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(Jason DeJong)

Optimizing Site Characterization to Evaluate and Incorporate Spatial Geologic Structure in 2-D/3-D Analysis

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November 4, 2016

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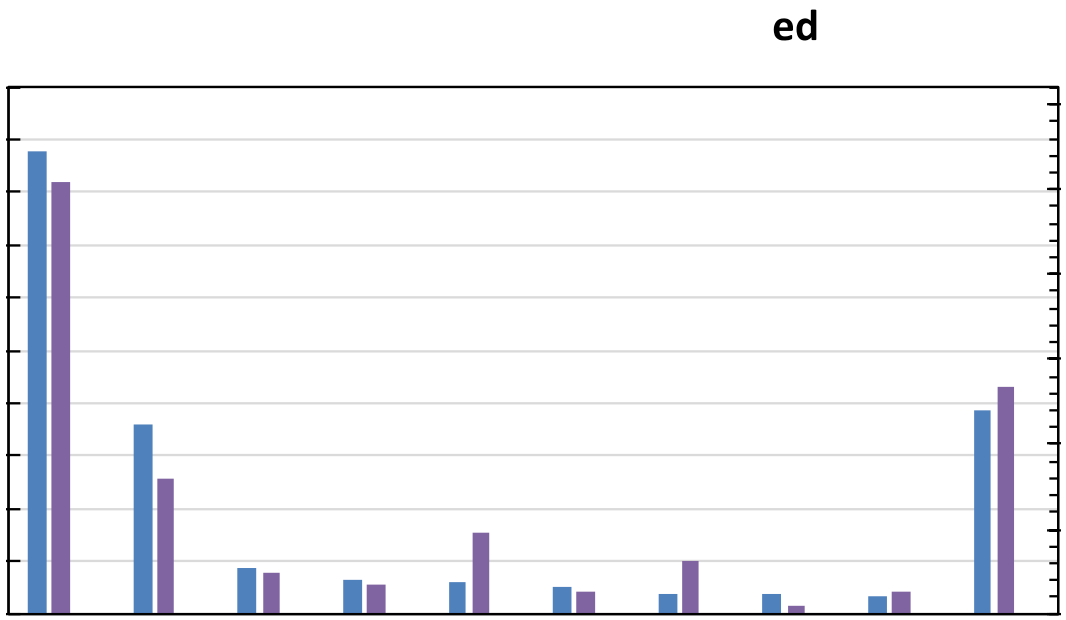
UCDAVIS

Importance of Site Characterization

- Site characterization errors comprise ~45% of all legal claims paid
- Based on study of 1500 claims over 25 yrs, 897 w/ insurance payouts



Lucia, Yabusaki & DeJong

Comments

Need

… need for *well documented* case histories ...

... need for comprehensive site characterization to accurately forward predict system performance ...

Required

Comprehensive characterization that captures geologic/depositional structure *AND* engineering properties.

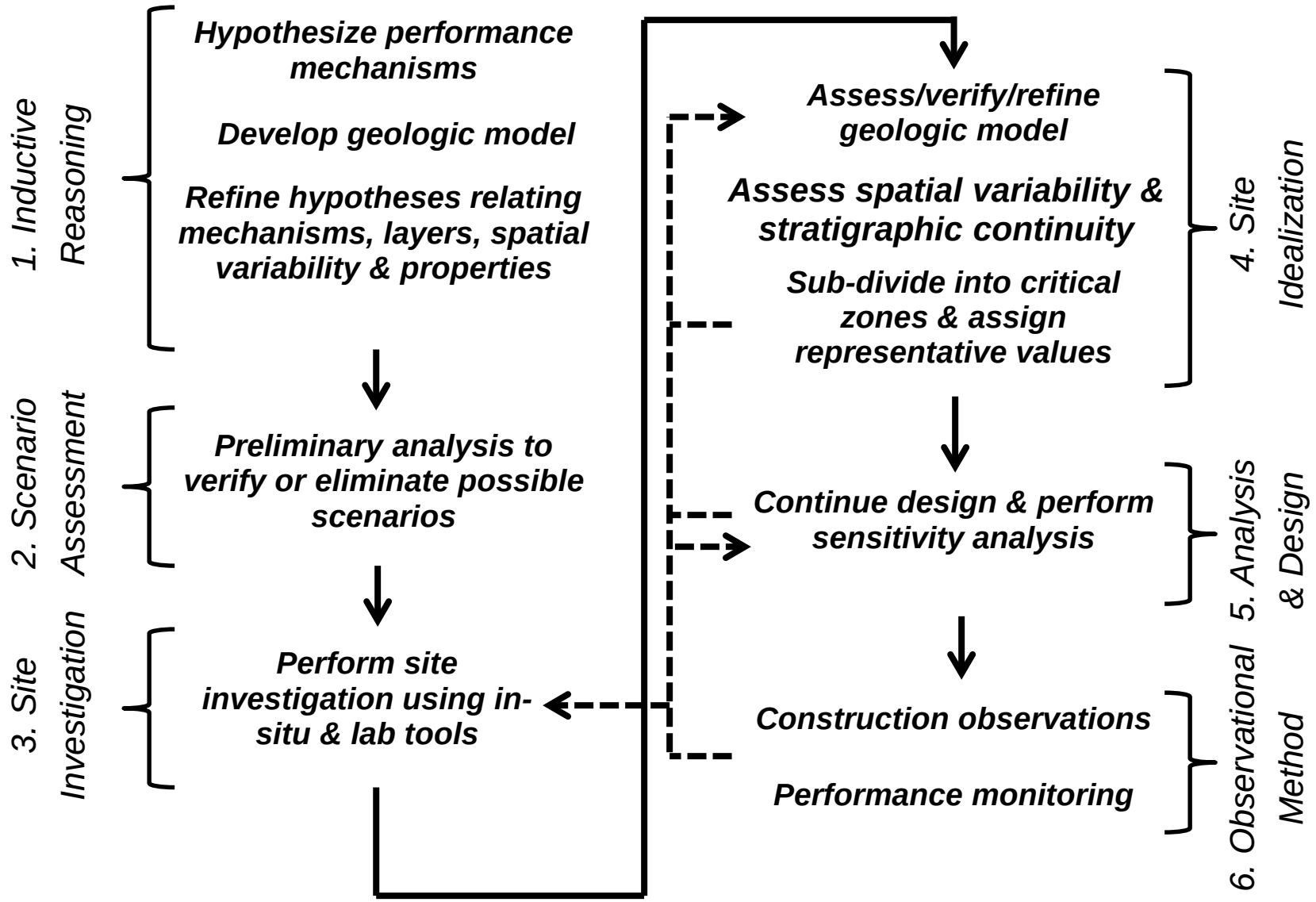
Points

- Toolbox of site investigation tools
- Framework for Integrated Site Characterization
- Scales of geologic characterization
- Mapping geologic units, depositional variability, or functional performance
- Optimization of site investigation program

Toolbox for Site Characterization

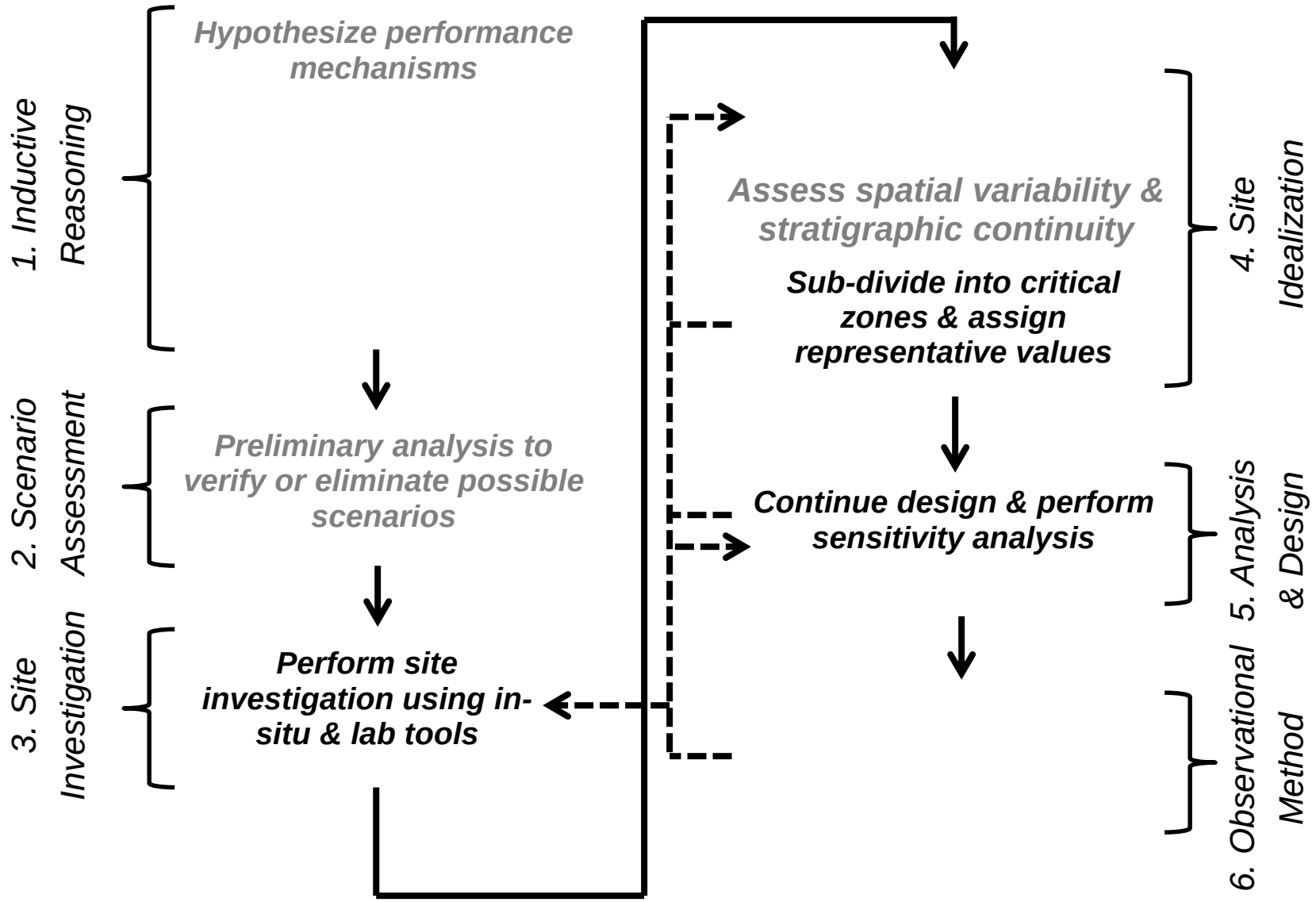
- Equipment
  - Continuous mapping – samples -> sonic, etc.; profiling -> VisCPT
  - Seismic – volume averaging? – Direct Push Crosshole for V_s & V_p
  - SCPTu – u_1 vs. u_2, w/ seismic
  - 'Undisturbed' sampling – no, piston samplers give intact samples
- Selection
  - More than CPT and SPT is necessary … just ask/research the options
  - Specification, specification, specification …
- Interpretation
  - CPT u_1 & u_2 or resistivity – fine layering interpretation
  - CPT q_c thin layer correction – global averaging vs. natural grading ??
  - Sample quality – SQD & Vs not confirmatory, can give false positives
  - Problematic soils – intermediate soils, crushable, & gravels

Integrated Site Characterization Methodology



DeJong et al (2016)

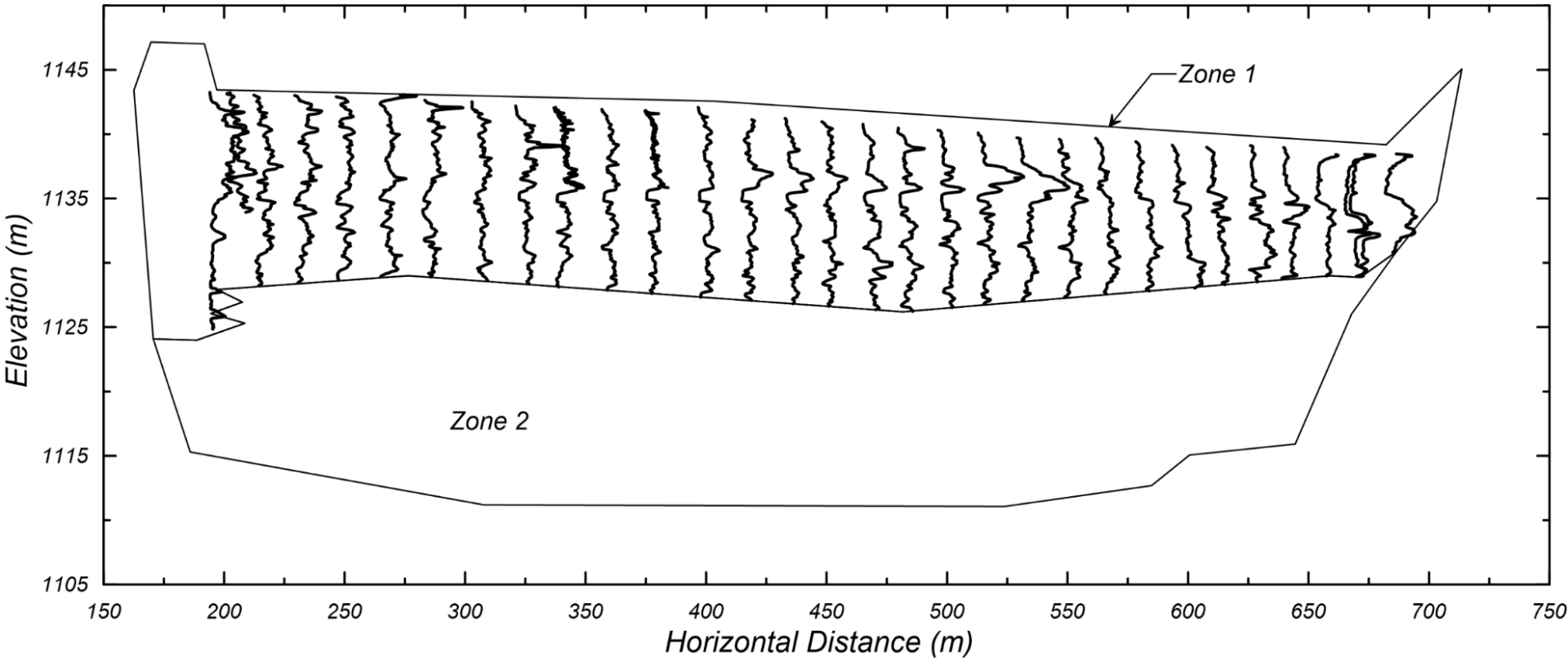
Integrated Site Characterization Methodology



DeJong et al (2016)

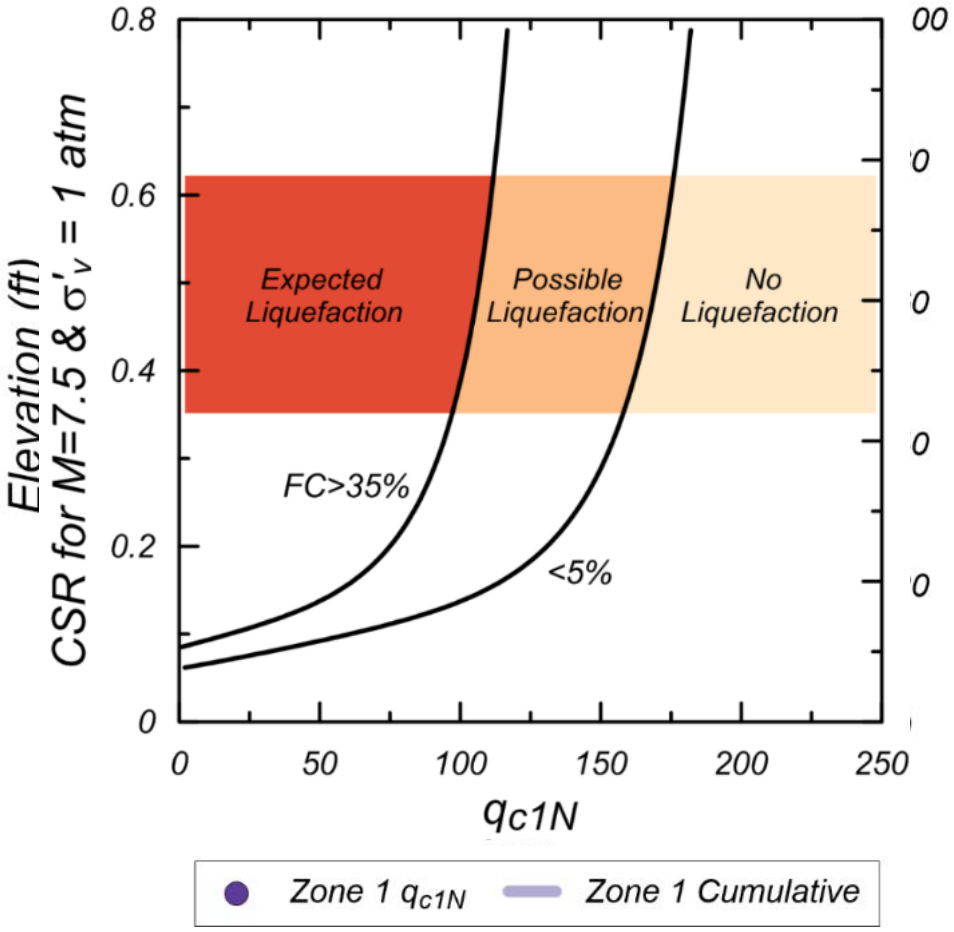
Geostatistical Approach for Conditioned Spatial Mapping/Performance

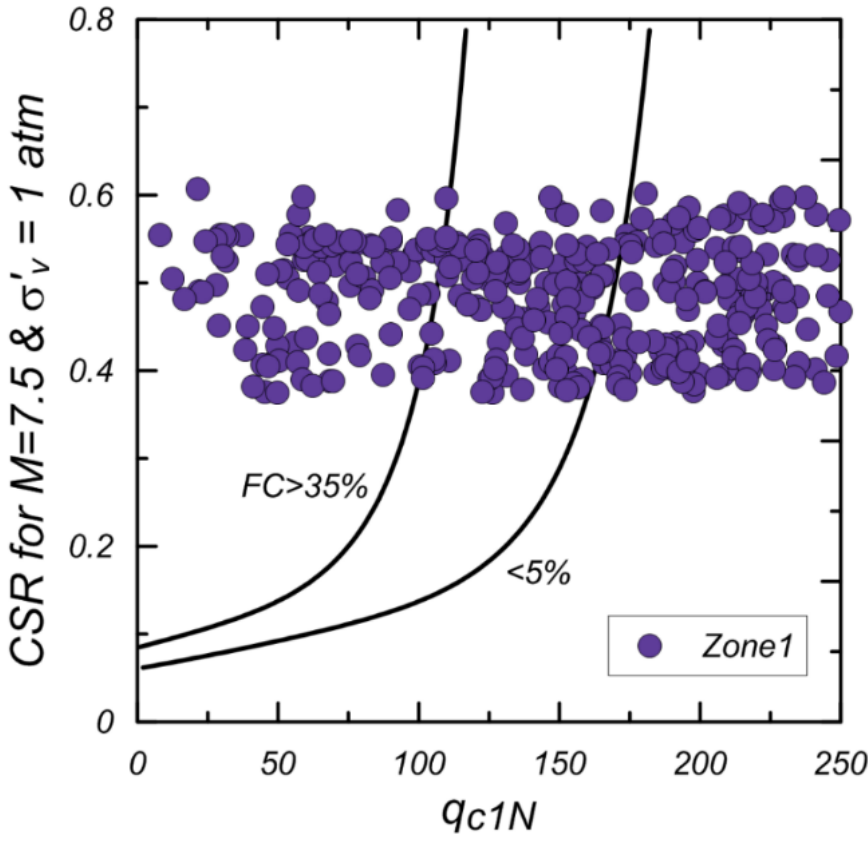
- Future dam site ... 39 CPTs across proposed alignment; 98%I_c < 2.6
- Transition probability geostatistics (Carle 1999) used to define transitions based on soil type (i.e. sand or clay), by soil property/resistance (i.e. q_{c1N} range), or by performance mechanism (i.e. liquefiable/non-liquefiable)
- Map zones of expected liquefaction, possible liq., & 'no' liq.



Example Application

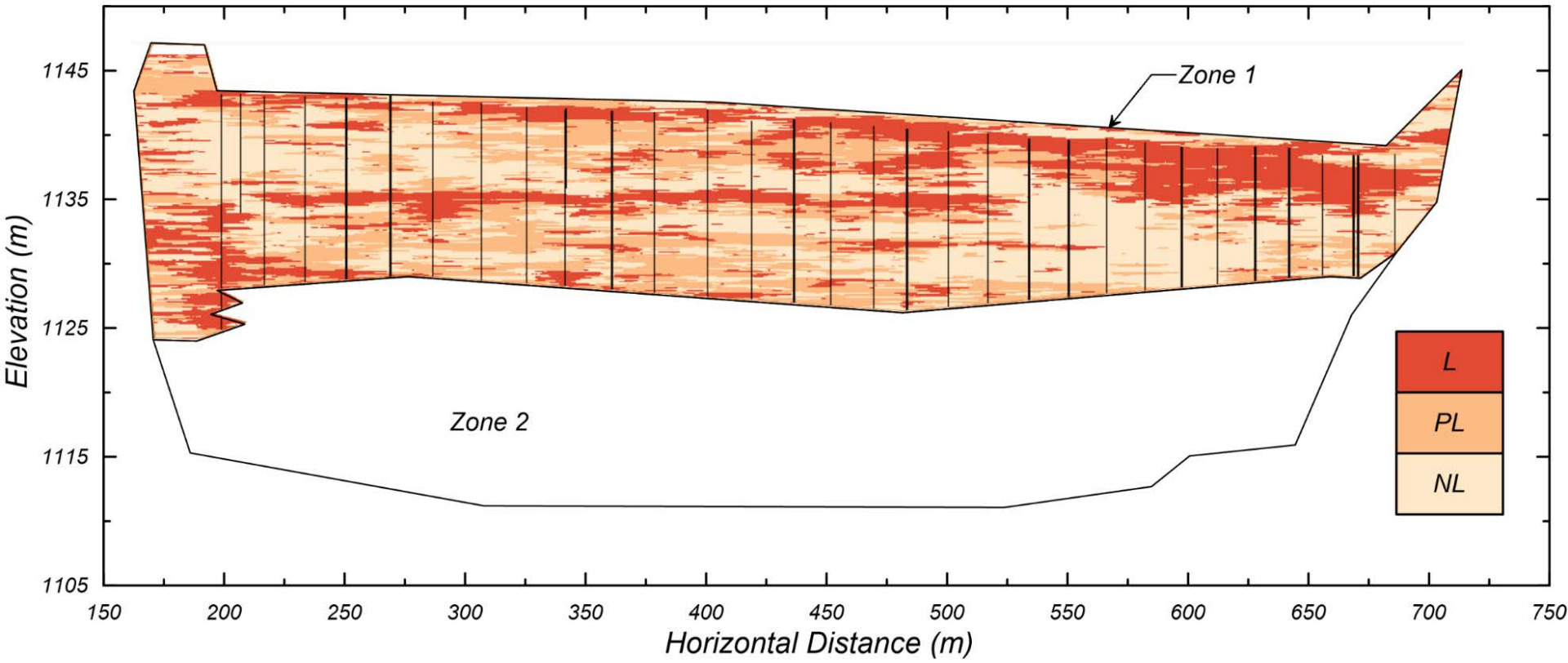
- Cloud of CPT q_{c1N} data -> Difficult to pick representative properties for triggering
- Categories defined by seismic demand and q_{c1N} triggering correlation





Example Application

- Conditional simulation directly map the connectivity of liquefiable deposits
- Can perform multiple realizations for evaluating simulation uncertainty

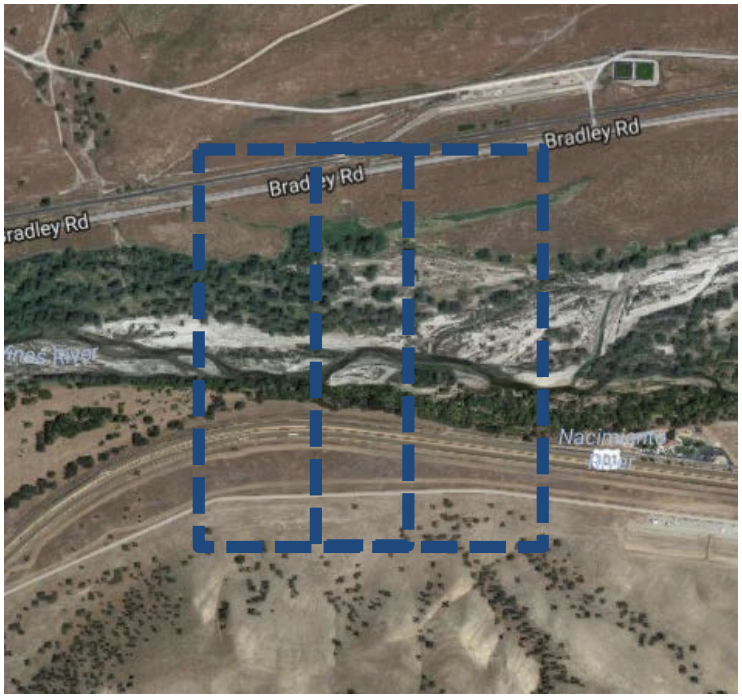


Optimizing Site Investigation Strategy

- Consider idealized scenario for site investigation of a future embankment dam.
- Example for braided river architecture uses:
  - Transitional probability geostatistics (Carle 1999)
    - mean length (correlation length)
    - sill (% material)
    - unique for 3 orthogonal directions
  - SI realizations conditioned on:

(A) • Typical Grid CPT soundings

(B) • Nested CPT soundings



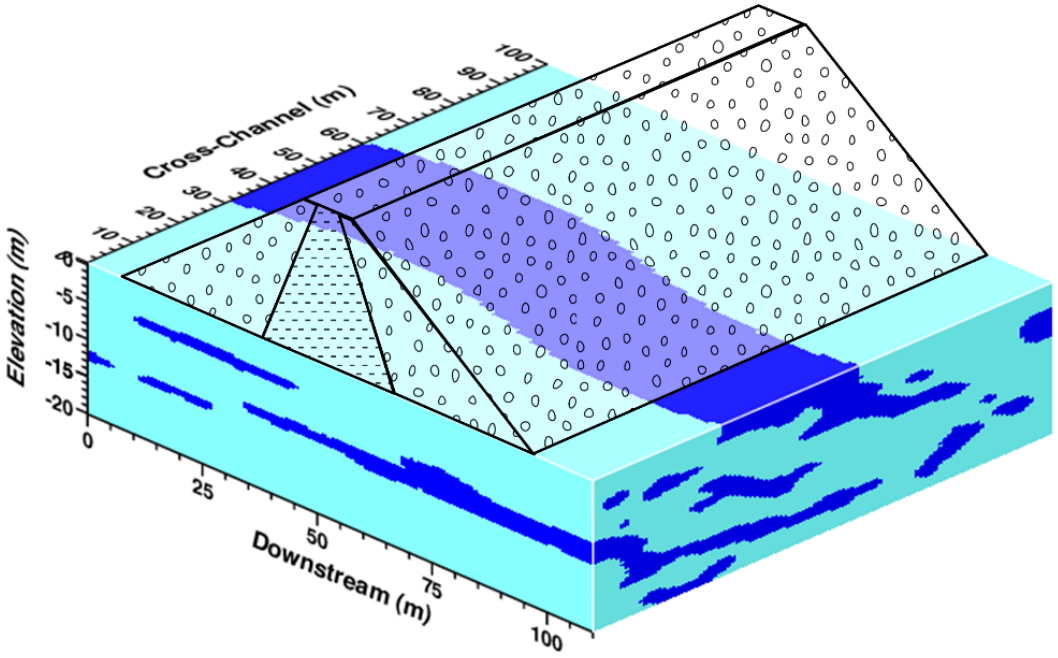
Optimizing Site Investigation Strategy

Sill

- Sill (channel deposits) = 30%
- Sill (overbank deposits) = 70%

Mean Length

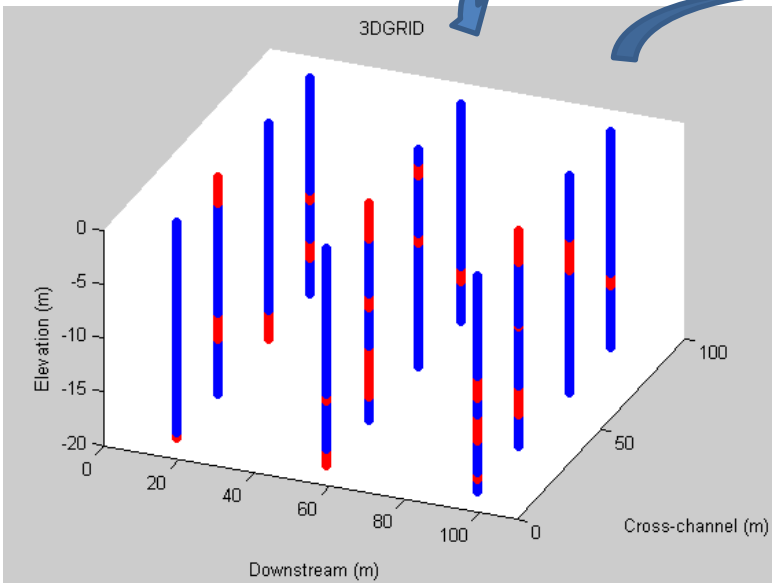
- Lx (downstream) = 200 m
- Ly (cross channel) =20 m
- Lz (vertical) = 3 m

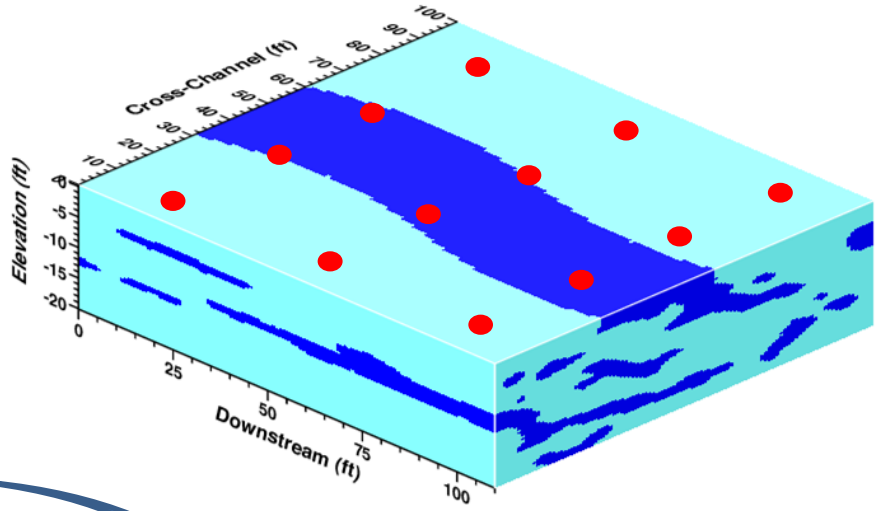


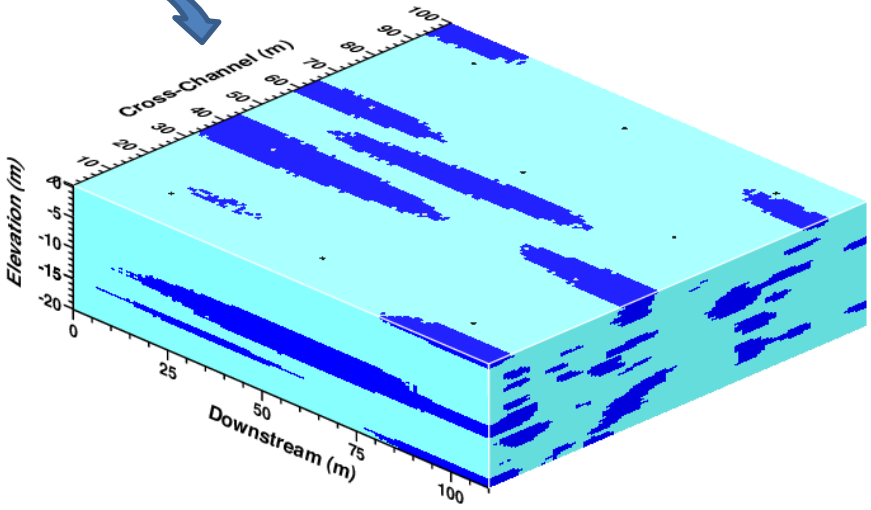
Surface Conditions

- Defined x-y condition at surface

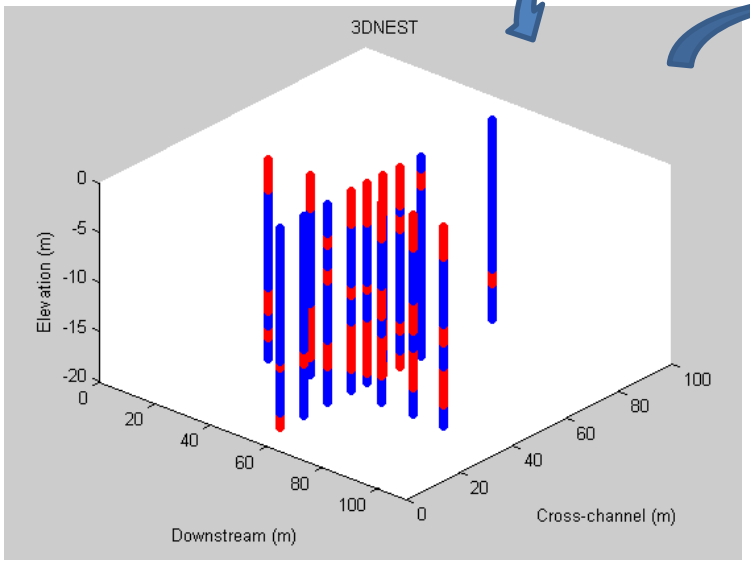
Case A: Grid Sampling

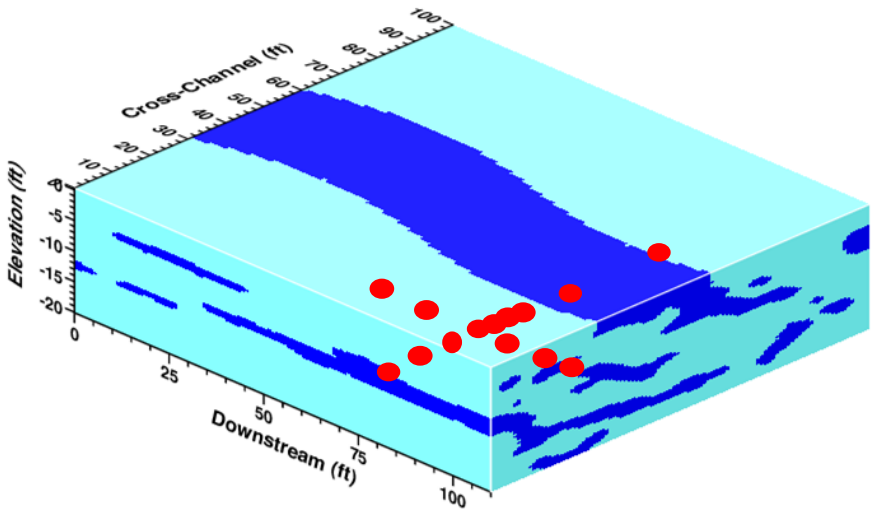


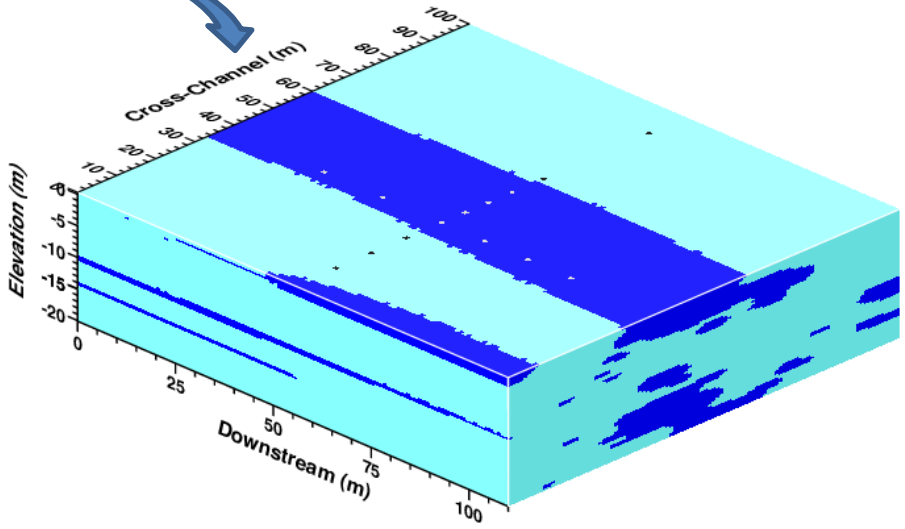




Case B: Nested Sampling

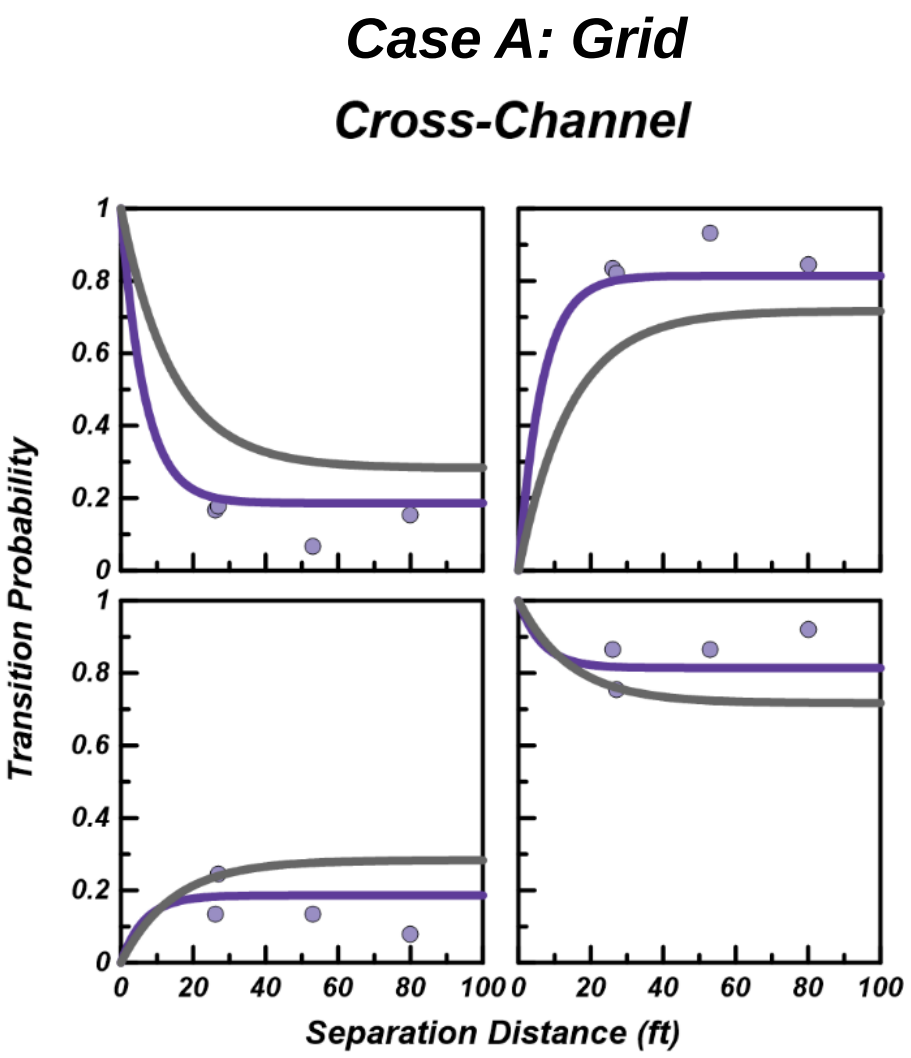


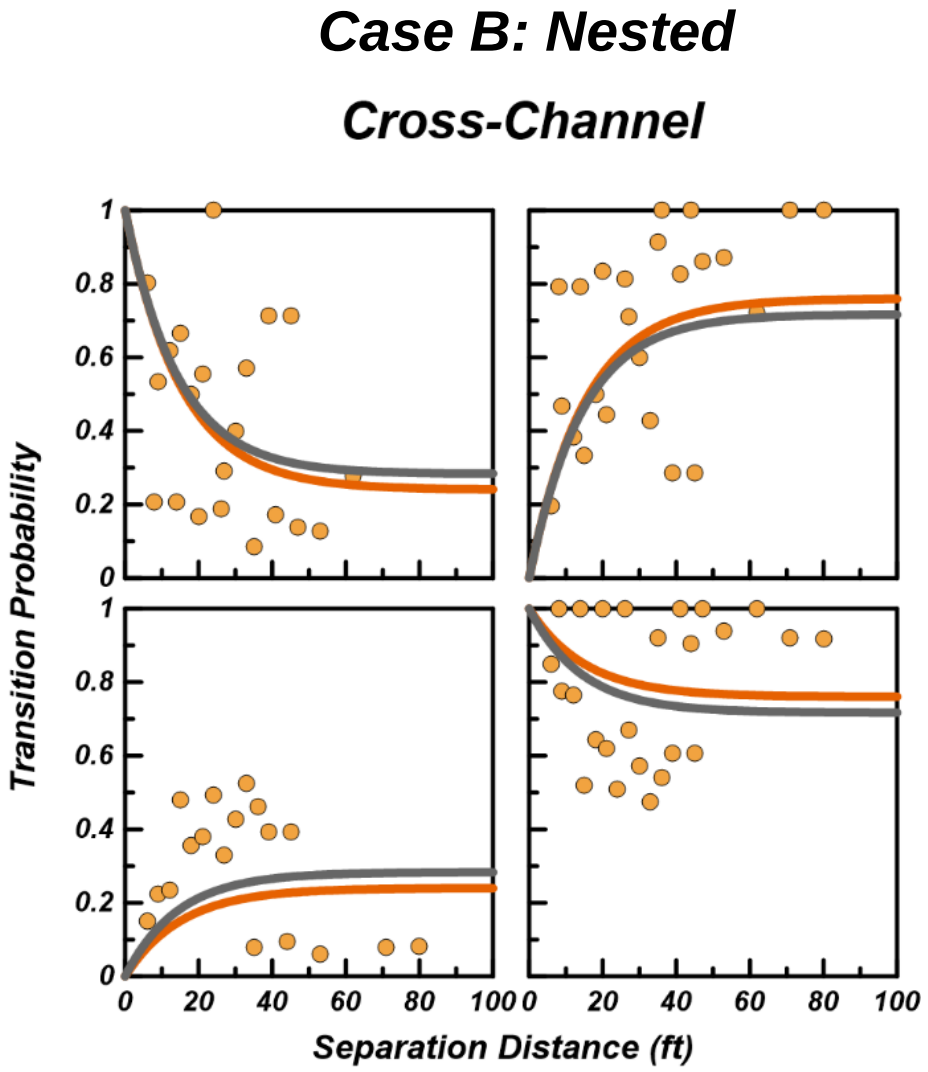




Comparison of Cases A & B

- Nested investigation improves mapping of transitional probability functions
- Opportunity for ‘real-time’ updating of SI plan





Paths Forward

- Tools
  - Improved equipment, equipment selection, and data interpretation
- Integrated Site Characterization
  - Hypothesis driven, geologist + coffee, SI is for confirmation NOT discovery
- Scales of Characterization / Modeling
  - Stratigraphic layers, inter-depositional variability, performance variability
- Optimized Site Characterization
  - Hypothesis driven, balance geologic structure **vs.** engineering properties, 'real-time' nested SI strategy updated w/ loss function

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(Katerina)

U.S. – New Zealand – Japan International Workshop

Liquefaction-Induced Ground Movements Effects

November 2-4, 2016

UC Berkeley

PATHS FORWARD TOWARD ASSESSING THE EFFECTS OF LIQUEFACTION ON STRUCTURES & LIFELINES: A TALE OF HONESTY AND BRAVERY

Katerina Ziotopoulou

Assistant Professor

UCDAVIS

Strong inference redirects a man to problem-orientation, but it requires him to be willing repeatedly to put aside his last methods and teach himself new ones

-- J. R. Platt 1964

Truth will sooner come out from error than from confusion

-- Francis Bacon

THREE ASSUMPTIONS (OR FACTS…)

1) Abundance of Time

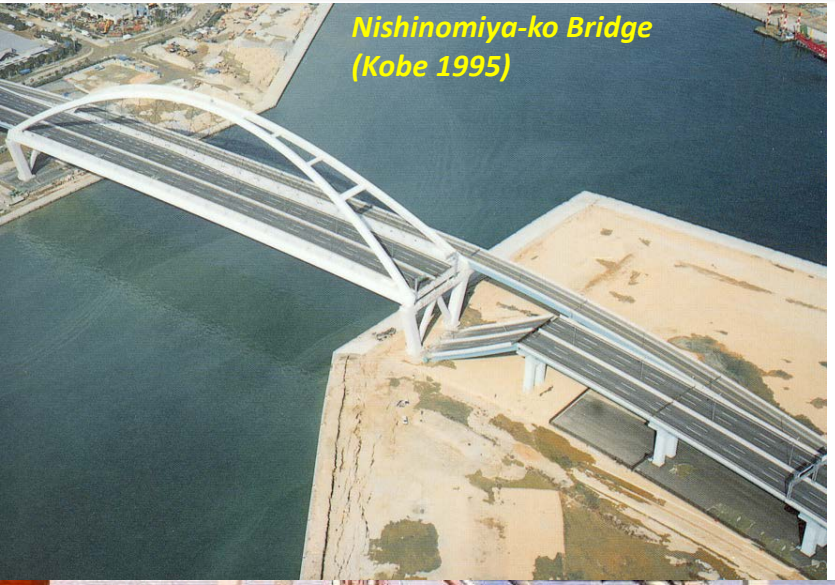
2) Abundance of Monetary Resources

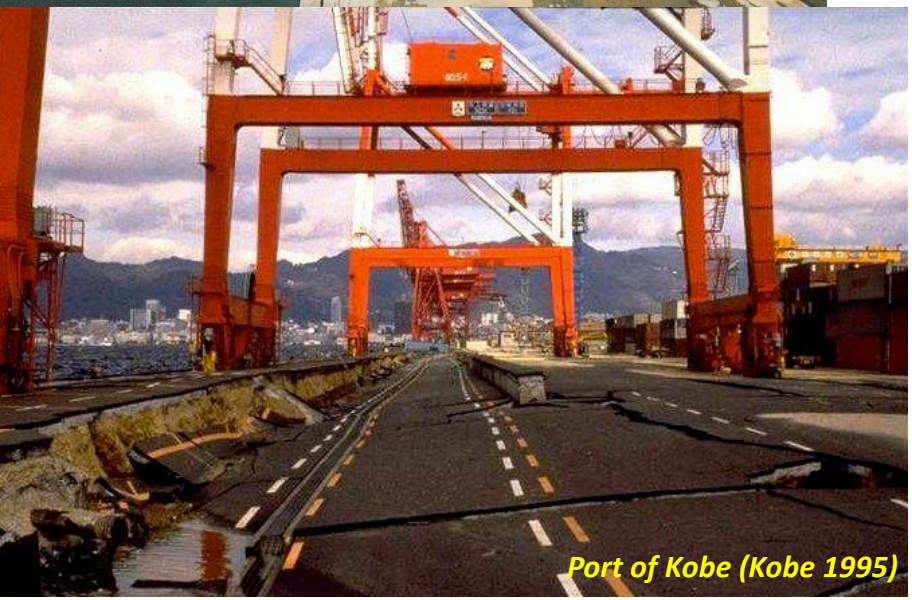
3) Applicability and Usability in Practice not of Immediate Concern

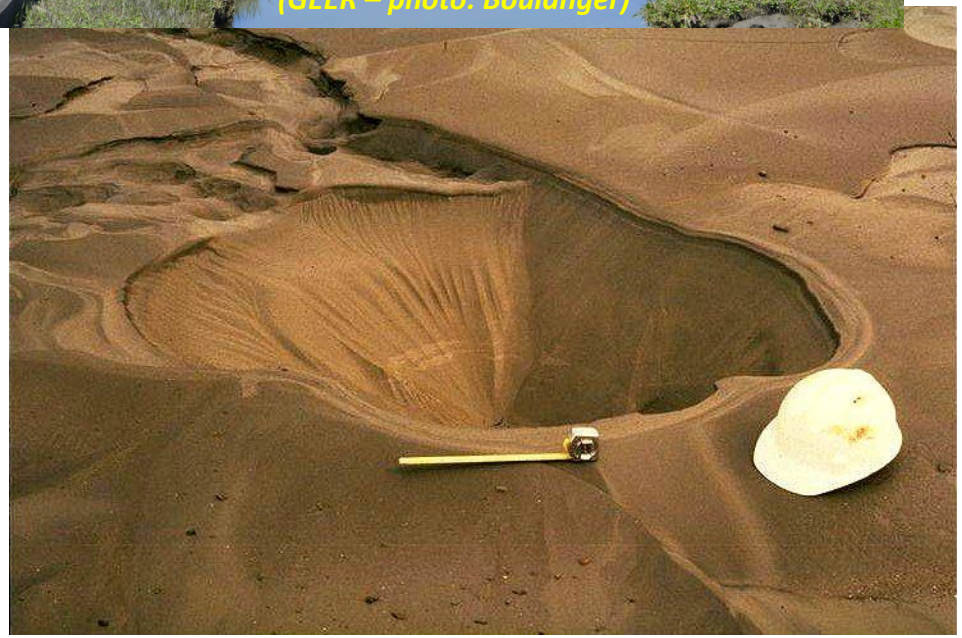
And ….

Experience (εμπειρία – empiria) is precious, empiricism alone not so much

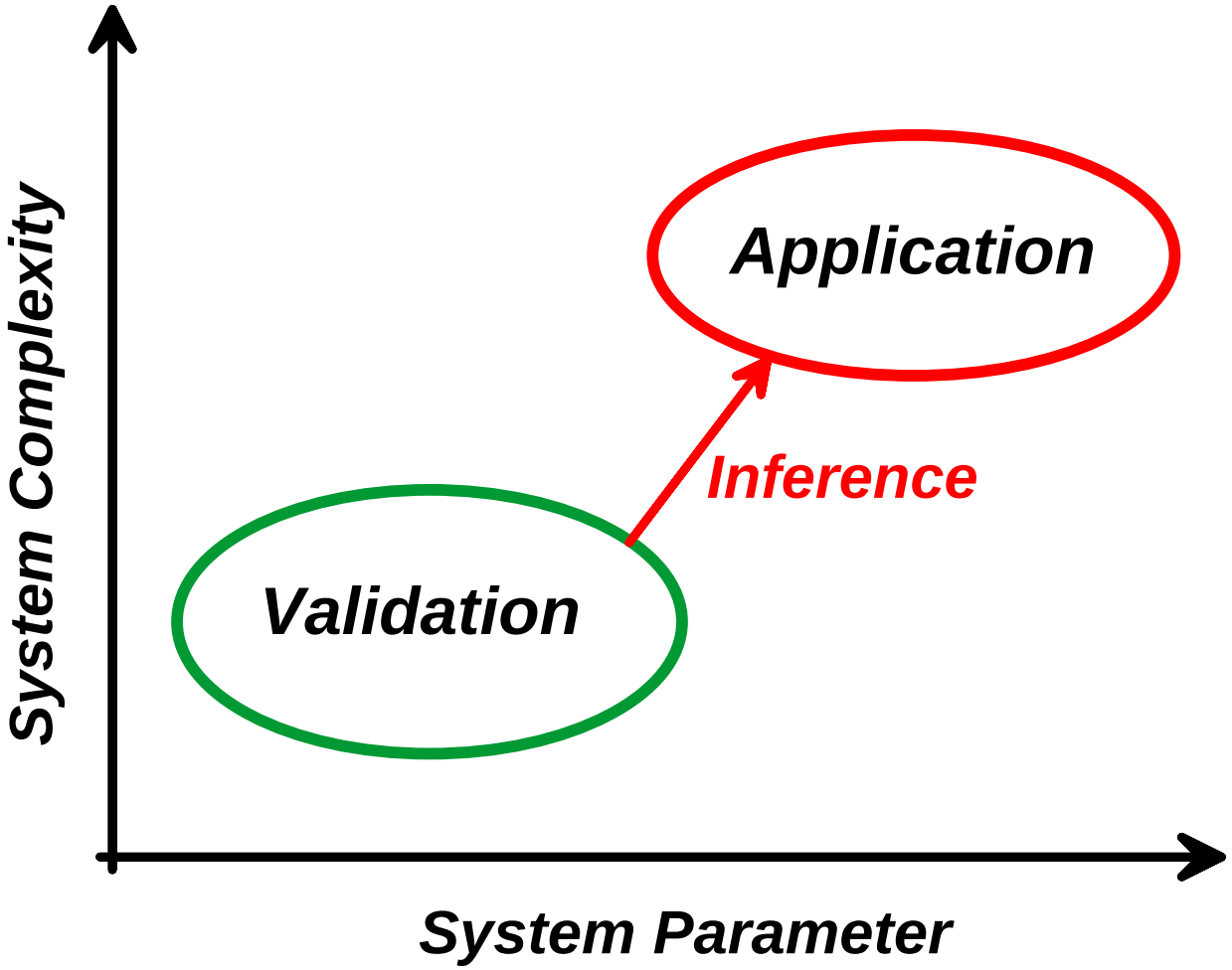
WHAT IS THE PROBLEM ?





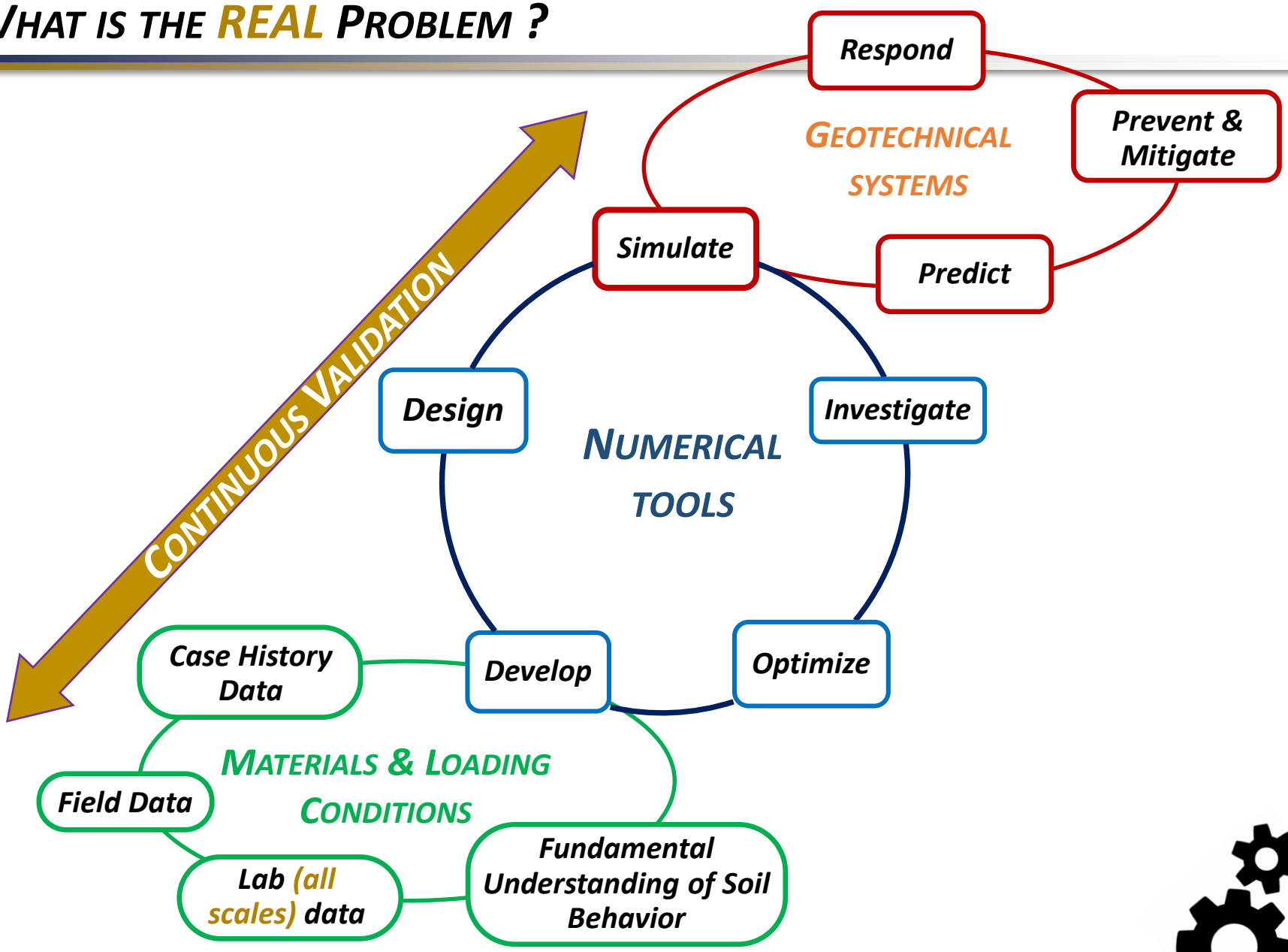


WHAT IS THE REAL PROBLEM ?



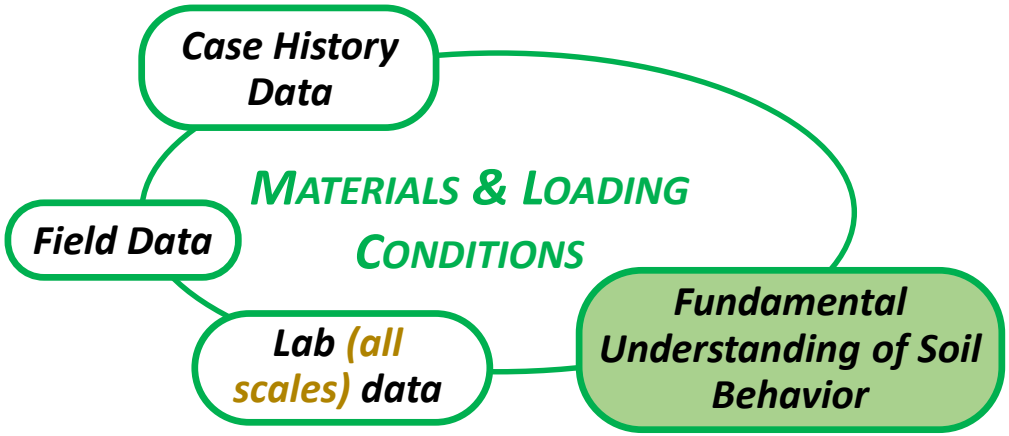
(after Oberkampf et al. 2002)

WHAT IS THE REAL PROBLEM ?



WHAT COULD BE THE SOLUTION ?

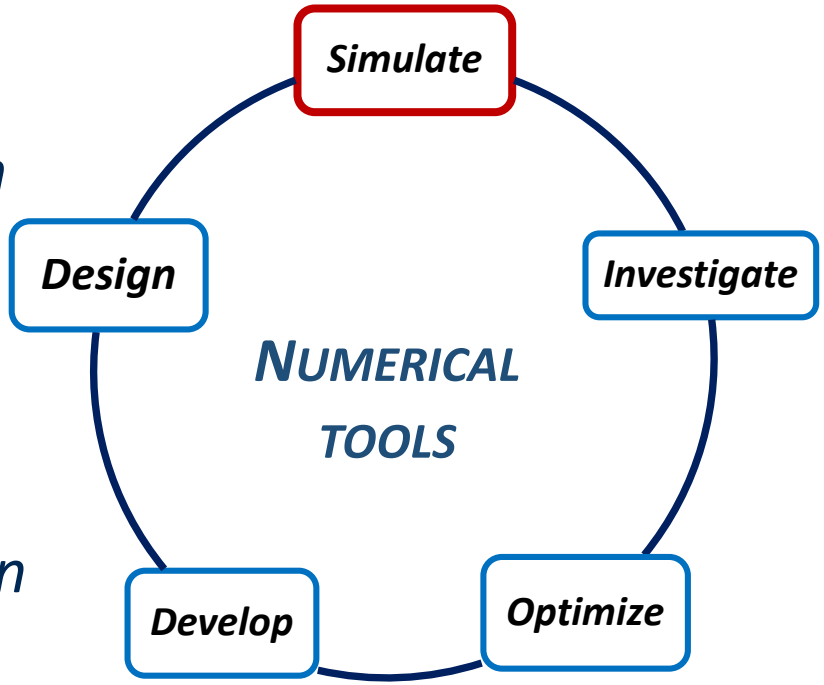
- ***Need to reveal the theories behind the mechanisms***
- *Geotechnical and hydrological data, better data, whatever it takes (development of instrumentation tools, development of site investigation tools etc.)*
- *Broader data:*
  - *Different compressibilities, e.g. test calcareous sands*
  - *Aged / cemented soils (MICP?)*
  - *Different depositional environments*
- *Instrumentation arrays? A big test-bed? … and patience?*



WHAT COULD BE THE SOLUTION ?

Mechanistically and numerically capture sand ejecta, void redistribution, deviatoric and volumetric strain components…

- *3D simulations*
- *Different formulations (DEM, MPM)*
- *More realistic (sic) constitutive models*
- *(even) better speeds of simulation*
- *Better capture water diffusion, and water patterns in general*
- ***Better simulation of tests** (e.g. element tests, centrifuge tests, shake table tests, site investigation tests, field tests)*



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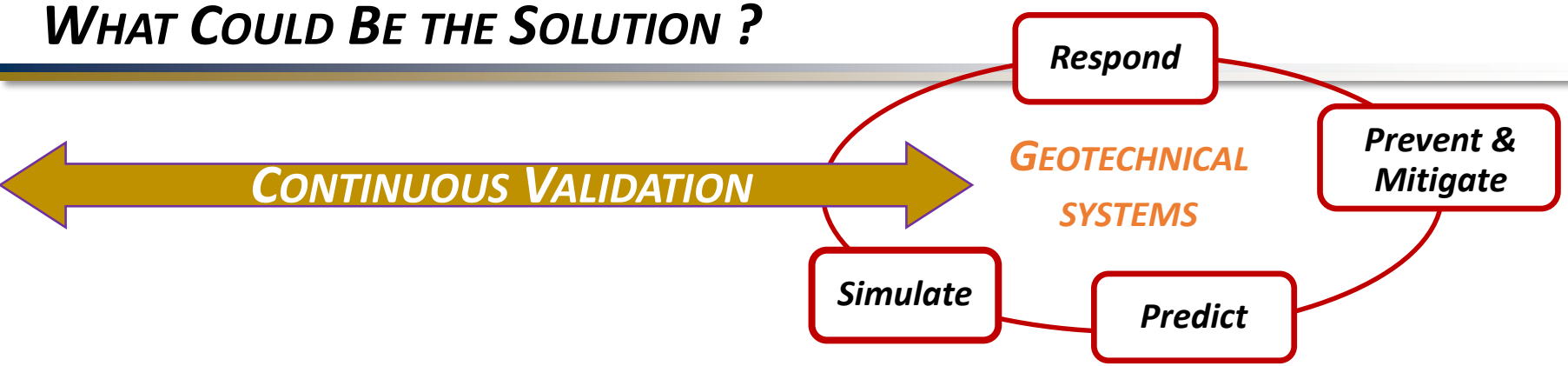

- *Need robust **metrics** on validation (when are we going to be happy enough?)*
- *Better uncertainty **representation**, uncertainty **quantification**, and uncertainty **propagation** through systems.*
- ***Systems engineering** (soil is a system, a structure is a system, a city and lifelines are a system of systems etc. etc.)*
- *Need for better communication across the board (almost there…)*

WHAT COULD BE THE SOLUTION ?

And*….*

- ***Educate*** *the next generation right now, much better (fundamental mechanics?)*

- ***Train*** *young researchers on cognitive skills:*

sensitivity, curiosity, creativity, imagination, ingenuity, logic

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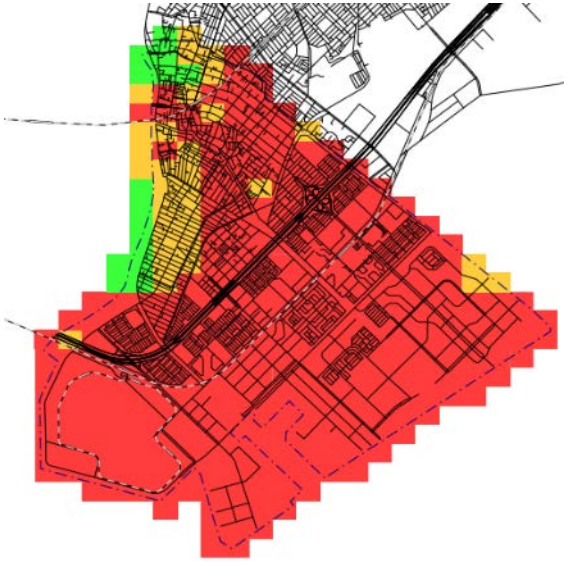
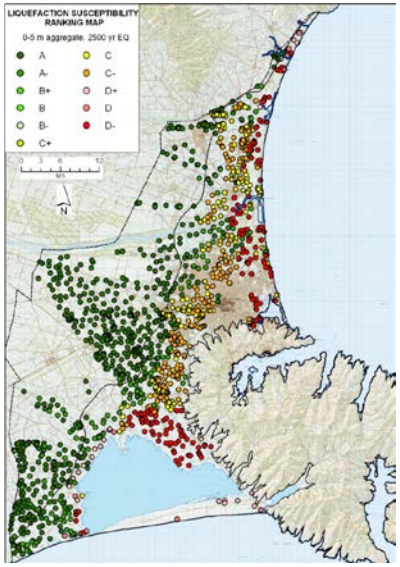
(Kiyota)

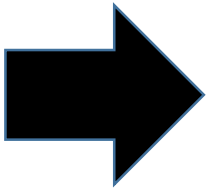
A NEW LIQUEFACTION HAZARD MAP



Urayasu City
(Chiba Pref.)



Christchurch
(GNS)



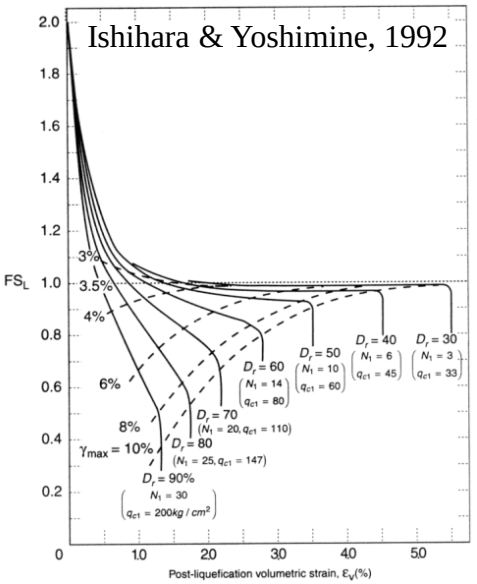
Takashi KIYOTA

Institute of Industrial Science, University of Tokyo

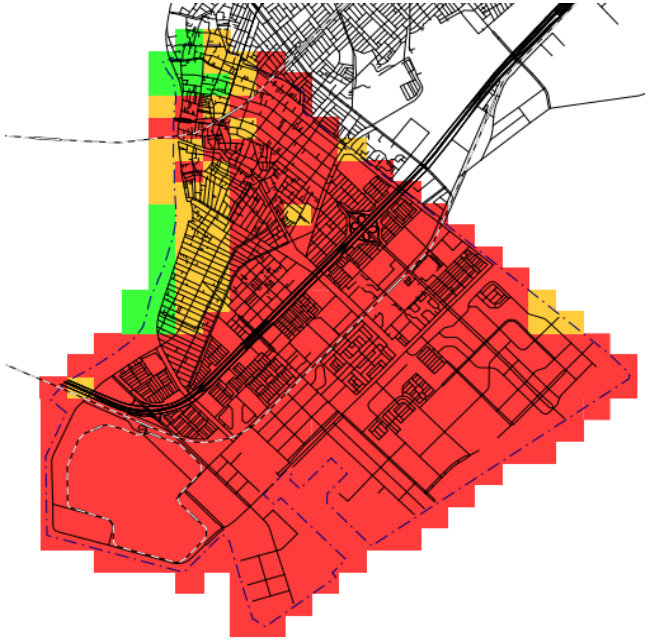
Challenge

To develop a new easy-to-understand and rational hazard map

Liquefaction in 2011 Tohoku Earthquake



- ✓ Settlement of houses, road subsidence, lifelines cut off



Liquefaction hazard map

- ✓ Map provides liquefaction probability
- ✓ **NO specific information** (quantitative information is preferred. e.g. settlement)
- ✓ **Inaccurate** (the same soil condition, but different damage)

Air-borne LiDAR

Air-borne LiDAR survey

Measure the distance between aircraft and objects by detecting the traveling time of emitted laser.

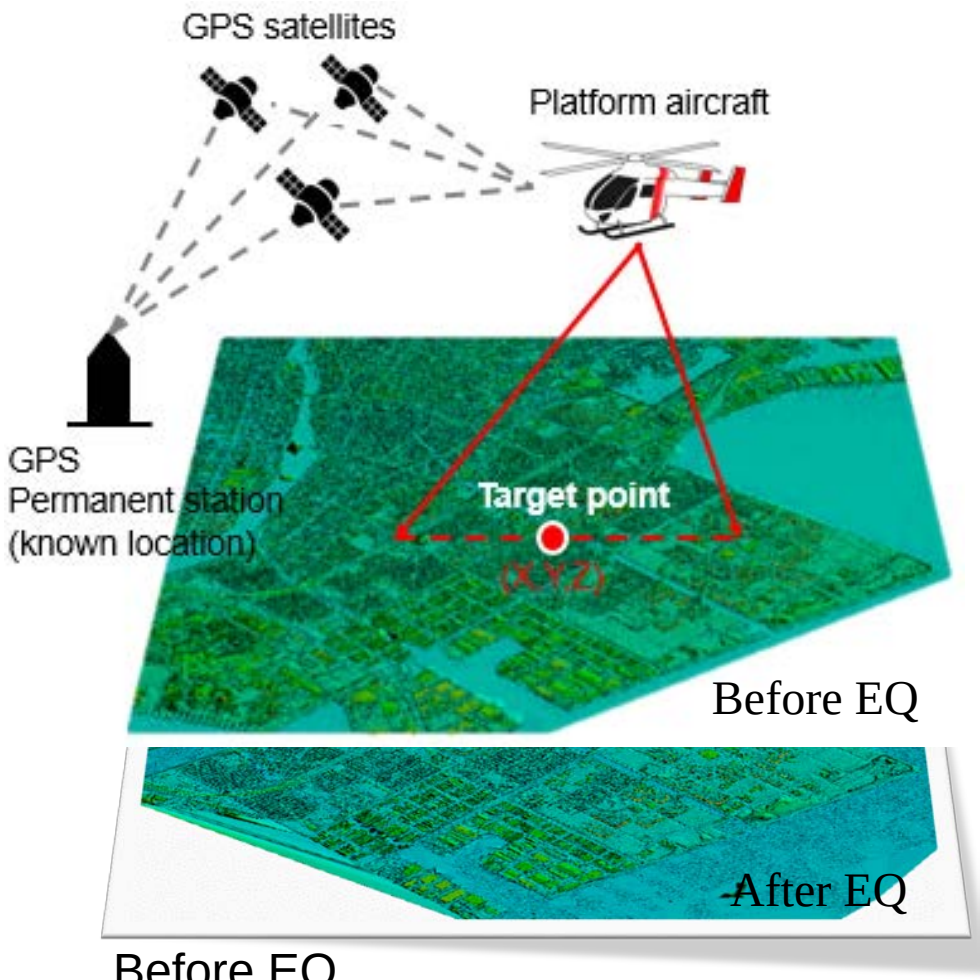
Detection of Ground subsidence

The change in elevation can be obtained by comparing two DSMs before and after EQ.

Spatial resolution:

Before 0.792 points/m^2

After 4.089 points/m^2



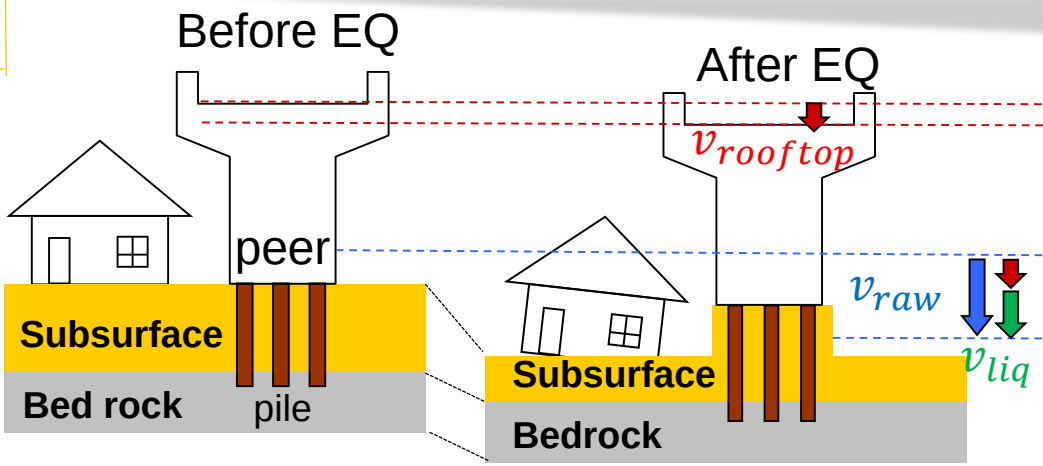
Cancelling tectonic deformation

$$v_{liq} = v_{raw} - v_{rooftop}$$

v_{liq} : liquefaction-induced subsidence(m)

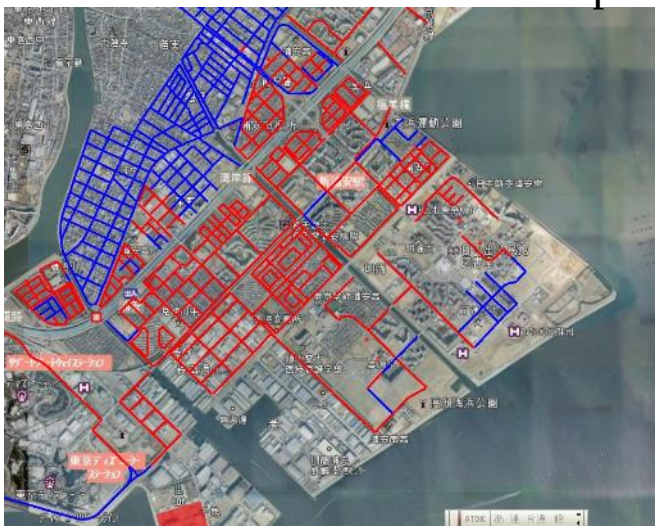
v_{raw} : Change in elevation observed from LiDAR(m)

$v_{rooftop}$: Change in elevation of pile-supported building(m)

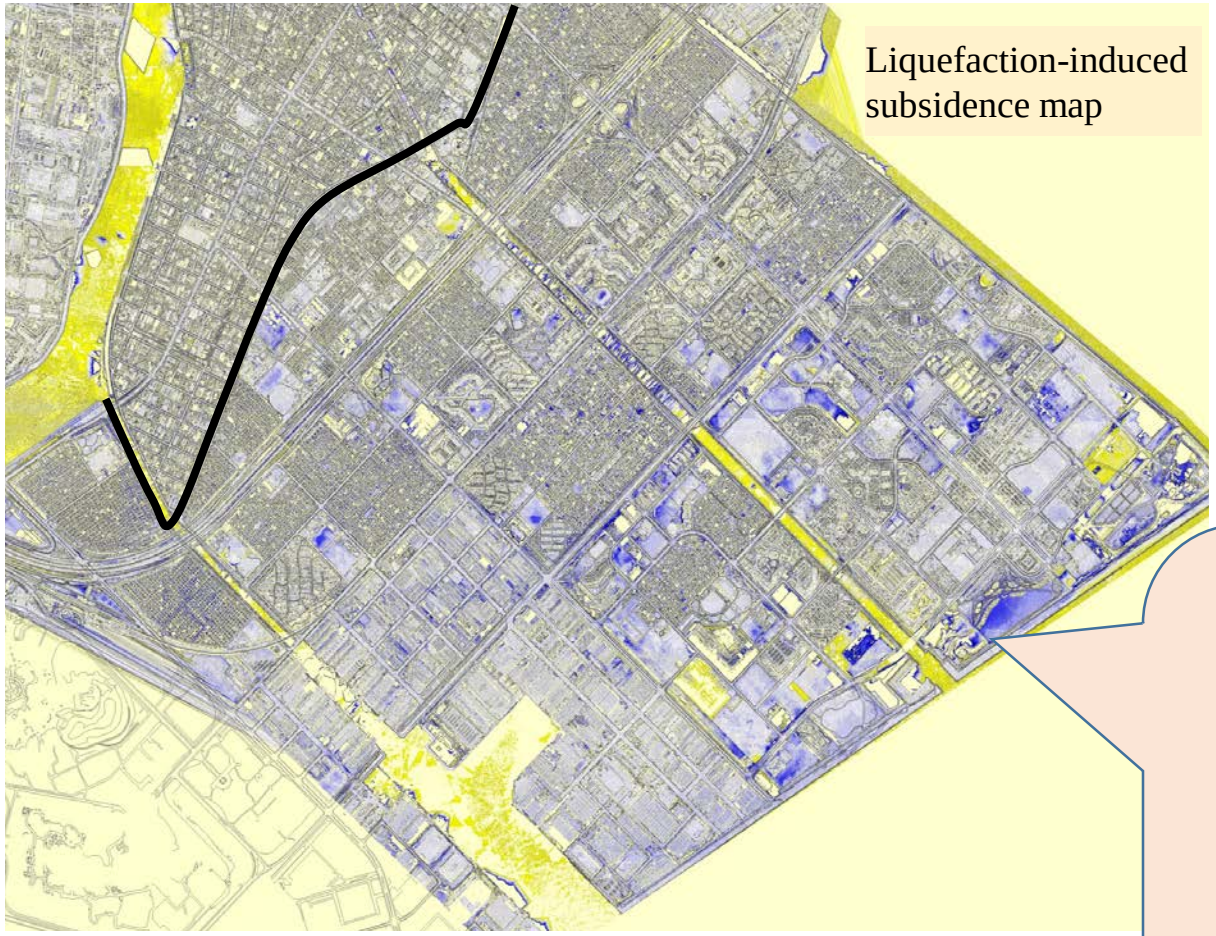


Liquefaction-induced subsidence map

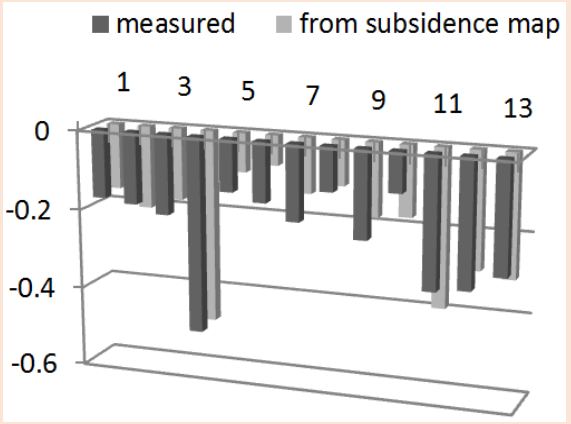
Boiled sand map



MLIT, 2011

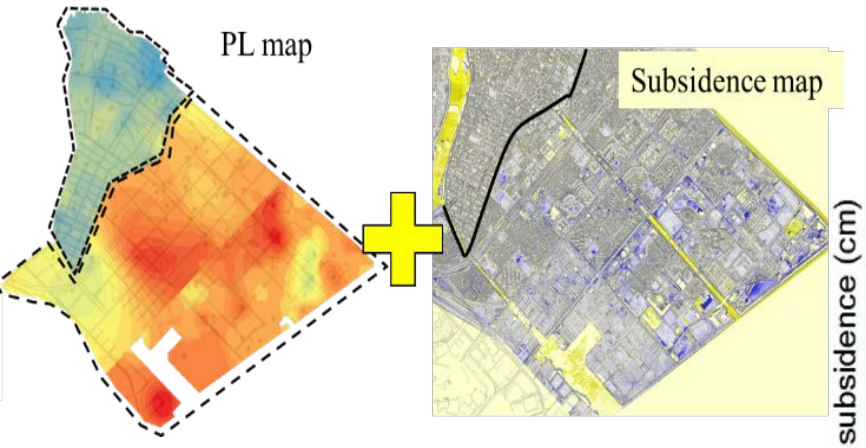


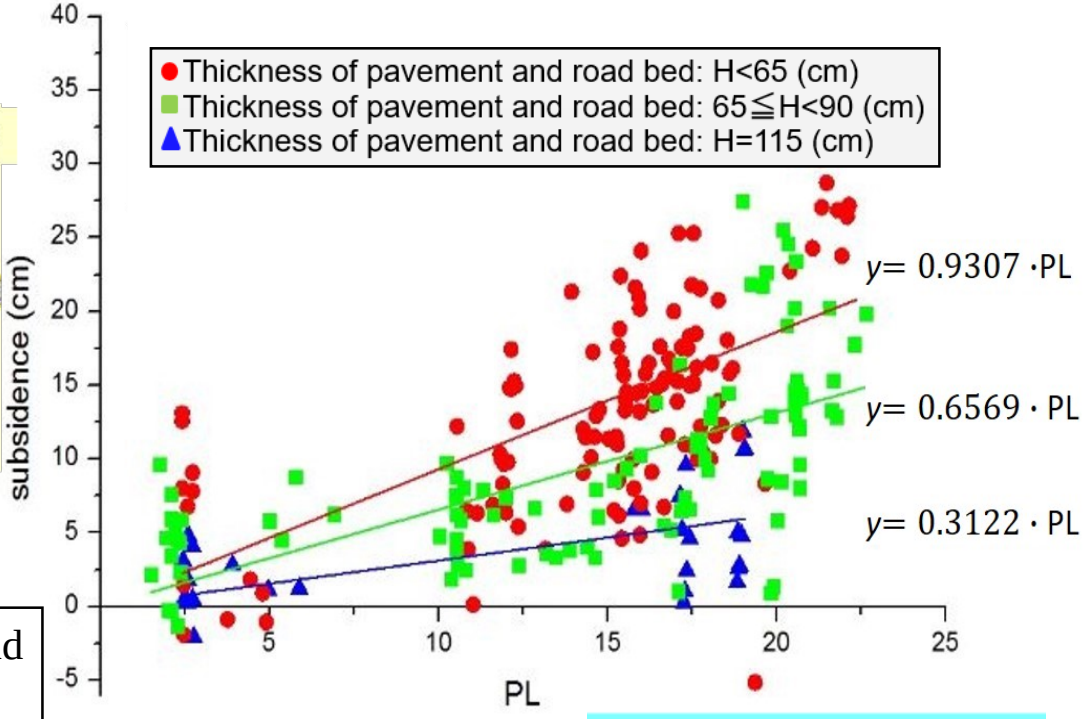
Konagai et al., 2013



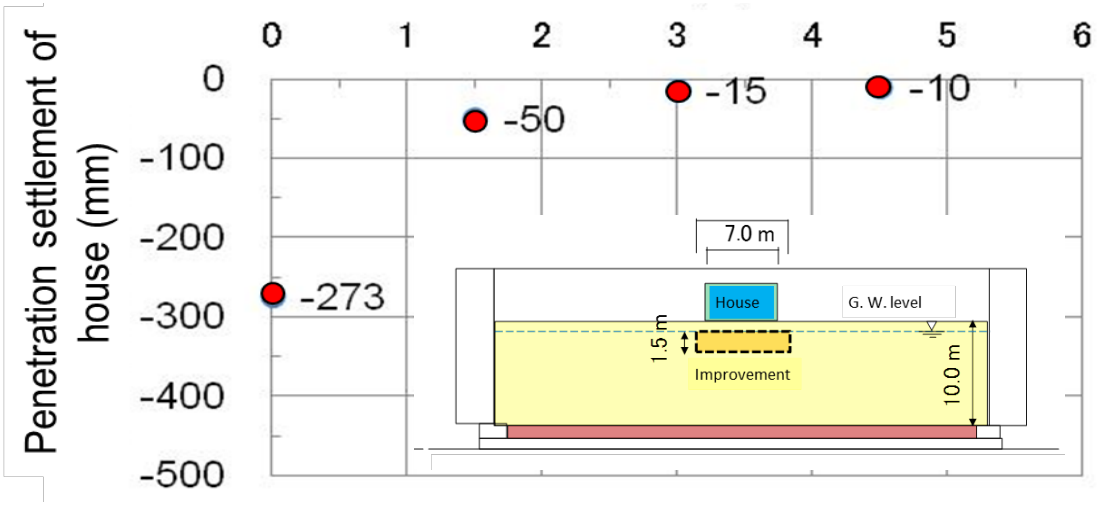
Average error: 13 mm
Standard deviation: 44mm

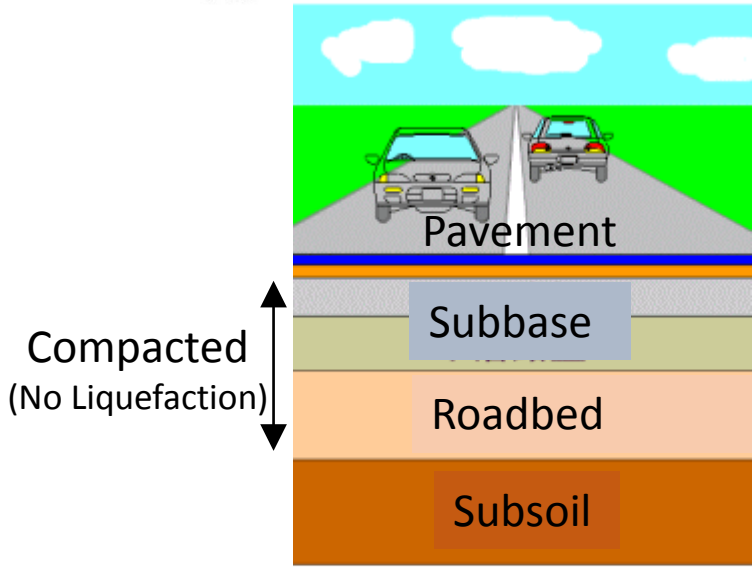
Extract liquefaction-induced road subsidence





The trend is similar to the shallow ground improvement for liquefaction mitigation

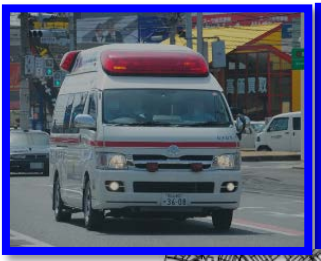




Tani et al., 2013

Liquefaction hazard map for road subsidence

For
Resident: Specific image of possible damage, prepare for evacuation (tsunami)
Government: Disaster management, lifeline management, route for emergency vehicle
PATH FORWARD: Important to store relevant record for future investigation/application



Current Hazard Map

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(Jenny Haskell)

Pile foundations in laterally spreading soils

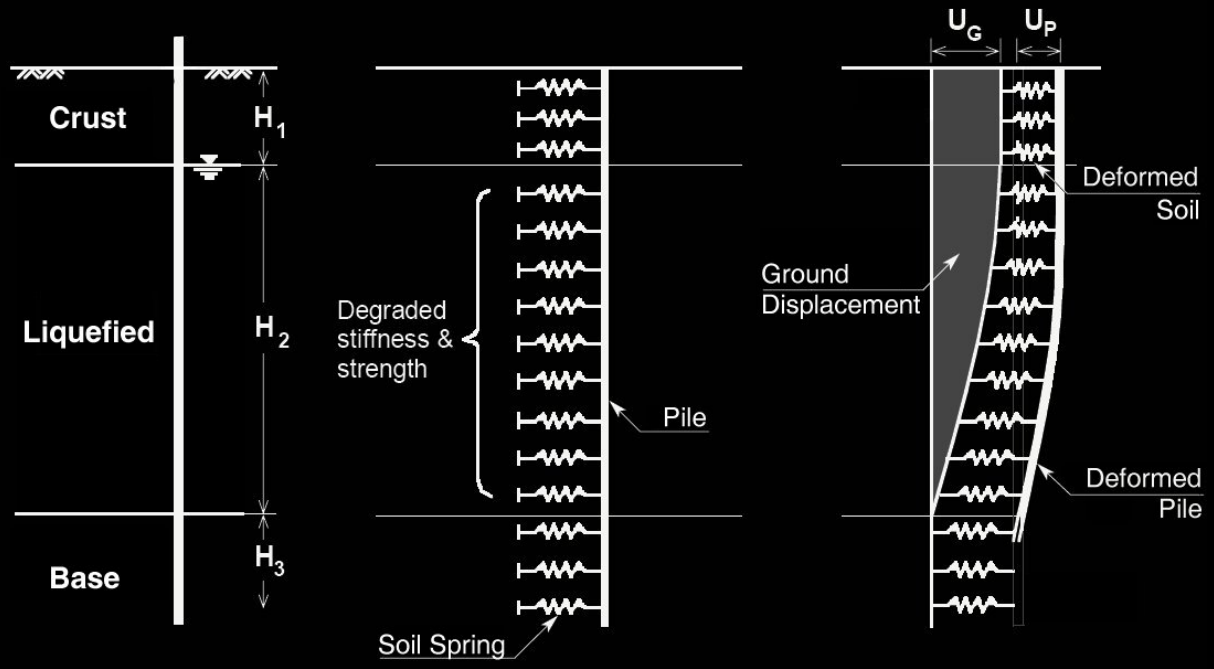
Building a mechanism-based framework?

Jennifer Haskell

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

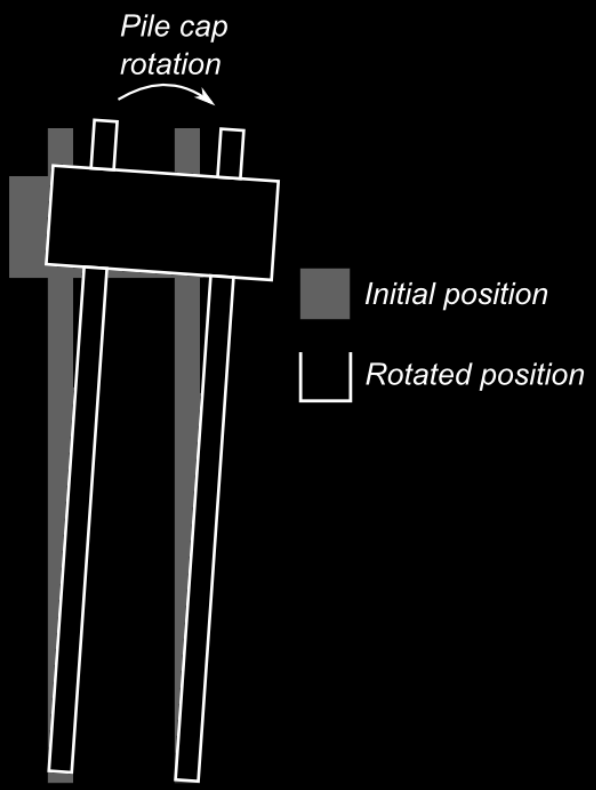
EQC
EARTHQUAKE COMMISSION
KŌMIHANA RŪWHENUA

PSEUDO-STATIC MODELLING/PARAMETRIC SENSITIVITIES

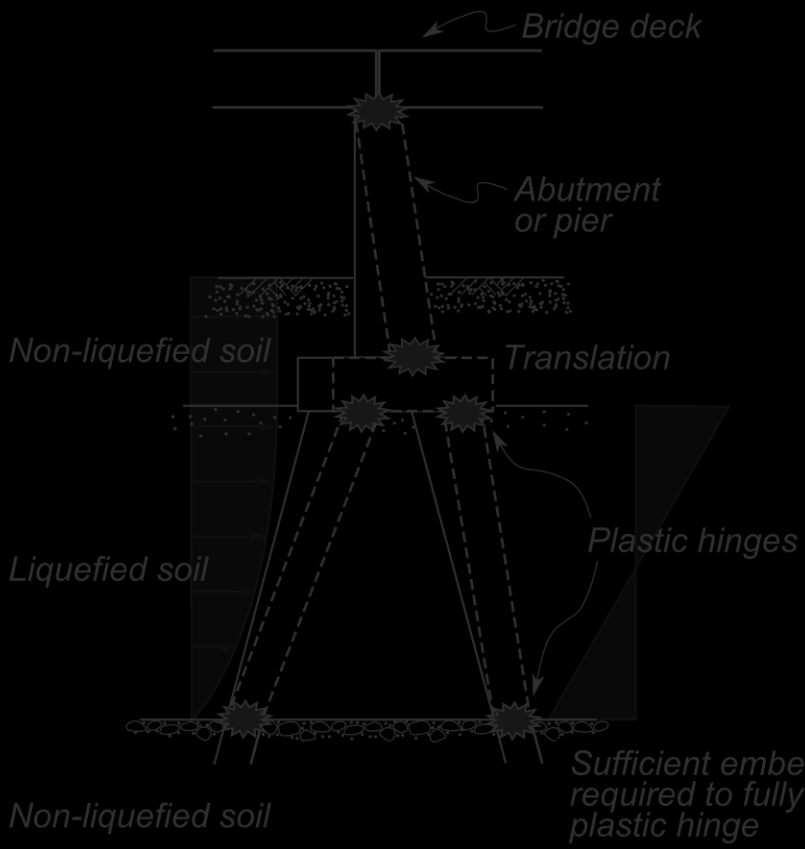


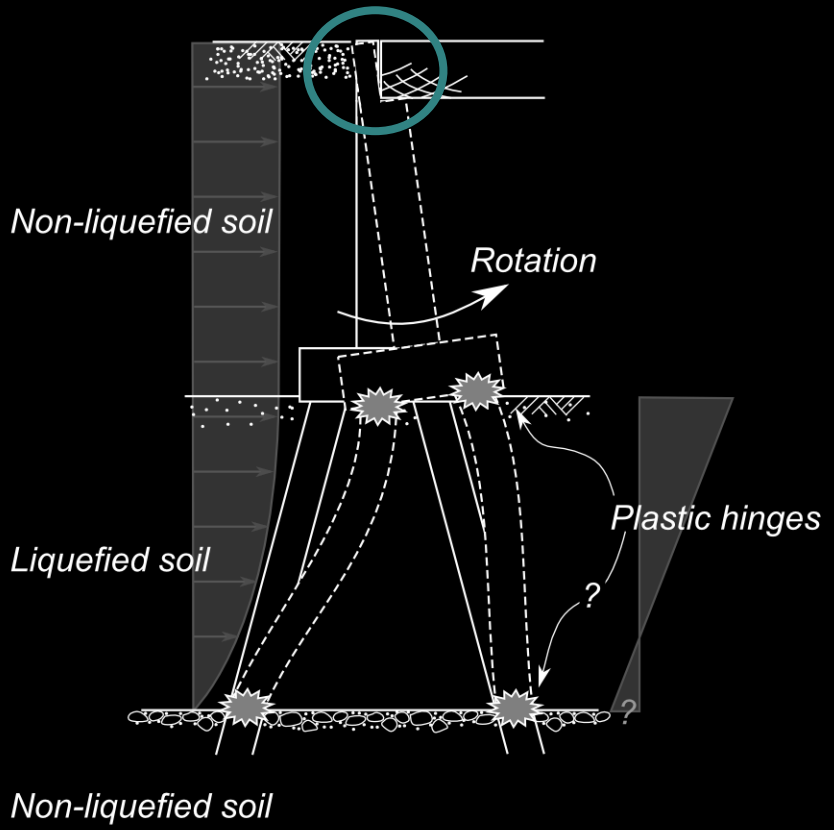
Credit: Cubrinovski

CENTRIFUGE EXPERIMENTS: RIGID OVERTURNING

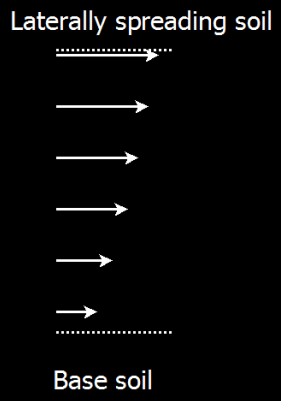


CHRISTCHURCH EARTHQUAKES: BACK-ROTATION





SOME MECHANISMS OF PILE GROUP RESPONSE

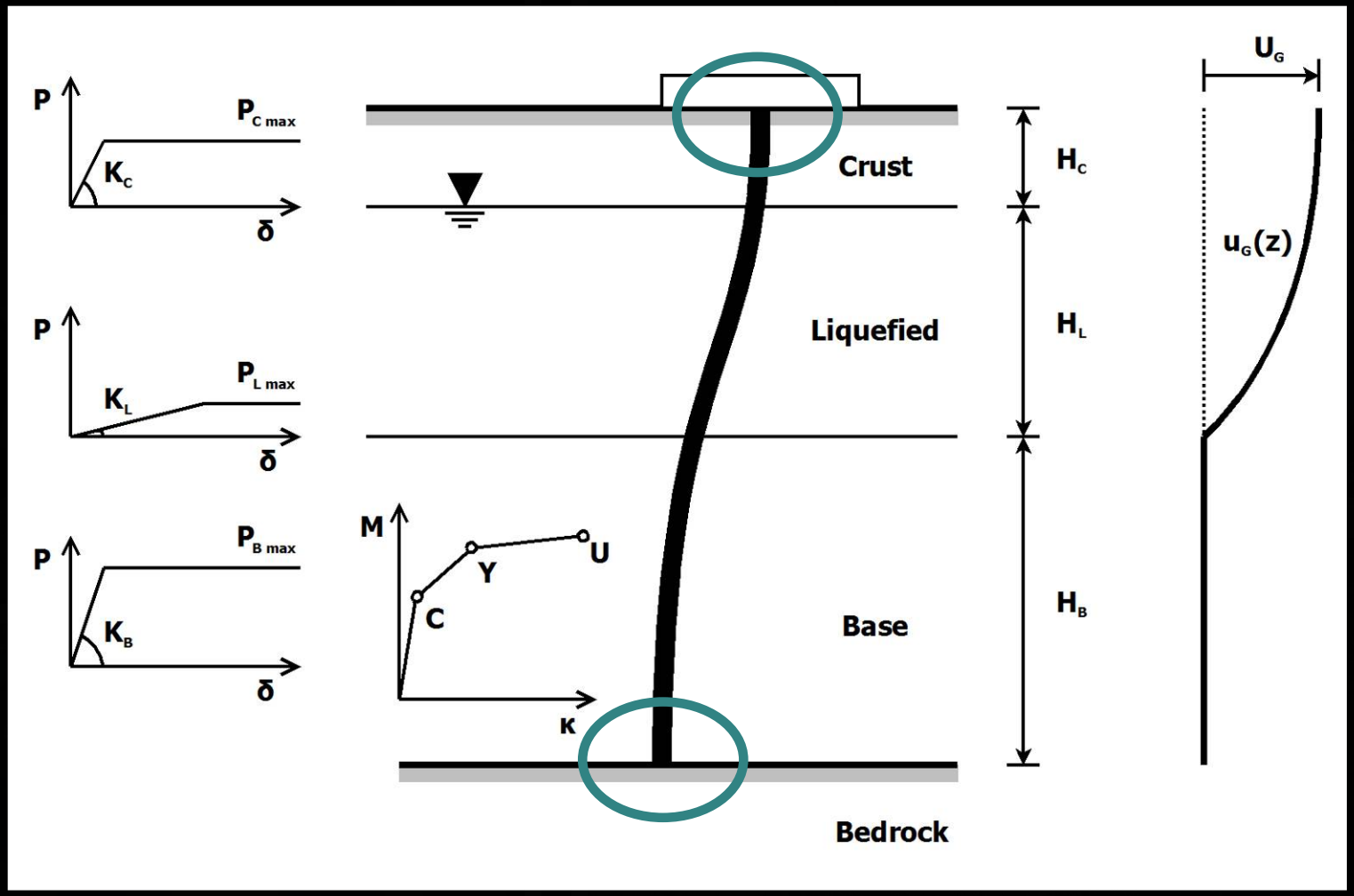


Free-field

Conventional mechanisms
- … assume good pile tip fixity
- … controlled by relative soil-pile stiffness

Other potential mechanisms?
- … can they develop in the field?
- … what are the consequences for performance?

Fundamental importance of boundary/fixity conditions...



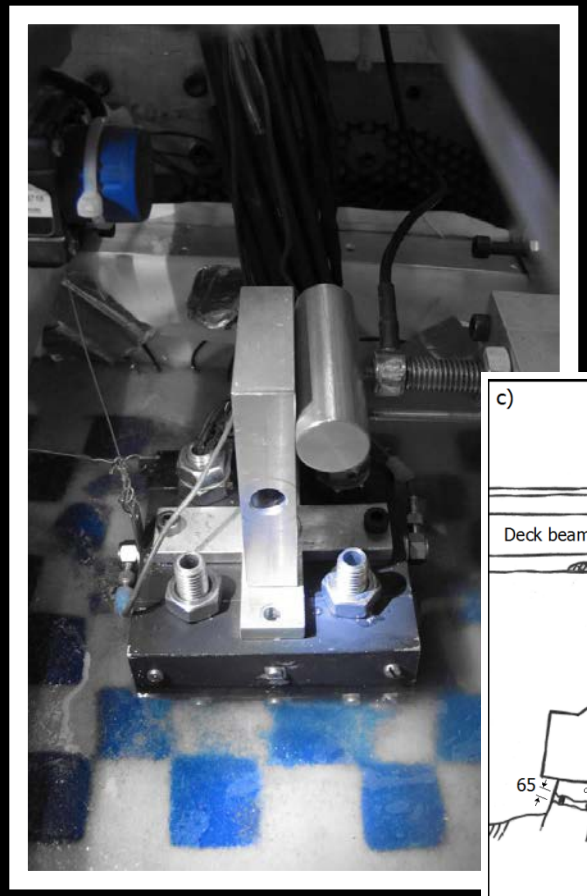
SOME DETAILS THAT MIGHT INFLUENCE/CONTROL PREVAILING MECHANISM...

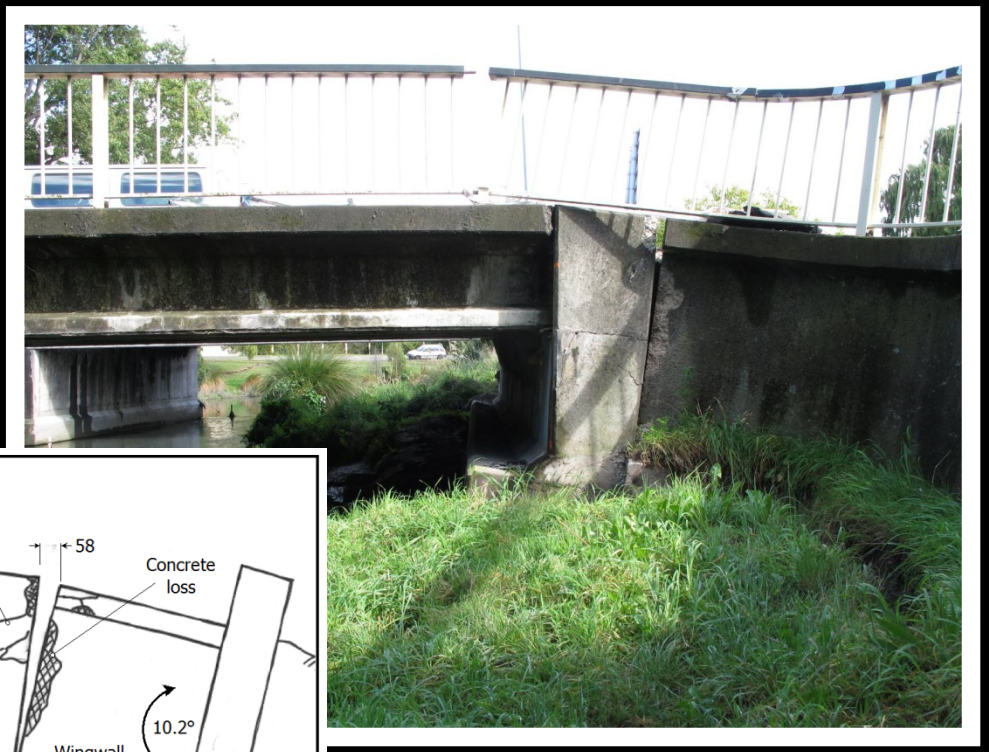
Identify the range of possible response mechanisms and governing/controlling parameters and design details that influence which mechanism ultimately prevails

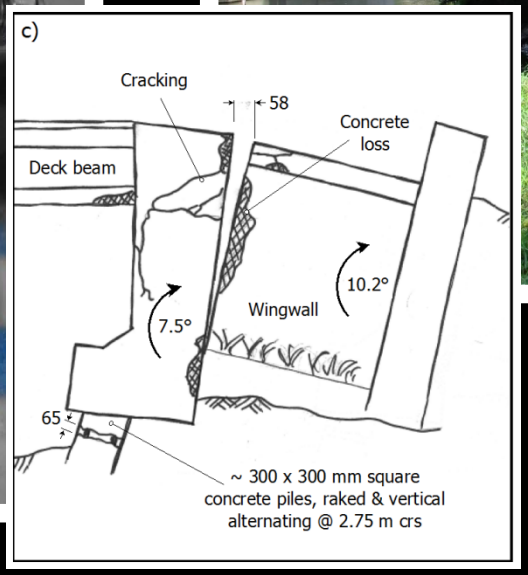
Develop a comprehensive mechanism-based framework for describing and anticipating which mechanisms might develop for a given scenario

Development of mechanism-specific design solutions and damage mitigation options for existing foundations

Thanks







UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

EQC
EARTHQUAKE COMMISSION
KŌMIHANA RŪWHENUA

Blank Slide
(Dong Youp)

Next-Generation Liquefaction (NGL)

Dongyoup Kwak
Scott J. Brandenberg
Yousef Bozorgnia
Steven L. Kramer
Jonathan P. Stewart

2016 US-NZ-Japan NSF Workshop, Berkeley

Database Contents

Site Information

- Borings (e.g., SPT, Tube)
- CPT
- Test pit
- Geophysical tests (Vs)

Ground Motion

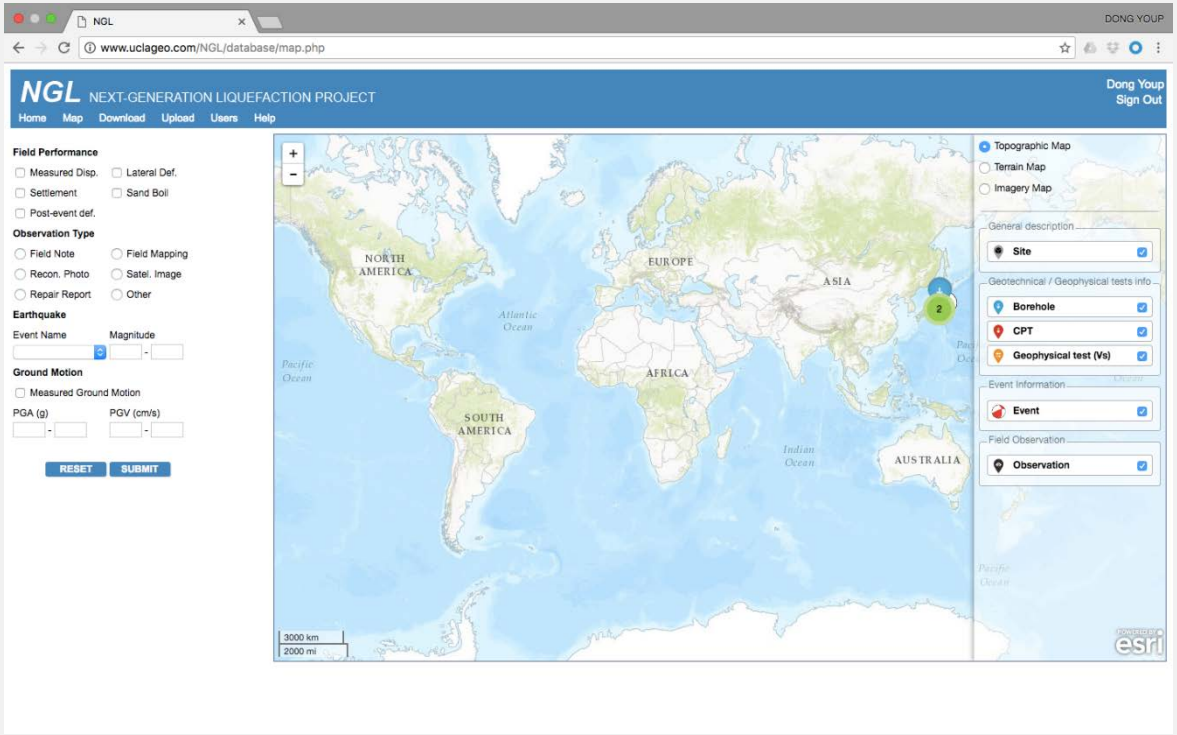
- Event information (e.g., **M**, fault solution, source-to-site distance)
- Intensity measures (PGA, PGV, SAs, duration, records…)

Field Performance

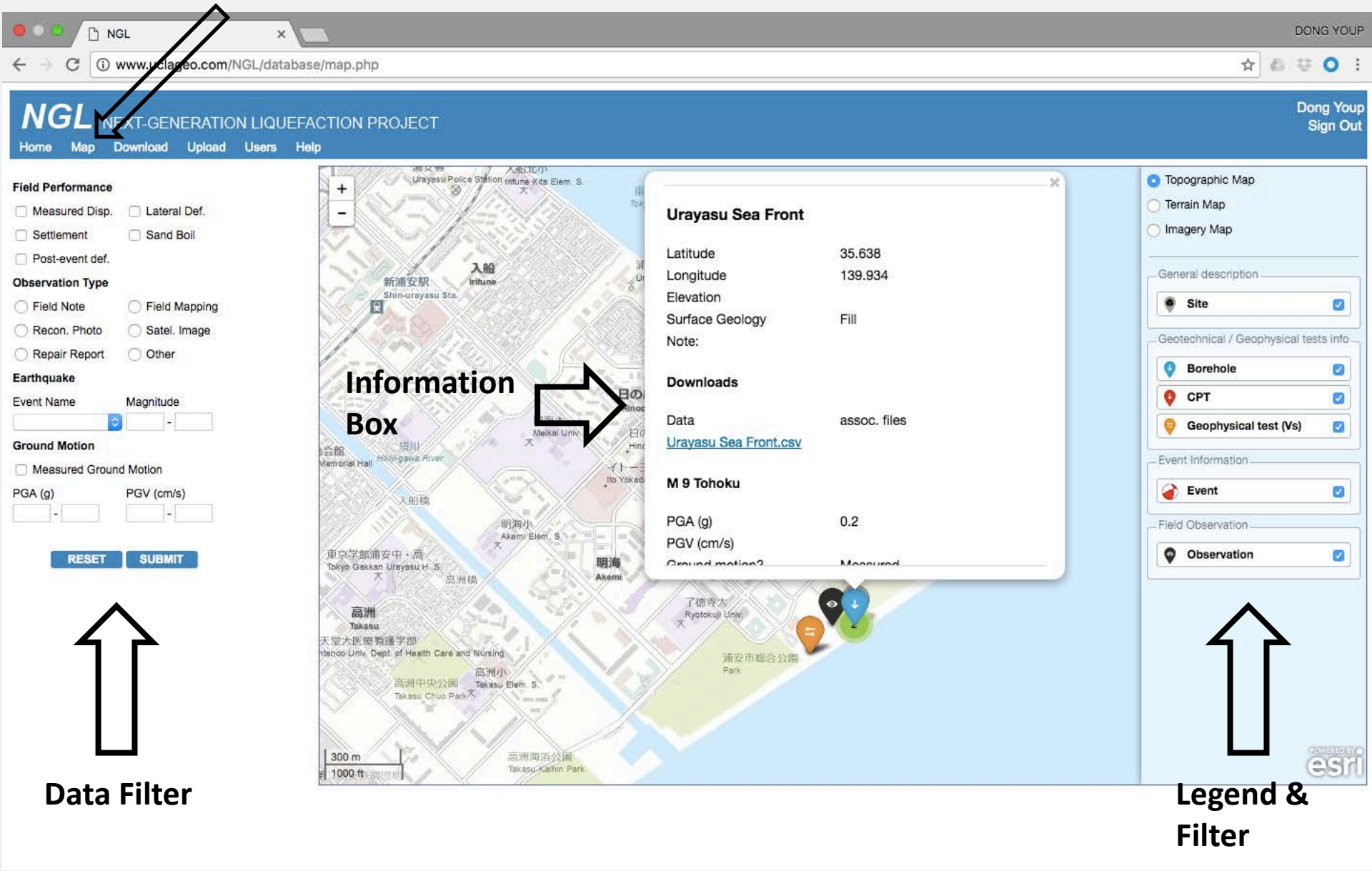
- Field notes
- Recon. photos
- Satellite images
- LiDAR image
- Vector maps

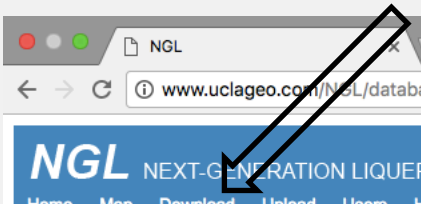
WEB-BASED DATABASE

- Data structure and format
  - Follow AGS4 file format (http://www.agsdataformat.com/datatransferv4/intro.php)
  - CSV file format; any format for attachment
  - SQL database for metadata
- Profile-view (i.e., Boring, CPT, Vs)
- Data filter
- Coupled with NGA West2 database



http://www.uclageo.com/NGL/database


NGL
www.uclageo.com/NGL/database/map.php
DONG YOUP
NGL NEXT-GENERATION LIQUEFACTION PROJECT
Home Map Download Upload Users Help
Dong Youp
Sign Out
Field Performance
Measured Disp.
Lateral Def.
Settlement
Sand Boil
Post-event def.
Observation Type
Field Note
Field Mapping
Recon. Photo
Satel. Image
Repair Report
Other
Earthquake
Event Name
Magnitude
Ground Motion
Measured Ground Motion
PGA (g)
PGV (cm/s)
RESET
SUBMIT
Information Box
Urayasu Sea Front
Latitude 35.638
Longitude 139.934
Elevation
Surface Geology Fill
Note:
Downloads
Data assoc. files
Urayasu Sea Front.csv
M 9 Tohoku
PGA (g) 0.2
PGV (cm/s)
Topographic Map
Terrain Map
Imagery Map
General description
Site
Geotechnical / Geophysical tests info
Borehole
CPT
Geophysical test (Vs)
Event Information
Event
Field Observation
Observation
300 m
1000 ft
Data Filter
Legend & Filter



NGL

DONG YOUP

www.uclageo.com/NGL/database/download.php

NGL NEXT-GENERATION LIQUEFACTION PROJECT

Home Map Download Upload Users Help

Dong Youp
Sign Out

Field Performance

- Measured Disp.
- Lateral Def.
- Settlement
- Sand Boil
- Post-event def.

Earthquake

Event Name
Magnitude -

Ground Motion

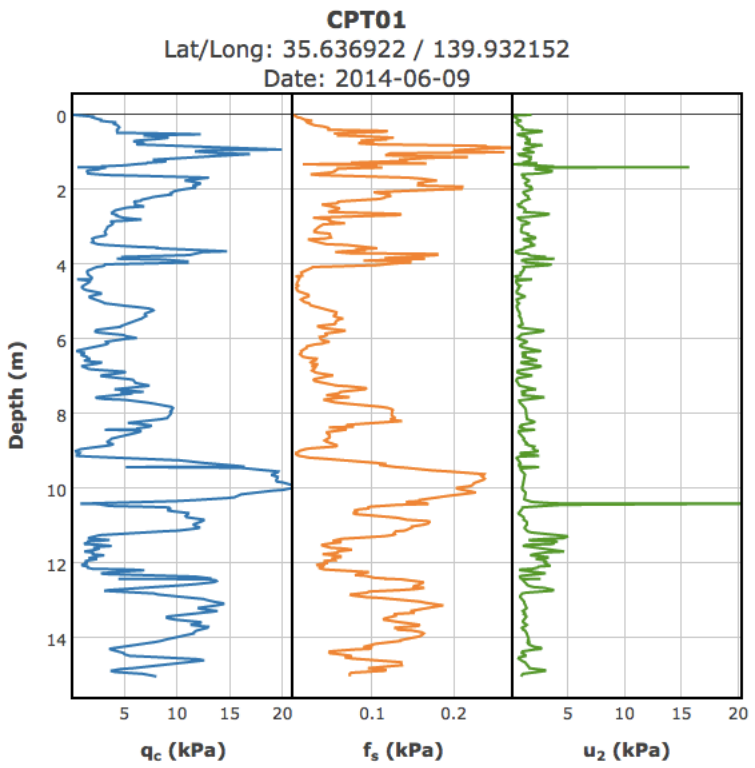
PGA (g) -
PGV (cm/s) -

RESET SUBMIT

Name	Description	File	Assoc. Files
Urayasu Sea Front	Site information (complete data).	Urayasu Sea Front.csv	
Urayasu Sea Front / SPT01	Borehole.	SPT01.csv plot	CHB-URY-SPT01.csv
Urayasu Sea Front / SPT01 / SPT-1	Lab test information.	SPT-1.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-2	Lab test information.	SPT-2.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-3	Lab test information.	SPT-3.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-4	Lab test information.	SPT-4.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-5	Lab test information.	SPT-5.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-6	Lab test information.	SPT-6.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-7	Lab test information.	SPT-7.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-8	Lab test information.	SPT-8.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-9	Lab test information.	SPT-9.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-10	Lab test information.	SPT-10.csv	ÀiUrayasu SPTÀj.pdf
Urayasu Sea Front / SPT01 / SPT-11	Lab test information.	SPT-11.csv	ÀiUrayasu SPTÀj.pdf

NGL | Profile | DONG YOUP

www.uclageo.com/NGL/database/graph.html



Dong Youp
Sign Out

CPT01 (Cone Penetration Test)

Latitude (deg)	35.6369
Longitude (deg)	139.932
Elevation (m)	
Limit of Investigation (m)	15.03
Activity Start Date	2014-06-09
Activity End Date	2014-06-09
Note:	

Downloads

Borehole information

Data assoc. files

CPT01.csv plot

Topographic Map
Terrain Map
Imagery Map

General description
Site

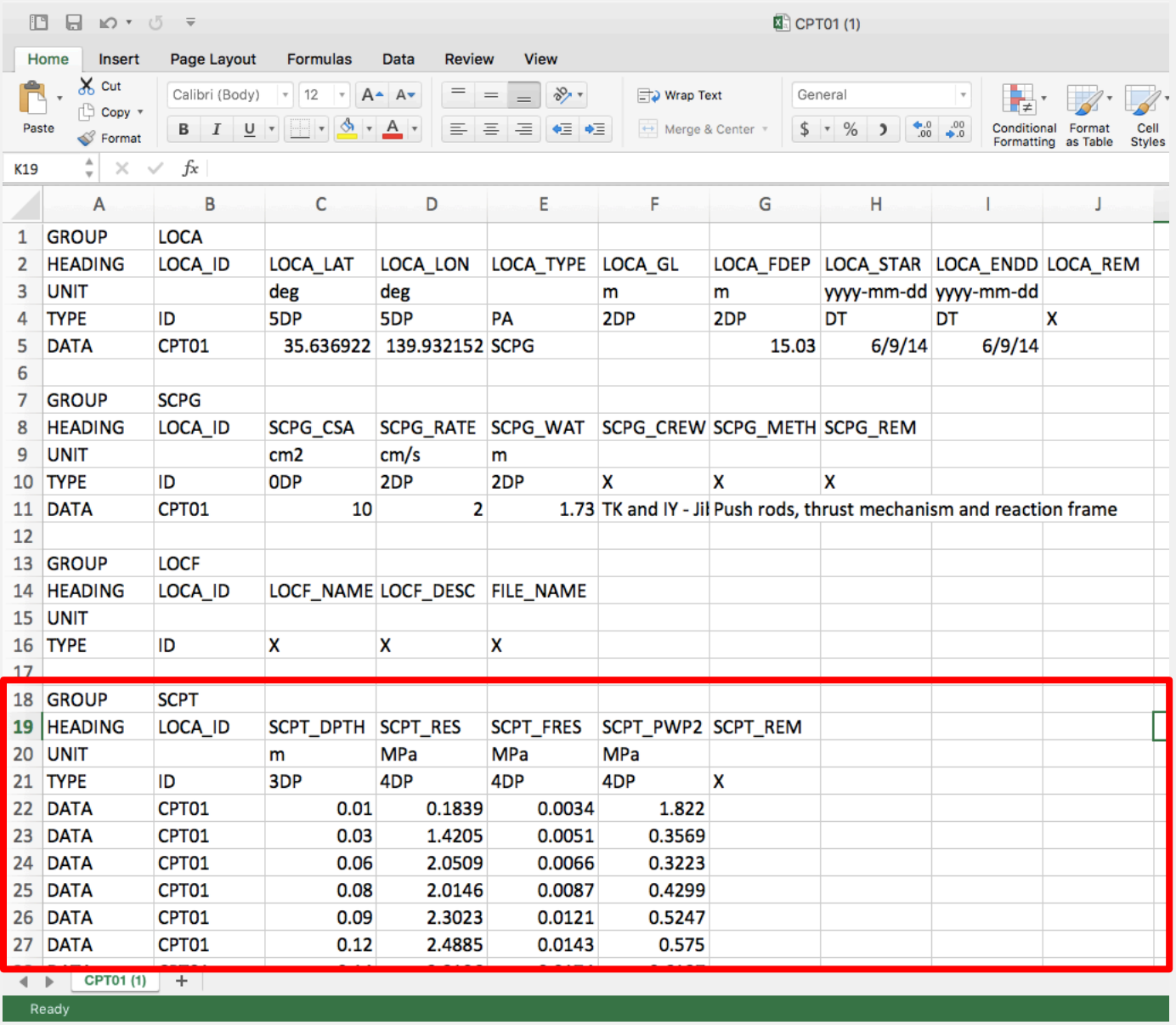
Geotechnical / Geophysical tests info
Borehole
CPT
Geophysical test (Vs)

Event Information
Event

Field Observation
Observation

Ryotoku Univ.
浦安市総合公園
Park

esri



	A	B	C	D	E	F	G	H	I	J
1	GROUP	LOCA								
2	HEADING	LOCA_ID	LOCA_LAT	LOCA_LON	LOCA_TYPE	LOCA_GL	LOCA_FDEP	LOCA_STAR	LOCA_ENDD	LOCA_REM
3	UNIT		deg	deg		m	m	yyyy-mm-dd	yyyy-mm-dd	
4	TYPE	ID	5DP	5DP	PA	2DP	2DP	DT	DT	X
5	DATA	CPT01	35.636922	139.932152	SCPG		15.03	6/9/14	6/9/14	
6										
7	GROUP	SCPG								
8	HEADING	LOCA_ID	SCPG_CSA	SCPG_RATE	SCPG_WAT	SCPG_CREW	SCPG_METH	SCPG_REM		
9	UNIT		cm2	cm/s	m					
10	TYPE	ID	0DP	2DP	2DP	X	X	X		
11	DATA	CPT01	10	2	1.73	TK and IY - Jil	Push rods, thrust mechanism and reaction frame			
12										
13	GROUP	LOCF								
14	HEADING	LOCA_ID	LOCF_NAME	LOCF_DESC	FILE_NAME					
15	UNIT									
16	TYPE	ID	X	X	X					
17										
18	GROUP	SCPT								
19	HEADING	LOCA_ID	SCPT_DPTH	SCPT_RES	SCPT_FRES	SCPT_PWP2	SCPT_REM			
20	UNIT		m	MPa	MPa	MPa				
21	TYPE	ID	3DP	4DP	4DP	4DP	X			
22	DATA	CPT01	0.01	0.1839	0.0034	1.822				
23	DATA	CPT01	0.03	1.4205	0.0051	0.3569				
24	DATA	CPT01	0.06	2.0509	0.0066	0.3223				
25	DATA	CPT01	0.08	2.0146	0.0087	0.4299				
26	DATA	CPT01	0.09	2.3023	0.0121	0.5247				
27	DATA	CPT01	0.12	2.4885	0.0143	0.575				

Follow AGS4 data format

GROUP
- Group name

HEADING
- Name for each field

UNIT
- Unit of the field

TYPE
- Type of the field

DATA
- Actual data

PLAN

- 80% complete
- Fix minor errors and bugs
- Plan to integrate PEER strong ground motion database

- Free to upload data, and contact NGL if any questions / suggestions.
  ngl@uclageo.com

Blank Slide
(David Frost)

Exploring New Approaches to Evaluate Particle Level Responses in Liquefiable Soils

J. David Frost

Elizabeth and Bill Higginbotham Professor

Georgia Tech School of Civil and Environmental Engineering
College of Engineering

UC Berkeley

November 4, 2016

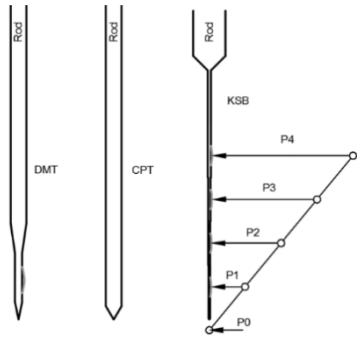
GEER
Geotechnical Extreme Events Reconnaissance
Turning Disaster into Knowledge

NSF

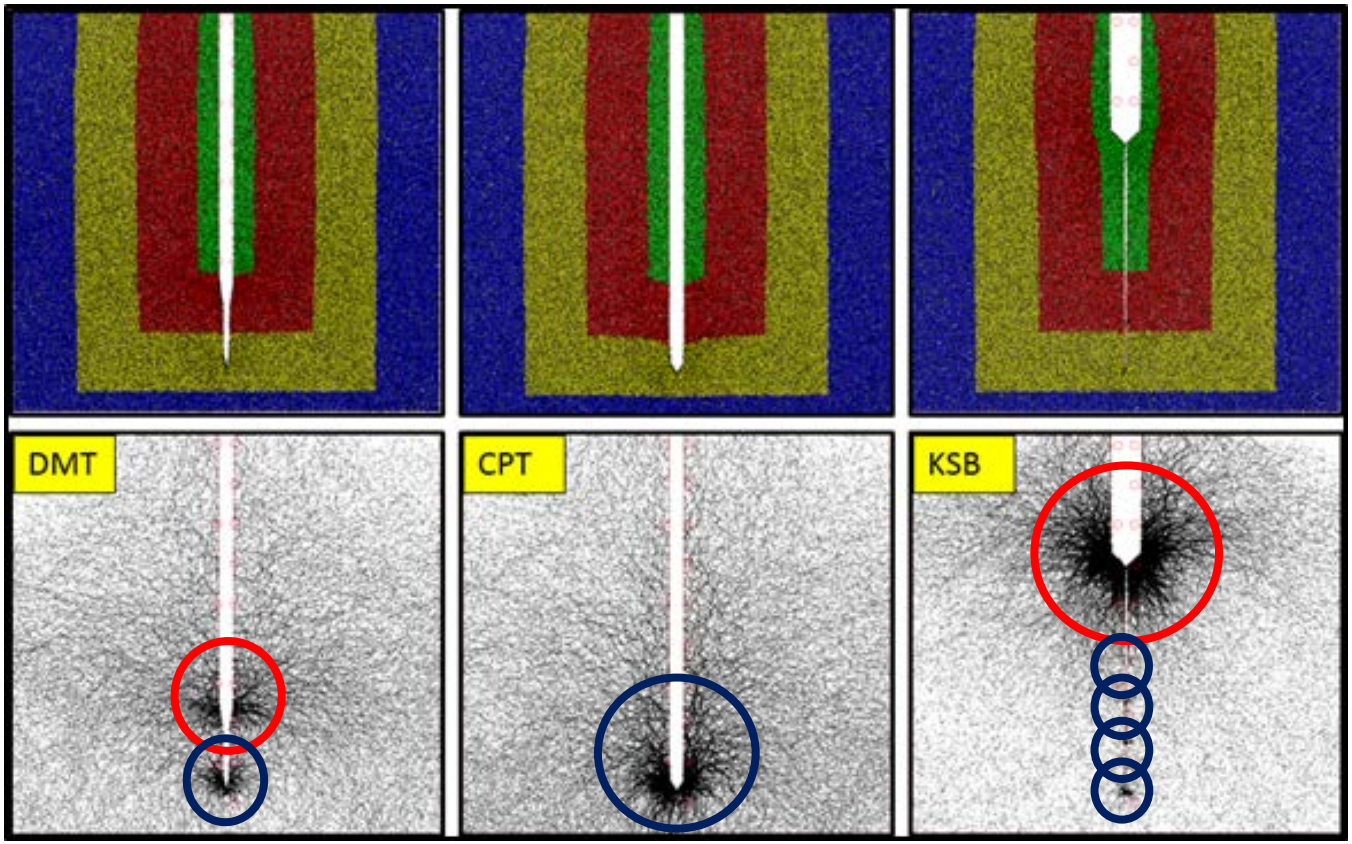
Contact Forces During Insertion

Rod Insertion

Device Insertion

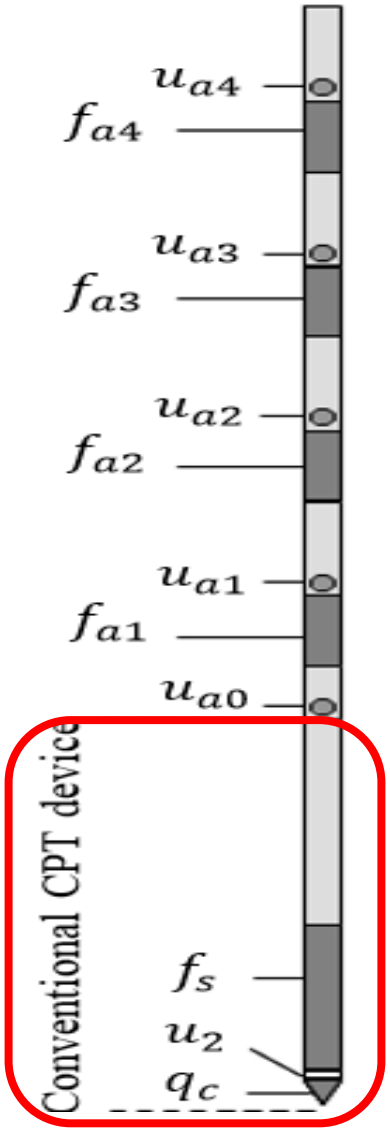


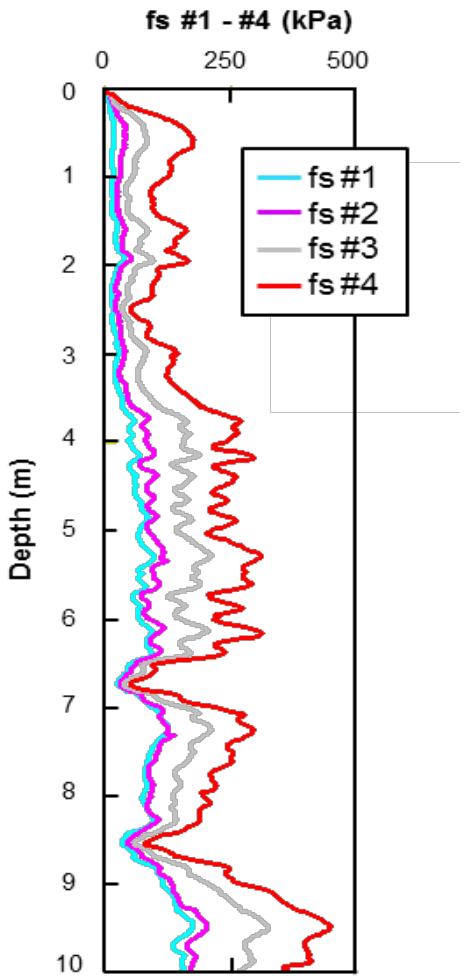
Relative sizes of devices



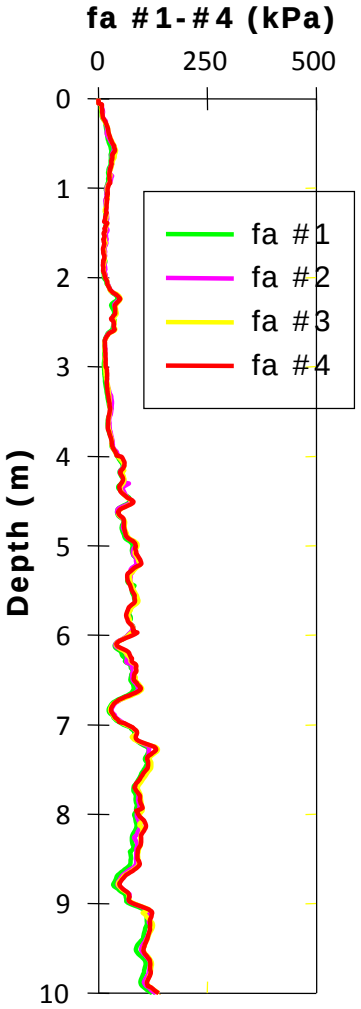
You can CORRECT but NOT CHANGE the data you start with!

Multi Friction Sleeve Technology

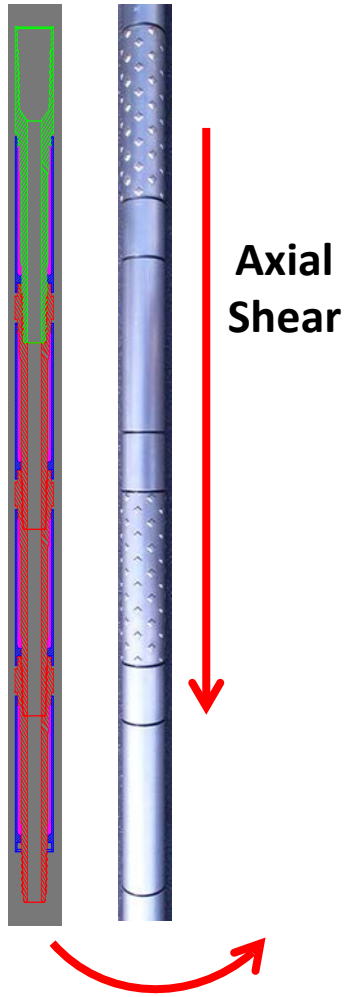




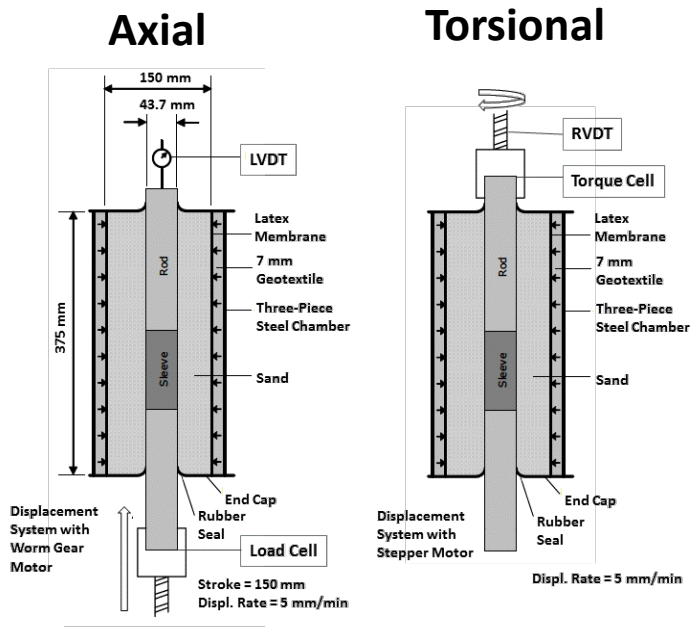
Sounding with 4 sleeves of increasing roughness

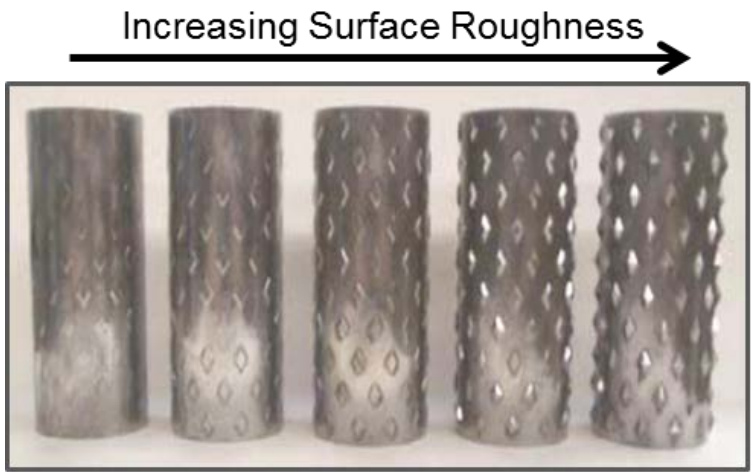


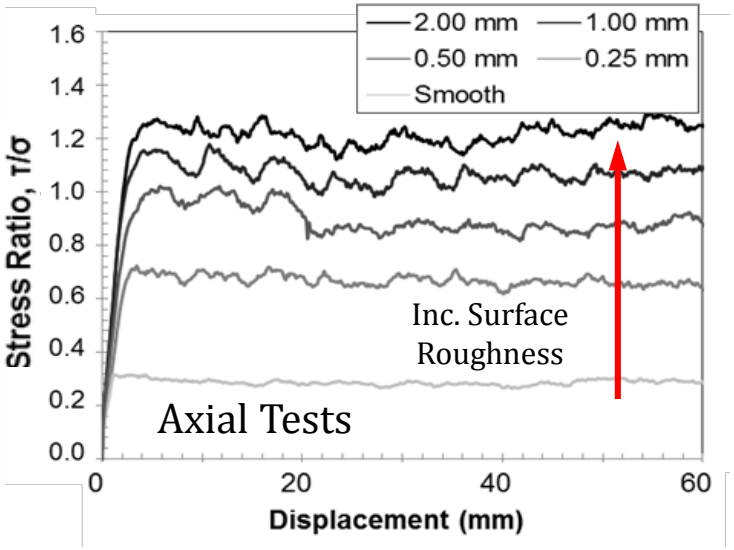
Sounding with 4 smooth sleeves

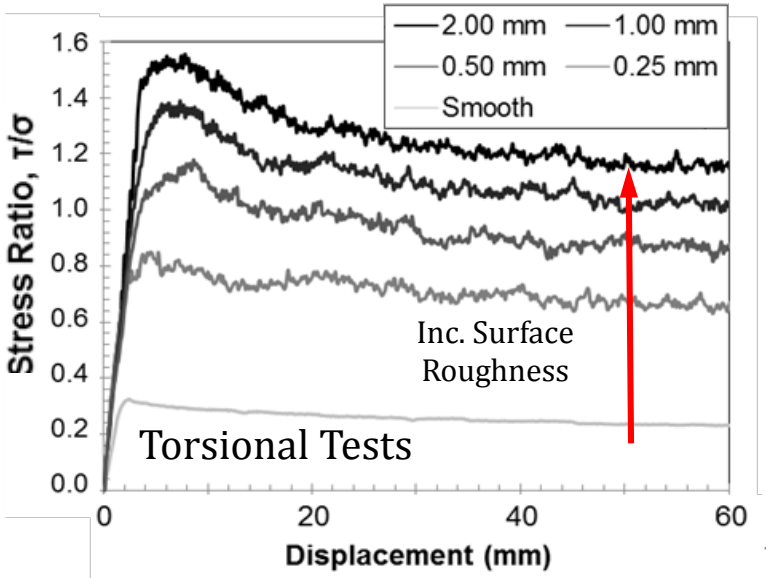


Effect of Sleeve Surface Roughness

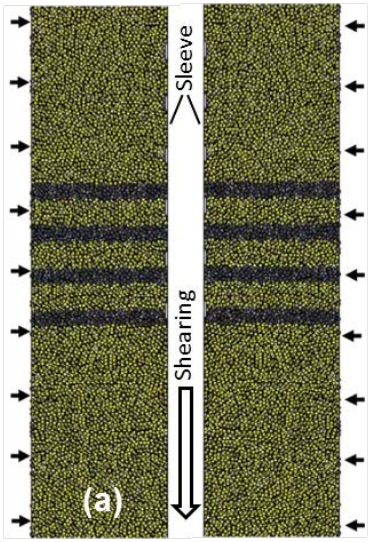




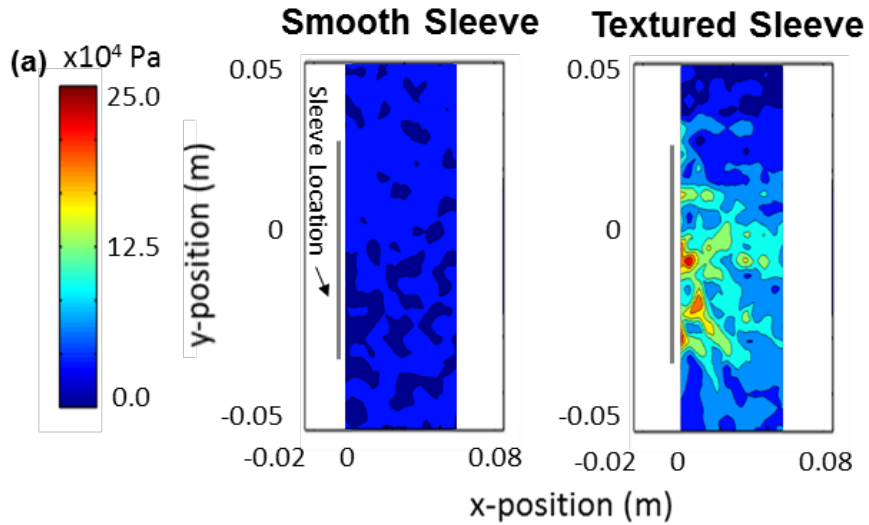




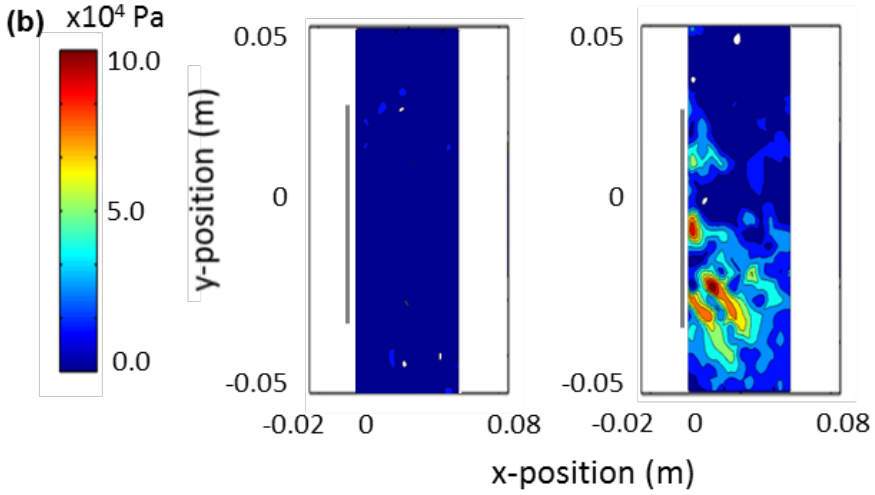
Normal and Shear Stresses from DEM Simulations



Normal stresses

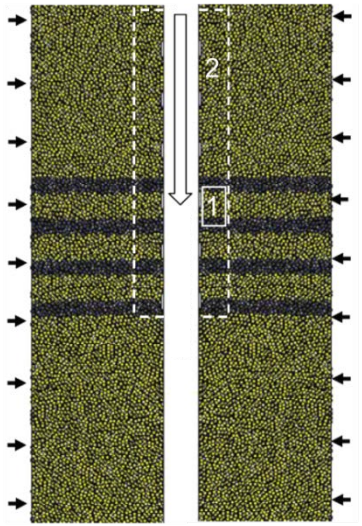


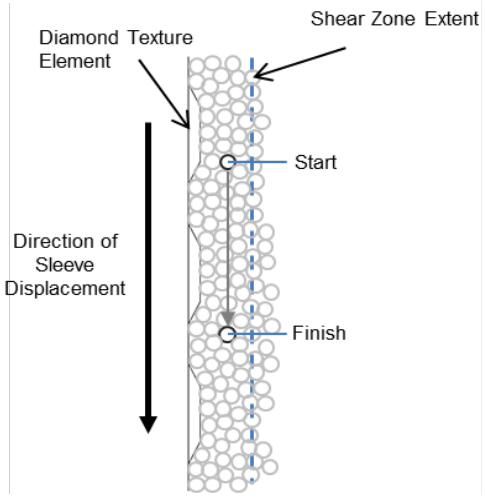
Shear stresses

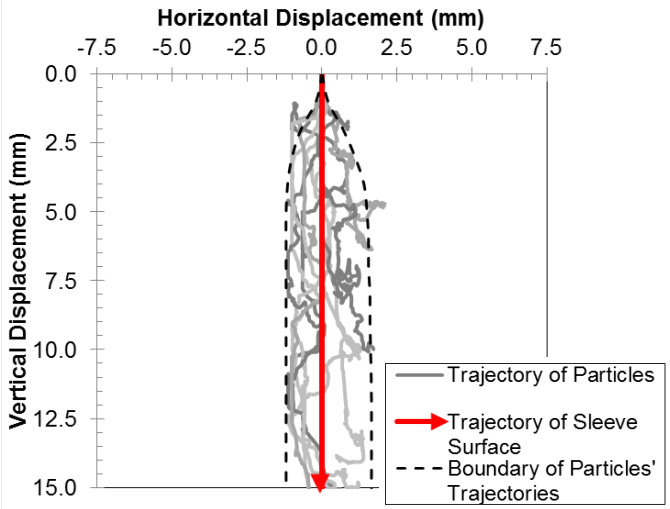


Simulation Particle Trajectories

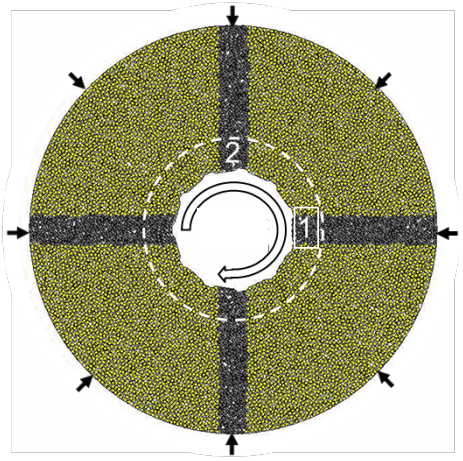
Axial Shear

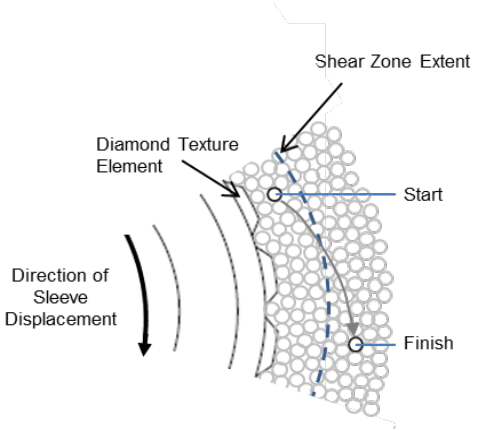


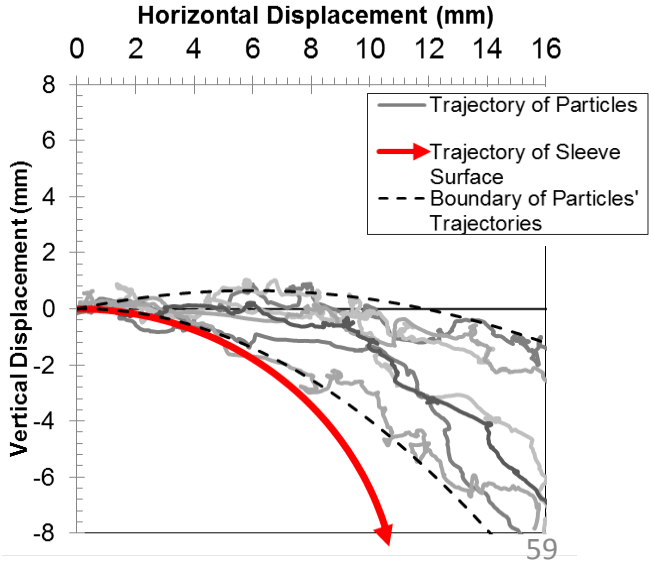




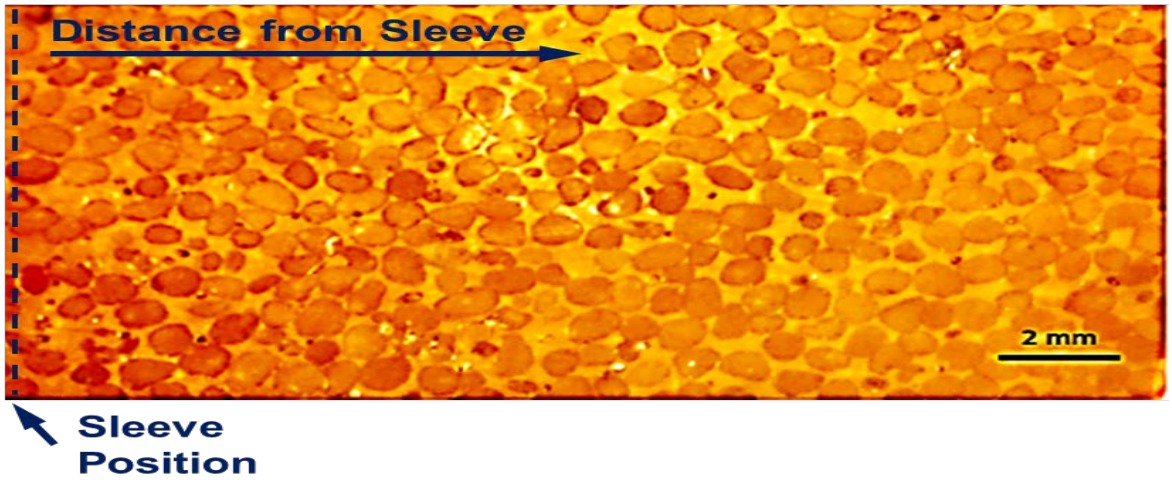
Torsional Shear

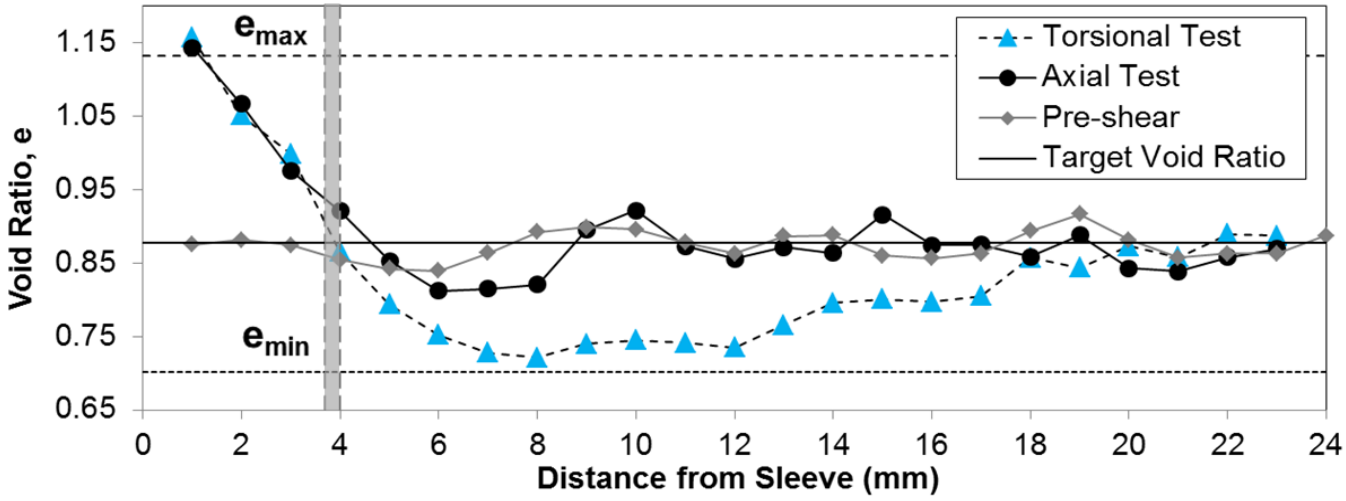


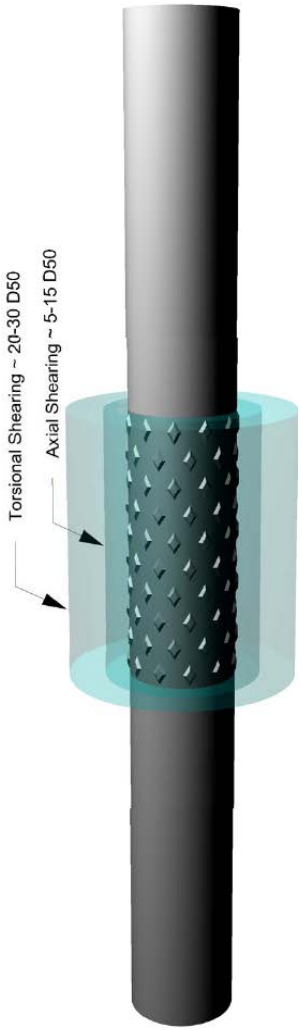




Shear-Induced Changes in Local Void Ratio







Summary

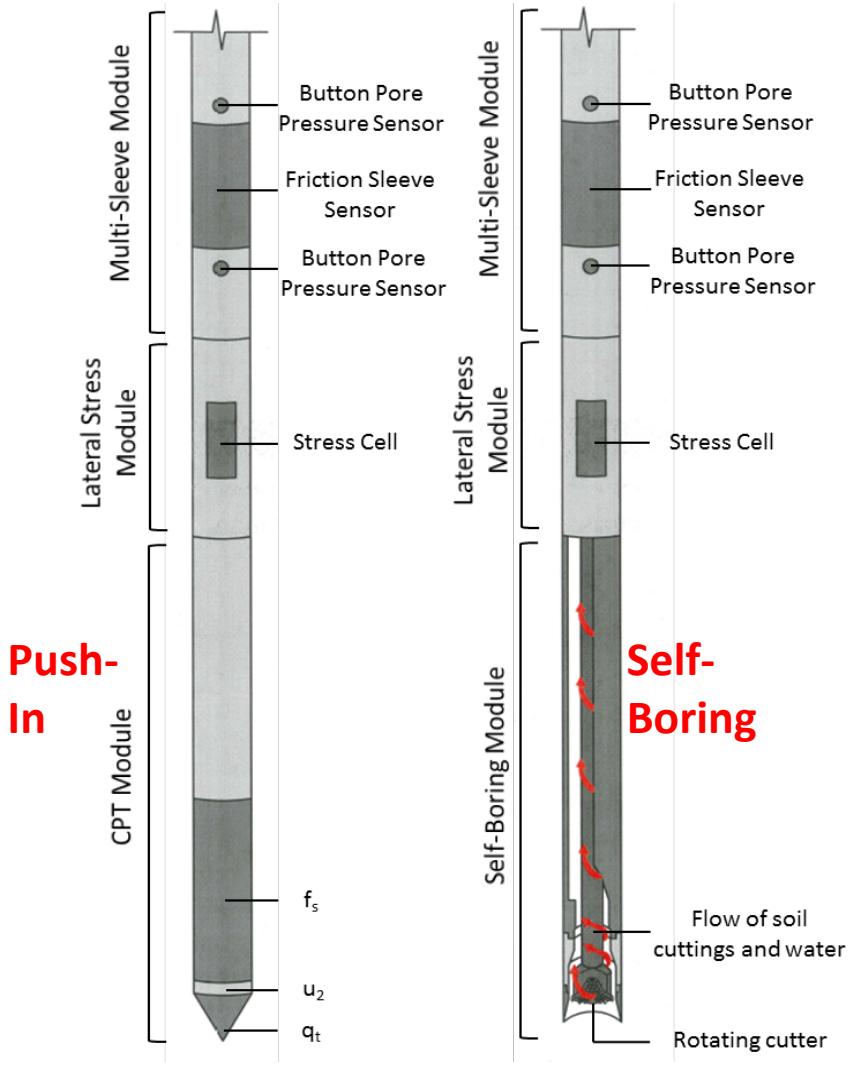
Devices that can minimize insertion effects and discern particle level responses offer ability to:

(i) better understand geologic variations at all scales

(ii) evaluate primary mechanisms at all scales

(iii) develop better evaluation procedures

(iv) advance state of the art.



Thank you.