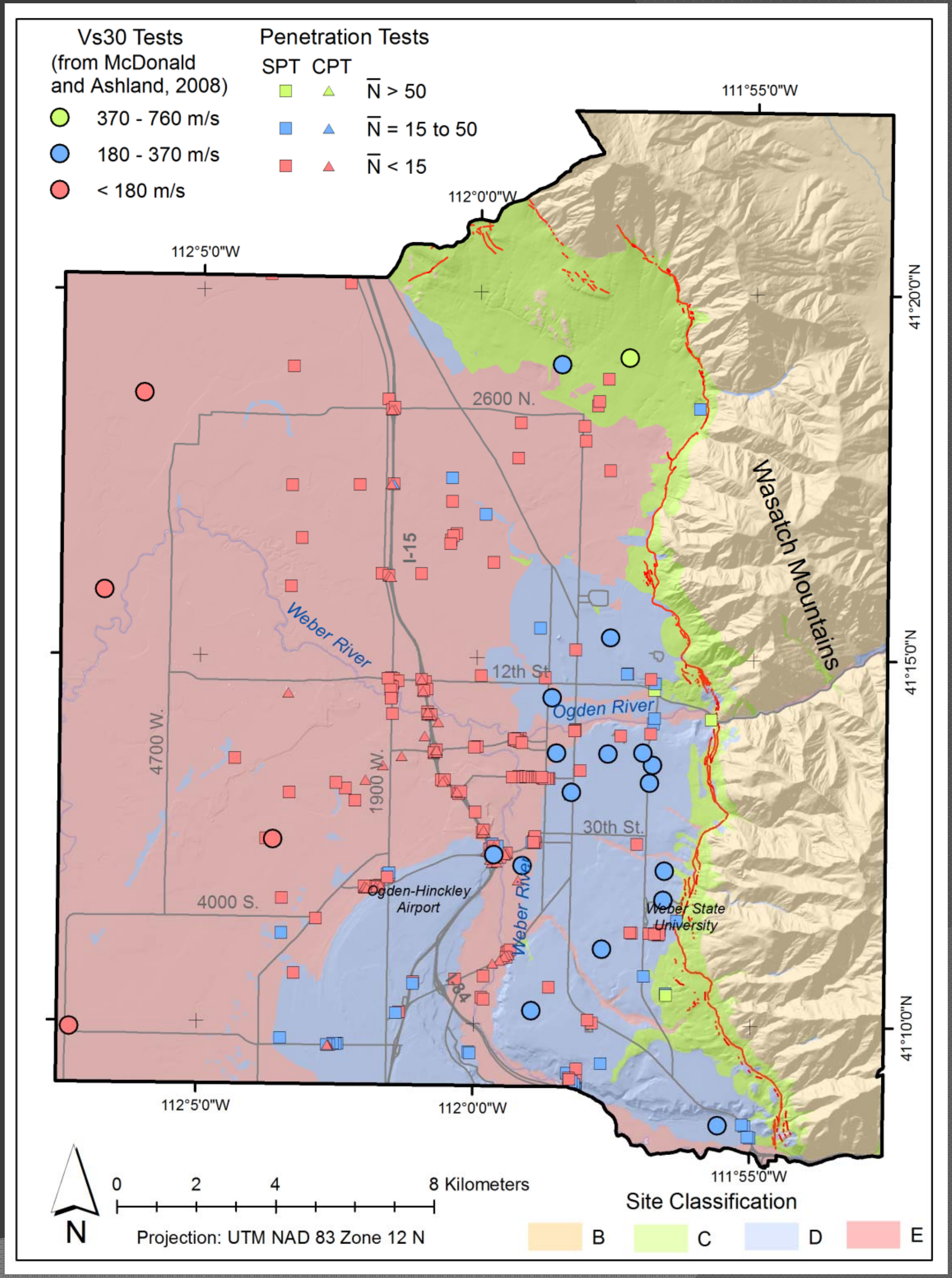


Free-face ratio: *W (%) = H / L * 100*

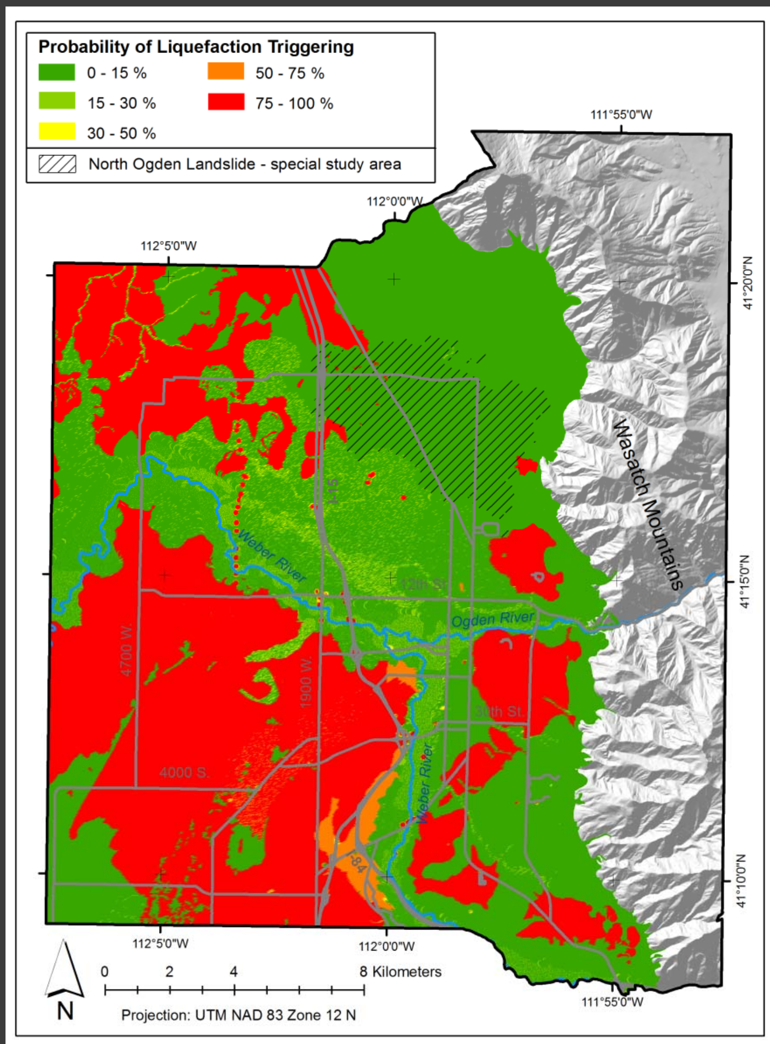
Seismic Inputs

- Mean seismic variables from interactive deaggragation of the seismic hazard

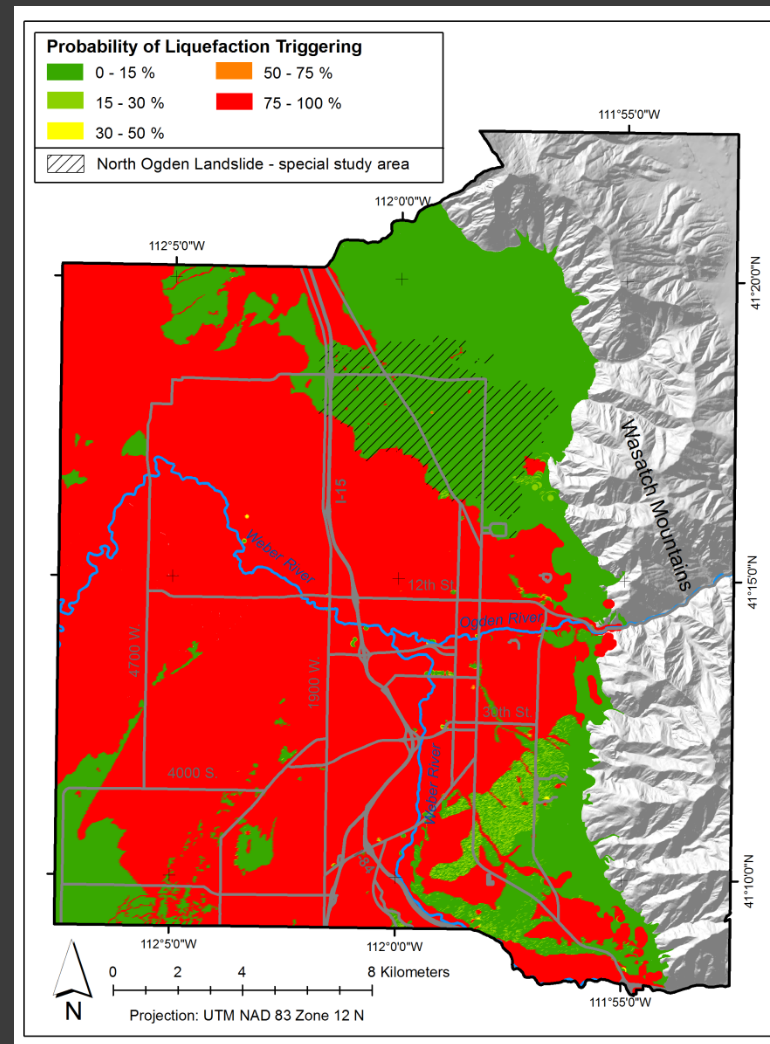
- Seismic hazard based on 2008 source and attenuation models of the National Seismic Hazard Mapping Project (Peterson et al., 2008)



Liquefaction Triggering Maps

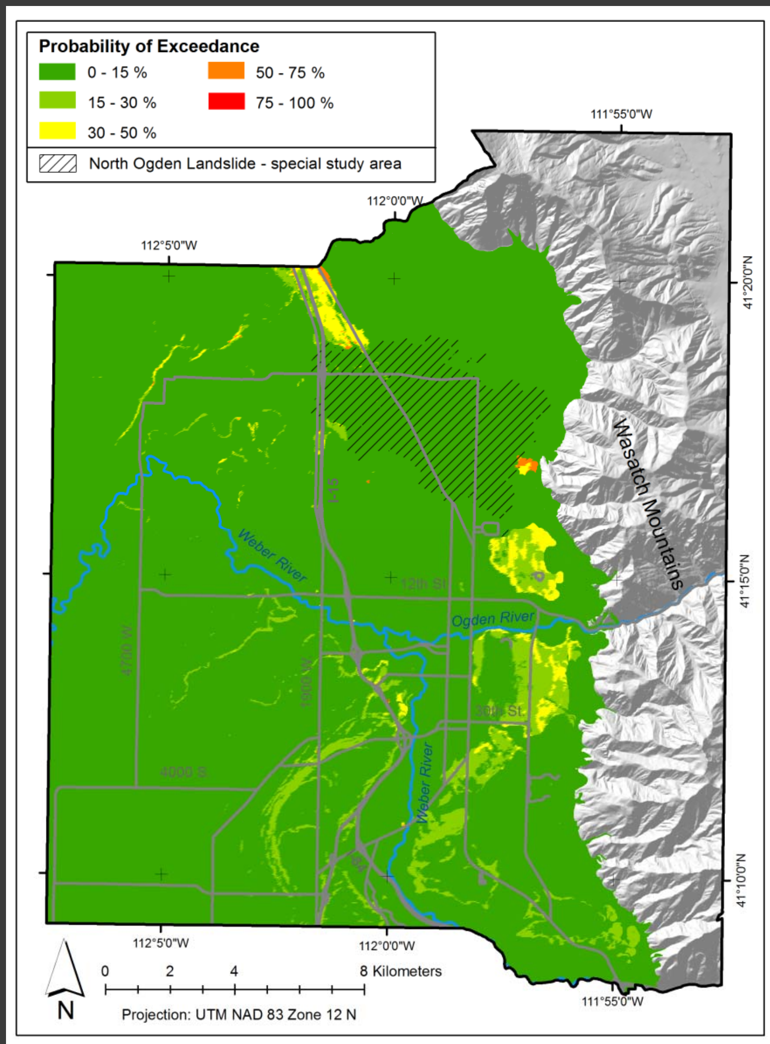


Median probabilities of P_L, 500-year seismic event

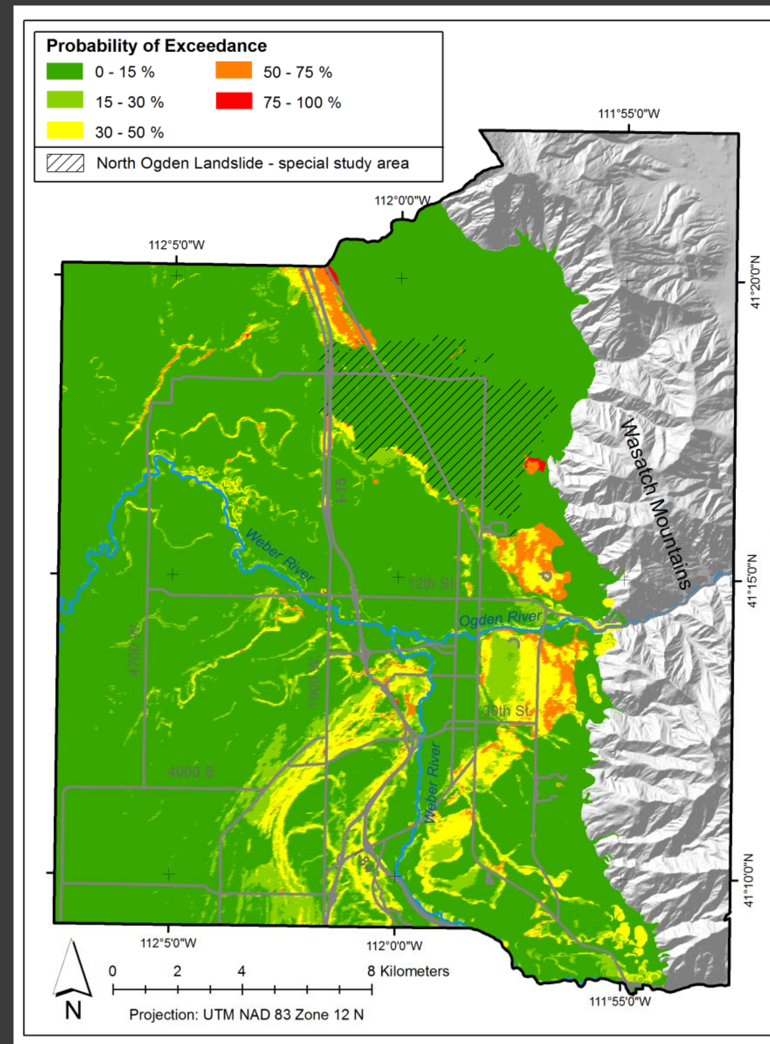


Median probabilities of P_L, 2,500-year seismic event

Lateral Spread Hazard Maps

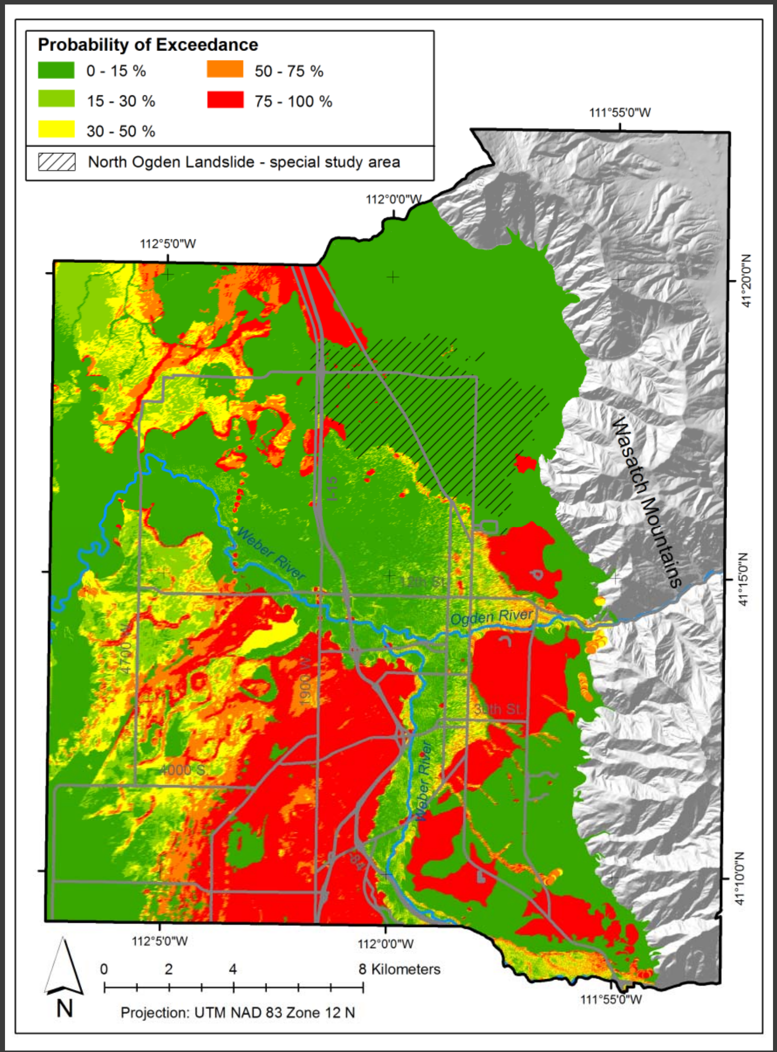


Median probabilities of exceeding 0.3 m, 500-year event

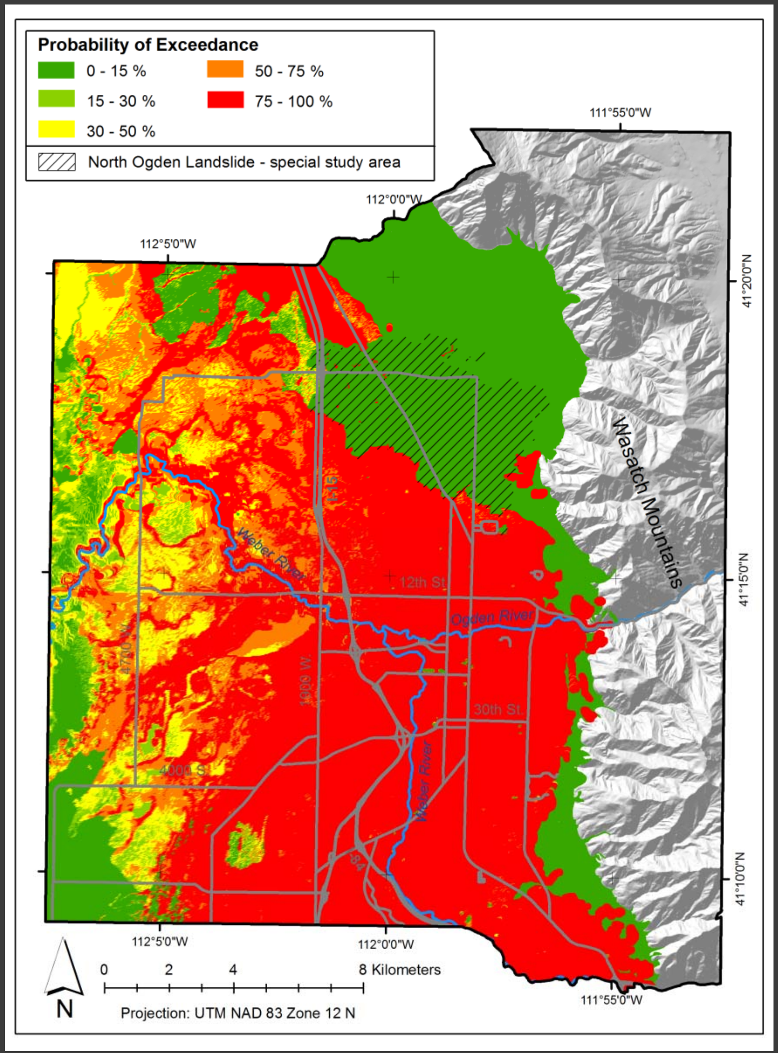


84th percentile probabilities, of exceeding 0.3 m, 500-year event

Lateral Spread Hazard Maps



Median probabilities of exceeding 0.3 m, 2,500-year event



84^{th} percentile probabilities, of exceeding 0.3 m, 2,500-year event

For more information:

http://www.civil.utah.edu/~bartlett/ULAG/

Multilinear Regression Equations for Predicting Lateral Spread Displacement from Soil Type and Cone Penetration Test Data

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