

Geotechnical Earthquake Engineering and Soil Dynamics V

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## Next Generation Liquefaction (NGL) Case History Database

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June 13, 2018



Engineer Change.

### **NGL Project Directors**



Jonathan P. Stewart UCLA



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### Outline

Introduction

Databases vs collection of data

The NGL database structure

Current status of the database

Final thoughts and perspectives



## **NGL Project Activities**

- 1. Develop a publicly available <u>database</u> of liquefaction/cyclic softening case histories.
- 2. Provide a coordinated framework for <u>supporting studies</u> to augment case history data for conditions that are poorly constrained by empirical data.
- Provide an open, collaborative process for <u>model</u>
   <u>development</u> in which developer teams have access to common resources and share ideas during development.



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## **NGL Database Contributors**

- Database working group: Scott Brandenberg (chair), Robb E.S. Moss (Cal Poly), K. Onder Cetin (METU), Kevin Franke (BYU), Paolo Zimmaro (UCLA), and Dong Youp Kwak (Hanyang University)
- Southwest Research Institute: John Stamatakos, Miriam Juckett, Bis Dasgupta, Joey Mukherjee, Zackary Murphy, Steven Ybarra
- Nuclear Regulatory Commission: Thomas Weaver
- *Caltrans*: Tom Shantz
- Lateral Spread Project: Steve Bartlett, Masoud Hosseinali



**UCLA** Samueli

## **NGL Database Contributors**

- **BYU**: Heidi Dacayanan, Lila Lasson
- Virginia Tech: Russell Green, Kristin Ulmer
- UC Berkeley: Jonathan Bray, Christine Beyzaei
- Tonkin & Taylor: Sjoerd Van Ballegooey, Mike Liu
- UCLA: Chris Nicas, Omar Issa, Trini Inouye, Arielle Sanghvi, Tristan Buckreis, Naoto Inagaki, Wyatt Iwanaga, Michael Winders, Bryan Ong, Siddhant Jain
- Others: Mike Greenfield, Teruo Nakai, Hideo Sekiguchi



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### What is a Database?

### **Definition Used by Engineers: "A Collection of Data"**

- Examples include experimental data archived in DesignSafe (formerly NEEShub), or ground motion records made available through various NGA projects (<u>typically spreadsheets</u>).
- This is not a database according to the data science community, who reserve the word "database" for a <u>relational database</u> (e.g., MySQL, Microsoft Access).



### **Example Database**

		Epicentral	Epicentral				
Event Name	Magnitude	Latitude	Longitude	Station Name	V <sub>S30</sub> (m/s)	R <sub>jb</sub> (km)	PGA (g)
Westwood Hills	6.3	34.0689	118.4452	Factor Building	380	2	0.84
Westwood Hills	6.3	34.0689	118.4452	Santa Monica Courthouse	215	14	0.28
Hollywood Valley	7.2	34.1027	118.3404	Factor Building	380	20	0.61
Hollywood Valley	7.2	34.1027	118.3404	Santa Monica Courthouse	215	30	0.32

Event



Station



Ground Motion





### **Example Database Schema**

E	vent 7	Table 🍯					
<u>_</u>	Event_id	Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude		
	1	Westwood Hills	6.3	34.0689	118.4452	<mark>0</mark> 7	Primary Key
	2	Hollywood Valley	7.2	34.1027	118.3404	07	Foreign Key



Motion T	able	<u> </u>		
<mark>⊙</mark> ⊐ Motion_id	<mark>o</mark> ⊐ Event_id	<b>⊙</b> ¬ Station_id	R <sub>jb</sub> (km)	PGA (g)
1	1	1	2	0.84
2	1	2	14	0.28
3	2	1	20	0.61
4	2	2	30	0.32

Relationships set through shared fields (keys) Primary key: unique identifier for each record

Foreign key: field in one table that identifies a record in another table

Benefits of relational databases: Smart database (query, advanced tools) Minimize duplicated fields Avoid null fields

### **Traditional vs Next-Generation**

#### **From** *spreadsheet* (Traditional data analysis)

Record Sequence Number 1 2 3 4	EQID 0001 0002 0003 0004	Earthquake Name Helena, Montana-01 Helena, Montana-02 Humbolt Bay	YEAR 1935 1935	MODY 1031	HRMN 1838
Sequence Number 1 2 3	EQID 0001 0002 0003	Helena, Montana-01 Helena, Montana-02	1935	1031	
Sequence Number 1 2 3	EQID 0001 0002 0003	Helena, Montana-01 Helena, Montana-02	1935	1031	
Sequence Number 1 2 3	EQID 0001 0002 0003	Helena, Montana-01 Helena, Montana-02	1935	1031	
1 2 3	0001 0002 0003	Helena, Montana-01 Helena, Montana-02	1935	1031	
2 3	0002 0003	Helena, Montana-02		_	1838
3	0003		1935	V	
		Humbolt Bay		1031	1918
1	0004		1937	0207	0442
	0004	Imperial Valley-01	1938	0606	0242
5	0005	Northwest Calif-01	1938	0912	0610
5	0006	Imperial Valley-02	1940	0519	0437
7	0007	Northwest Calif-02	1941	0209	0945
В	0008	Northern Calif-01	1941	1003	1614
9	0009	Borrego	1942	1021	1622
10	0010	Imperial Valley-03	1951	0124	0717
11	0011	Northwest Calif-03	1951	1008	0411
12	0012	Kern County	1952	0721	1153
	0012	Kern County	1952	0721	1153
13	0012	Kern County	1952	0721	1153
13 14	6040			0704	4450
-	3	3 0012 4 0012	B       0012       Kern County         4       0012       Kern County         PSA_H2_d005       Sa_H2_d005	2 0012 Kern County 1952 3 0012 Kern County 1952 4 0012 Kern County 1952 4 0012 Kern County 1952 9 PSA_H2_d005 Sa_H2_d005 ⊕	2       0012       Kern County       1952       0721         3       0012       Kern County       1952       0721         4       0012       Kern County       1952       0721         5       0012       Kern County       1952       0721

		-	1/-	1
1	T7.50	00S	T8.0	00S
8151	0.0	000247	0.	000231
8152	0.0	003331	0.	003473
8153	0.0	000661	0.	000639
8154	0.0	000486	0.	000700
8155	0.0	001060	0.	001011
8156	0.0	001217	0.	001057
8157	0.0	000836	0.	000772
8158	0.0	008571	0.	007123
8159	0.0	011123	0.	009935
8160	0.0	002338	0.	001956
8161	0.1	134076	0.	112643
8162	0.3	298595	0.3	233477
8163	0.0	002516	0.	002555
8164	0.0	004065	0.	005418
0465				
4	- F	PSA_H	l2_d005	Sa_H2_

Η7

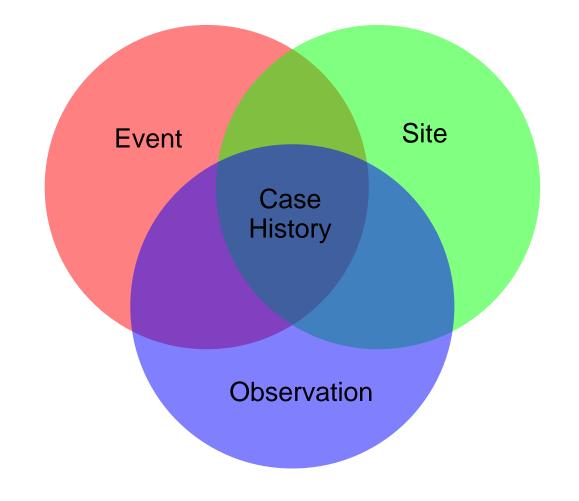
Ready

....

**To** relational database (big-data analytics) **NGL** NEXT-GENERATION LIQUEFACTION PROJECT Topographic Map Tarroin Mon Measured Disp. Lateral Def CPT 911 (Cone Penetration Test) Imagery Ma Settlement Sand Boil E Post-event def Latitude (deg) -43.4851 Longitude (deg) 172.712 Observation Type Field Note Field Mapping Elevation (m) Site Limit of Investigation (m) Satel, Image Activity Start Date Activity End Date O Bo Note CPT Geophysical test ( Downloads Data CPT\_911.csv plot Measured Ground Motion assoc. files PGV (cm/s) Event Observation . CPT\_911 -43.485103 / 172.711970 Lat/Long q. (Mpa) f, (Mpa) u<sub>2</sub> (Mpa)

Next-Generation Liquefaction Database, Zimmaro et al. (2018a, SSA), UCLA Samueli Brandenberg et al. (2018b, GEESD)

### **NGL Case History Definition**





### **NGL Database Schema: General**

	Users (USER)		Sites (SITE)		Tests (TEST)		Files (FILE)
<mark>0</mark> 7	USER_ID	<mark>0</mark>	SITE_ID		TEST_ID	<mark>0</mark> 7	FILE_ID
	user_name		SITE_NAME	07	SITE_ID		FILE_NAME
	first_name		SITE_LAT		TEST_NAME		FILE_TYPE
	last_name		SITE_LON		TEST_TYPE		FILE_SIZE
	email		SITE_GEOL		TEST_LAT		FILE_FILE
	reg_date		SITE_REM		TEST_LON		
	organ		SITE_STAT		TEST_ELEV		
	country		SITE_REVW		TEST_REM	С	
	region				TEST_STAT		<mark>O</mark> ⊐ Primary key
	zip				TEST_REVW		
	user_pass						O ☐ Foreign key
	num_visit	S	Site Files (SITF)	Т	est Files (TESF)		
	num_download	<mark>0</mark> 7	SITF_ID	07	TESF_ID		
	num_upload	07	SITE_ID	07	TEST_ID		
		07	FILE_ID	07	FILE_ID		
			SITF_DESC		TESF_DESC		

### **NGL Database Schema: Site**

Boreholes (BORH)	Index Tests (INDX)		ta (SCPT)
			SCPT_ID
	O∃ SPEC_ID		SCPG_ID
BORH_TYPE	INDX_BDEN		CPT DPTH
BORH_RIG	INDX_DDEN		SCPT RES
BORH_DIA	INDX_GS		CPT FRES
BORH_CREW	INDX_WC		CPT PWP
BORH_MECH	INDX_FINE	SCPG STAR	
BORH_METH	INDX_METH	SCPG ENDD	
BORH STAR Sample Files (SAMF)	INDX_REM	SCPG PWP	
BORH ENDD OR SAME ID		SCPG REM	
BORH_REM	Particle-Size Dist. (GRAG) PartSize Dist. data (GRAT)	Invasive Geophysical (GINV) Vel.Prof. from	n Invasive (GIND)
©⊐ FILE ID	GRAG ID GRAT ID		GIND ID
SAMF_DESC	O□ SPEC ID O□ GRAG ID	이구 TEST ID 이구	GINV ID
Samples (SAMP)	GRAG METH GRAT SIZE	GINV TYPE G	IND DPTH
SAMP ID Specimens (SPEC)	GRAG_REM GRAT_PERP	GINV CONF	GIND VS
OF       TEST ID       OF       SPEC ID         SAMP NAME       OF       SAMP ID		GINV CREW	GIND VP
	Atterberg Limits (PLAS)	GINV STAR	
SAMP TYPE SPEC REF SAMP TOP SPEC TOP		GINV ENDD	
SAMP_TOP SPEC_TOP SAMP_BASE SPEC_BASE		Surface Wave (GSWG) SW disp. cu	urves (GSWD) V <sub>S</sub> -V <sub>P</sub> profiles info (SWVG) Vel. profiles from SW (SWVD)
SAMP SDIA SPEC BASE	PLAS LL		
			SSWG ID OF GSWG ID OF SWVG ID
SAMP_DATE SPEC_REM SAMP_REC	PLAS PL PLAS METH		SWD FREQ SWVG NAME SWVD TOP
SAMP_REC SAMP_DESC SPT Data (ISPT)	PLAS REM		SWD PHVL SWVG DESC SWVD BTTM
SAMP DESC SPT Data (ISPT)	PLAS_REIVI	GSWV VS	SWVD VS
	Relative Density (RDEN)	GSWV VP	SWVD VP
Stratigraphy (STRA)		GSWV RHO	SWVD RHO
OR STRAID ISPT TOP			
OF TEST ID ISPT TPEN		Within-Layer info (DETL)	
STRA TOP	RDEN EMAX		
STRA BASE ISPT ERAT	RDEN METH		
STRA USCS ISPT REM	RDEN REM	DETL DPTH	O¬ Primary key
STRA COL	KOEN KEM	DETL DESC	
STRA DESC	Other Lab. Tests (OTHR)		Tests (OTHF)
31104_0230			OTHE ID Foreign key
Water Table (WATR)			TEST_ID
O- WATR ID			THF_NAME
O∃ TEST ID	OTHR NAME		ITHF_TYPE
WATR DPTH	OTHR TYPE		THF_DESC
WATR DATE	OTHR DESC		THF_STAR
WATR REM			THF_ENDD
		TEPT REM	

### **NGL Database Schema: Observation**

0	bservations (FLDO)	
<mark>0</mark>	FLDO_ID	
() ()	EVNT_ID	
O	SITE_ID	
	FLDO_DESC	
	FLDO_STAT	
	FLDO_REVW	
	Or Primary key	
	O Foreign key	

Motion at site (GMIM)	Obs
GMIM_ID	<u></u>
FLDO_ID	07
GMIM_LAT	07
GMIM_LON	
GMIM_TYPE	[
GMIM_VALUE	[
GMIM_STDDEV	_
GMIM_UNIT	
GMIM_METHOD	

Ground

()<del>,</del>

servation Files (FLDF)
FLDF_ID
FLDO_ID
FILE_ID
FLDF_LAT
FLDF_LON
FLDF_DESC

Liquefa	ction Manifestations (FLDM)
<u></u>	FLDM_ID
07	FLDO_ID
	FLDM_LAT
	FLDM_LON
	FLDM_ELEV
	FLDM_SFEV
	FLDM_SNBL
	FLDM_LTSP
	FLDM_STTL
	FLDM_STDM
	FLDM_DESC

Disp. Vectors (FLDD)		
<mark>o</mark> r	FLDD_ID	
07	FLDO_ID	
	FLDD_LAT	
	FLDD_LON	
	FLDD_AZIM	
	FLDD_HDIS	
	FLDD_VDIS	
	FLDD_METH	



### **NGL Database Schema: Event**

EVNT DIP

Earthquake Event (EVNT)		Recording Station (STAT)		Fault Segment (SEGM)		Recorded IMs (RCIM)	
<mark>0</mark> 7	EVNT_ID	<mark>0</mark> 7	STAT_ID	<mark>0</mark> 7	SEGM_ID	<b>O</b>	RCIM_ID
	EVNT_ID		STAT_NAME	07	EVNT_ID	(OF)	EVNT_ID
	EVNT_EQID		STAT_SEQN		SEGM_NAME	(OF)	STAT_ID
	EVNT_NM		STAT_NET		SEGM_LENGTH		IM_RJB
	EVNT_YR		STAT_LAT		SEGM_WIDTH		IM_EPI
	EVNT_MD		STAT_LON		SEGM_STRIKE		IM_HYPO
	EVNT_HM		STAT_HOUSE		SEGM_DIP		IM_R_DIST
	HYPO_LAT		STAT_ELE		SEGM_RAKE		IM_RMS
	HYPO_LON		STAT_VS30		ULC_LAT		IM_CLST
	HYPO_DT		STAT_SIGVS30		ULC_LON		IM_RX
	EVNT_MAG		STAT_NEHRP		ULC_DEPTH		IM_AZIMUTH
	MAG_TY		STAT_REG				PGA
	MAG_UNCK		STAT_DEPTH				PGV
	MAG_UNCST		STAT_GEOL		Op Primary key		PGD
	EVNT_MO						T0.010S
	EVNT_MECH						T0.020S
	EVNT_RUP				O Foreign key		T S
	EVNT_FFMOD						
	EVNT_STRIKE						T20.000S
	EVNT_RAKE					-	

# NGL includes NGA West-2 events ...soon NGA Sub

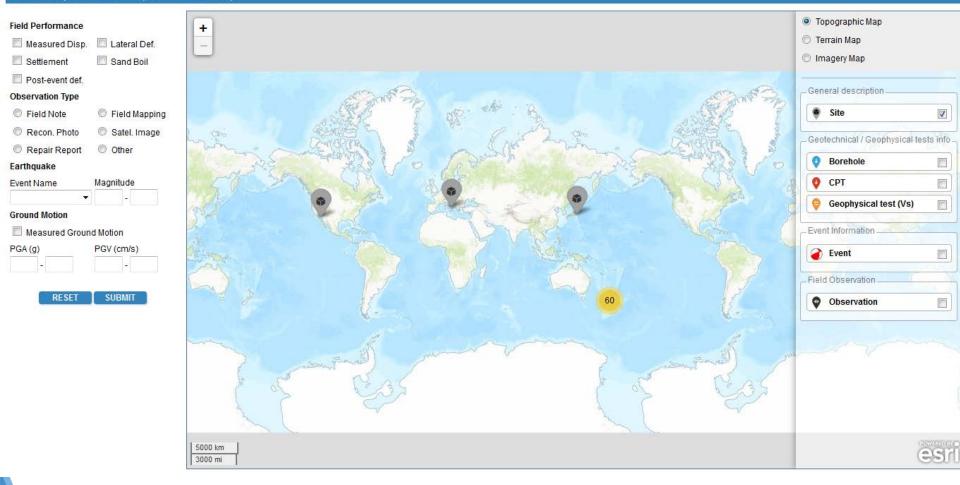


## **Community Vetting of Schema**

- The schema is the outcome of a **broad community effort** involving review by the database working group and others.
- A 2-day workshop involving about 50 people was held in July 2017 in which the schema was presented and discussed in detail.



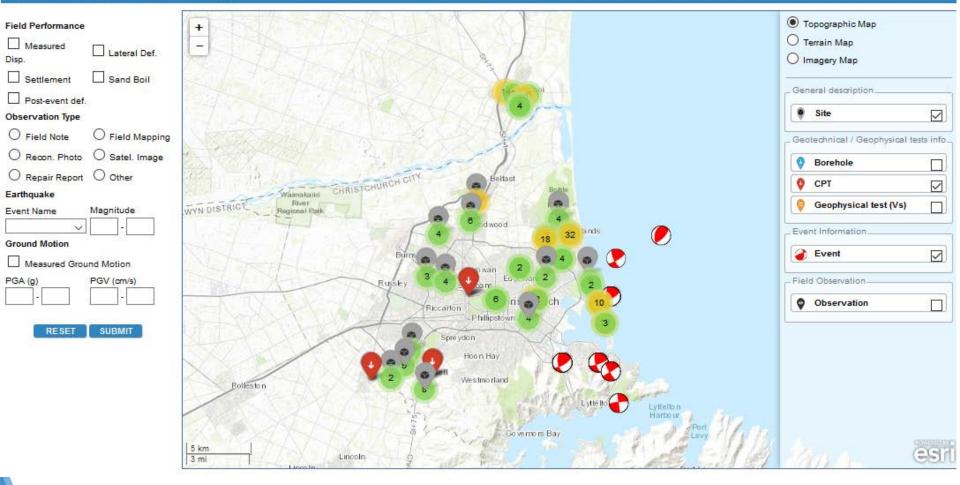
Home Map Download Upload Users He



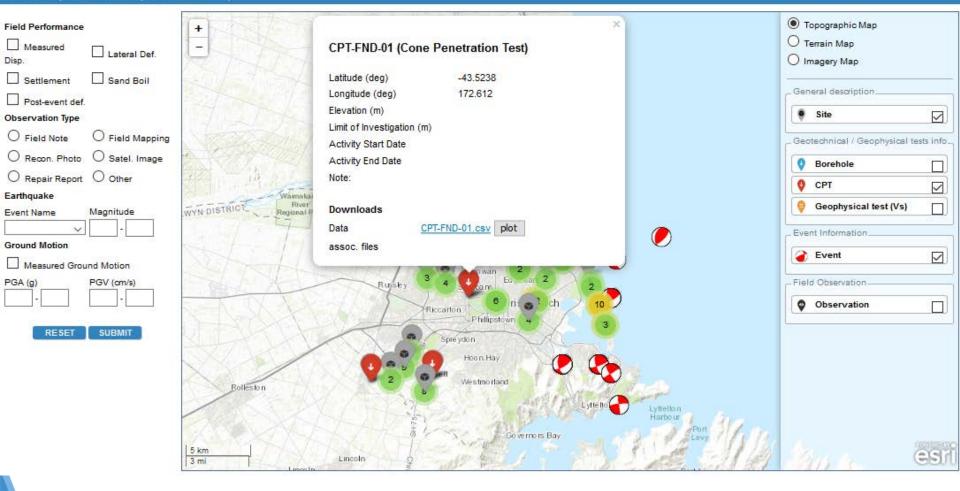
Developed as Structured Query Language (SQL) database management system

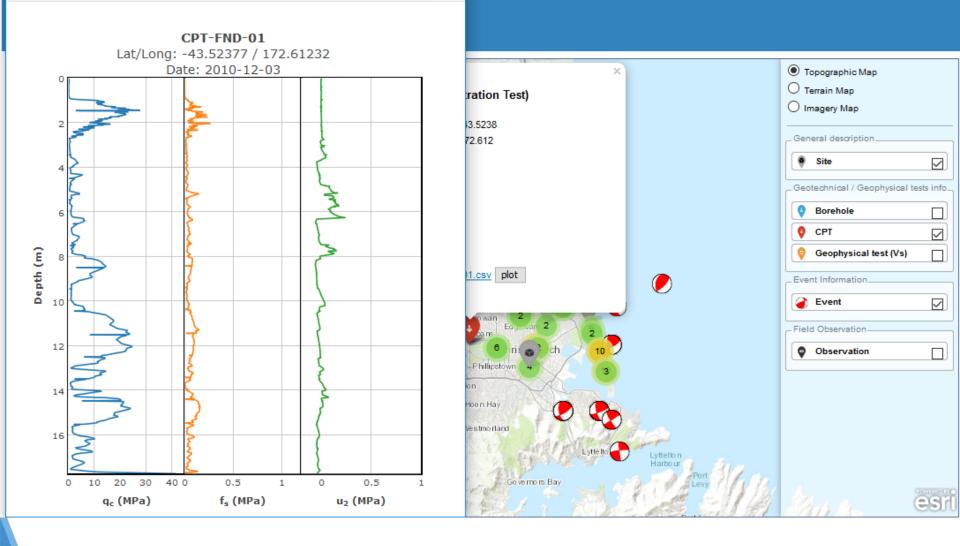
KPHP platform, GIS-based mapping tool

Home Map Download Upload Users He



Home Map Download Upload Users Help





PGA (g)

RESET

PGV (cm/s)

SUBMIT

Bolleston

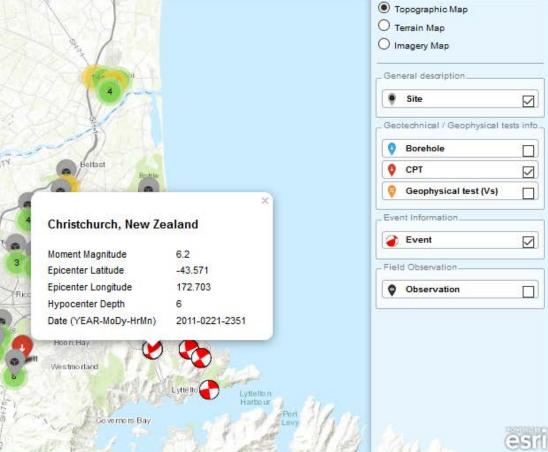
5 km

3 mi

Home Map Field Performance + Measured -Lateral Def. Disp. Settlement Sand Boil Post-event def. Observation Type O Field Note O Field Mapping O Recon. Photo O Satel. Image CHRISTCHURCH CITY O Repair Report O Other Beltast Earthquake Waimakatiri River WYN DISTRICT Magnitude Event Name logional Park × V Christchurch, New Zealand Ground Motion Measured Ground Motion

Lincoln

Russe



Field Performance	+			×	Topographic Map	
Disp. Lateral Def.	-	by M9 Tohoku			O Terrain Map O Imagery Map	
Settlement Sand Boil		Latitude	35.6379			
Post-event def.		Longitude	139.933		General description	
Observation Type		Observation type	Reconnaissance photo		Site	
C Field Note C Field Mapping		Observations	Measured displacement / Lateral deformation / Settlement / Sand		Geotechnical / Geophysical te	
O Recon. Photo O Satel. Image		Note: Recon. photo by GEEF	boil		Borehole	
O Repair Report O Other		Note: Recon. photo by GEEP	( leani		0 CPT	
Earthquake		Downloads			Geophysical test (Vs)	
Event Name Magnitude		Data	assoc. files		Veophysical test (VS)	
		Tohoku-731.csv		2	_ Event Information	
Ground Motion					Event	
Measured Ground Motion				$\sim$		
PGA (g) PGV (cm/s)					Field Observation	
					Observation	
RESET				1		
				1		
	20 m 50 ft					esri

#### **Old case-histories**

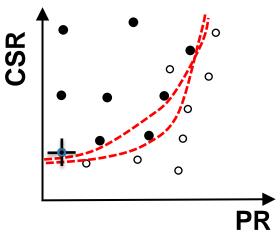
face clay silt layer. Following the 1977 earthquake, signs of liquefaction such as ejection of fine sand through the fissures or cracks were observed here and there in this area. Photo.2 shows typical sand ejection



Bucarest (1977, Vrancea earthquake) From Ishihara and Perlea (1984)

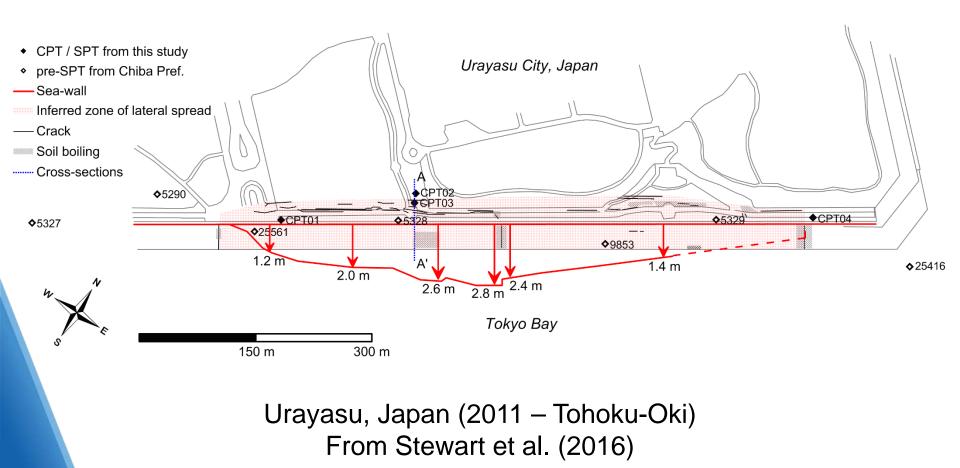
Earthquake	M <sub>w</sub>
1977 Vrancea, Romania	7.20±0.11
Site	Liquefied?
Site 2	No

- Liquefaction
- No Ground Failure

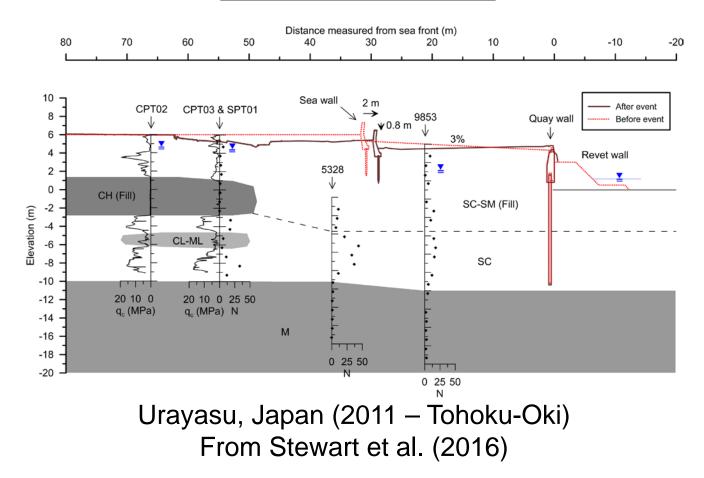


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#### **Recent case-histories**



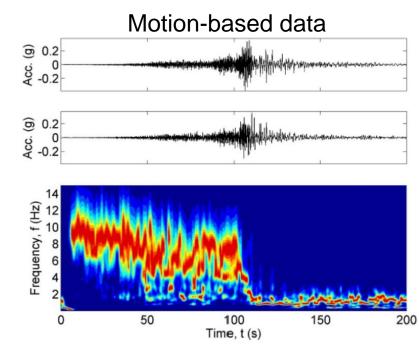
#### **Recent case-histories**



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#### **Recent case-histories**





Ibaraki, Japan (2011 – Tohoku-Oki) From Kramer et al. (2016) and M. Greenfield pers. comm.

### **Current Status**

- 63 sites (~200 case histories) in current version of NGL website.
- During development, we have created 25 additional case histories using a CSV template that can easily be uploaded to the new website.
- Legacy case-histories will be added
- **Beta version of new website** is being evaluated now, and we anticipate official release within a few weeks.



### **Review Process**

- The <u>database working group</u> will review all of the uploaded data.
- Users will indicate when a dataset is ready for review, and the data will be immediately available.
- After review, the data will be marked as reviewed.
- Purpose of review is to verify that all required fields are present and the inputs match source materials.



### **Vision for Community Access**

- Due to <u>large amount of data</u>, downloading data and processing them on a laptop is inefficient and undesirable (though <u>still possible</u>).
- We plan to <u>mirror the database to DesignSafe</u> (<u>www.designsafe-ci.org</u>), where users will be able to interact with the data using SQL queries in Jupyter notebook Python scripts.
- Python can be used to extract and process data, and has a wide array of data processing libraries available.







### **Final Remarks**

- Need for high-quality, transparent, liquefaction case-history database
- The NGL relational database (being populated): capabilities for big data analytics
- Relational databases are more powerful than flatfiles (transformational shift from past practices!)
- NGL-NGA interaction
- Future task: Completion of database population, NGL database mirroring (DesignSafe)



### **Save the Date**

### Second workshop to be held at UCLA:

### September 24 and 25, 2018







### Thank you!

### **Questions?**

### **Relevant References**

- Brandenberg S.J., Kwak D.Y., Zimmaro P., Bozorgnia Y., Kramer S.L., Stewart J.P. (2018). Next-Generation Liquefaction (NGL) Case History Database Structure. Fifth decennial Geotechnical Earthquake Engineering and Soil Dynamics Conference, Earthquake Engineering and Soil Dynamics Committee of the Geo-Institute. Austin, TX (USA), June 10-13.
- Zimmaro P., Kwak D.Y., Brandenberg S.J., Stewart J.P. (2018). NGL: An Open Source Global Database for Next-Generation of Liquefaction Assessment. SSA-LACSC scientific conference - Seismology of the Americas. Miami, FL (USA), May 14-17.
- Stewart J.P., Kramer S.L., Kwak D.Y., Greenfield M.W., Kayen R.E., Tokimatsu K., Bray J.D., Beyzaei C.Z., Cubrinovski M., Sekiguchi T., Nakai S., Bozorgnia Y. (2016). PEER-NGL project: Open source global database and model development for the next-generation of liquefaction assessment procedures. Soil Dyn. Earthquake Eng., 91, 317–328.

