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Richmond Field Station, Richmond CA



PEER

UCLA Samueli
School of Engineering

Next Generation Liquefaction (NGL) Case History Database

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August 07, 2018



Engineer Change.

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

NGL Project Activities

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

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



NGL Database Contributors

- **BYU:** Heidi Dacayanan, Lila Lasson
- **Virginia Tech:** Russell Green, Kristin Ulmer
- **UC Berkeley:** Jonathan Bray, Christine Beyzaei
- **Tonkin & Taylor:** Sjoerd Van Ballegooy, 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, ...



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 (**typically spreadsheets**).
- This is not a database according to the data science community, who reserve the word “database” for a **relational database** (e.g., MySQL, Microsoft Access).

Example Database

Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude	Station Name	V_{S30} (m/s)	R_{jb} (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

Event Table 




 Event_id	Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude
1	Westwood Hills	6.3	34.0689	118.4452
2	Hollywood Valley	7.2	34.1027	118.3404

 Primary Key
 Foreign Key

Station Table 

 Station_id	Station Name	V_{S30} (m/s)
1	Factor Building	380
2	Santa Monica Courthouse	215

Motion Table 

 Motion_id	 Event_id	 Station_id	R_{jb} (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)

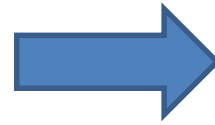
Primary key: unique identifier for each record

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

- Benefits of relational databases:**
- Smart database (query, advanced tools)**
 - Faster (it uses indexes)**
 - Minimize duplicated fields**
 - Avoid null fields**

Traditional vs Next-Generation

From *spreadsheet*
(Traditional data analysis)



To **relational database**
(big-data analytics)

	A	B	C	D	E	F
	Record Sequence Number	EQID	Earthquake Name	YEAR	MODY	HRMN
1	1	0001	Helena, Montana-01	1935	1031	1838
2	2	0002	Helena, Montana-02	1935	1031	1918
3	3	0003	Humboldt Bay	1937	0207	0442
4	4	0004	Imperial Valley-01	1938	0606	0242
5	5	0005	Northwest Calif-01	1938	0912	0610
6	6	0006	Imperial Valley-02	1940	0519	0437
7	7	0007	Northwest Calif-02	1941	0209	0945
8	8	0008	Northern Calif-01	1941	1003	1614
9	9	0009	Borrego	1942	1021	1622
10	10	0010	Imperial Valley-03	1951	0124	0717
11	11	0011	Northwest Calif-03	1951	1008	0411
12	12	0012	Kern County	1952	0721	1153
13	13	0012	Kern County	1952	0721	1153
14	14	0012	Kern County	1952	0721	1153
15	15	0012	Kern County	1952	0721	1153

	HZ	IA
1	T7.500S	T8.000S
8151	0.000247	0.000231
8152	0.003331	0.003473
8153	0.000661	0.000639
8154	0.000486	0.000700
8155	0.001060	0.001011
8156	0.001217	0.001057
8157	0.000836	0.000772
8158	0.008571	0.007123
8159	0.011123	0.009935
8160	0.002338	0.001956
8161	0.134076	0.112643
8162	0.298595	0.233477
8163	0.002516	0.002555
8164	0.004065	0.005418

NGL NEXT-GENERATION LIQUEFACTION PROJECT

Home Map Download Upload Users Help

Field Performance

- Measured Chop
- Lateral Cut
- Settlement
- Sand Boil
- Post-event def.

Observation Type

- Field Note
- Field Mapping
- Recon. Photo
- Sat. Image
- Recon. Report
- Other

Earthquake

- Event Name
- Magnitude

Ground Motion

- Measured Ground Motion
- PGA (g)
- PGV (cm/s)

CPT_911 (Cone Penetration Test)

Latitude (deg): -43.4851
 Longitude (deg): 172.712
 Elevation (m):
 Limit of Investigation (m):
 Activity Start Date:
 Activity End Date:
 Note:

Downloads

Data: [CPT_911.csv](#) | plot
 assoc. files

Geotechnical / Geophysical tests info

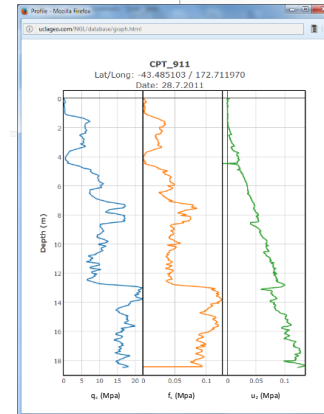
- Borehole
- CPT
- Geophysical test (Vs)

Event Information

Event

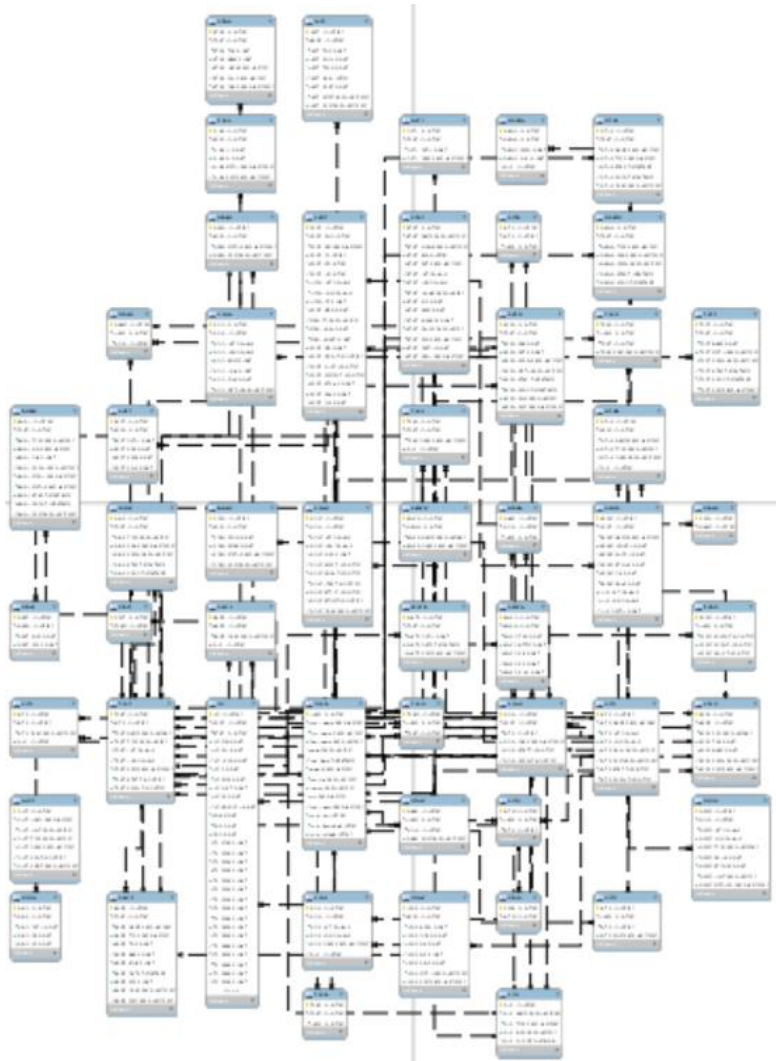
Field Observation

Observation



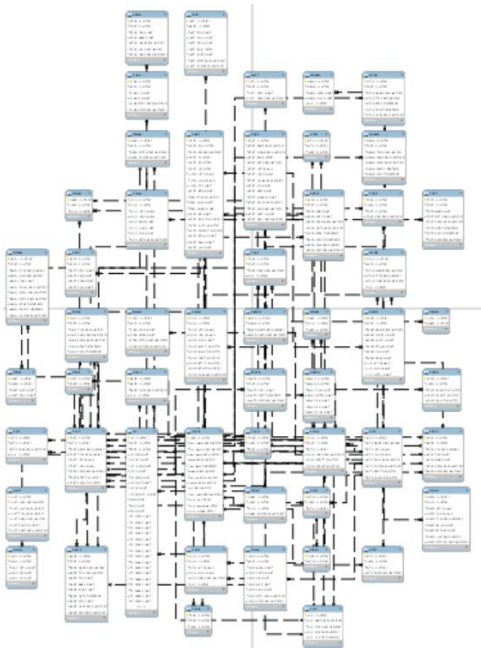
Next-Generation Liquefaction Database, Zimmaro et al. (2018a, SSA),
 Brandenburg et al. (2018b, GEESD) **UCLA** Samueli

NGL Database Schema





- 53 Tables
- Linked through Primary/Foreign keys
- Use of access indexes to improve query tools and accessibility
- Four Sections:
 1. General
 2. Site
 3. Observation
 4. Event



NGL Database Schema







General Tables




Users (USER)	
	USER ID
	user_name
	first_name
	last_name
	email
	reg_date
	organ
	country
	region
	zip
	user_pass
	num_visit
	num_download
	num_upload

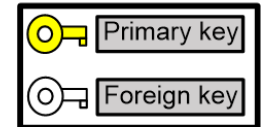
Sites (SITE)	
	SITE ID
	SITE_NAME
	SITE_LAT
	SITE_LON
	SITE_GEOL
	SITE_REM
	SITE_STAT
	SITE_REVW

Tests (TEST)	
	TEST ID
	SITE ID
	TEST_NAME
	TEST_TYPE
	TEST_LAT
	TEST_LON
	TEST_ELEV
	TEST_REM
	TEST_STAT
	TEST_REVW

Files (FILE)	
	FILE ID
	FILE_NAME
	FILE_TYPE
	FILE_SIZE
	FILE_FILE

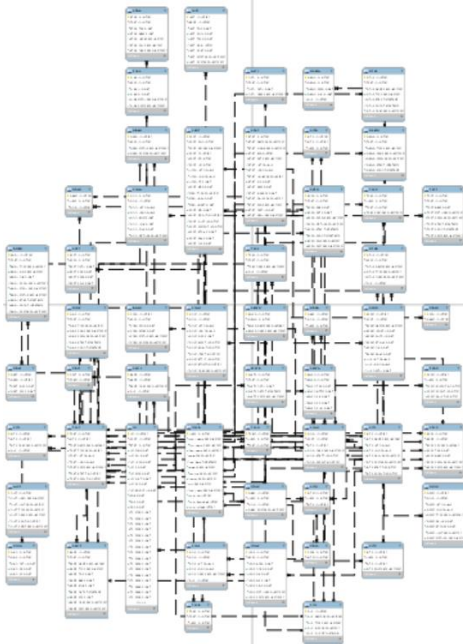
Site Files (SITF)	
	SITF ID
	SITE ID
	FILE ID
	SITF_DESC

Test Files (TESF)	
	TESF ID
	TEST ID
	FILE ID
	TESF_DESC



NGL Database Schema

Site Tables



Boreholes (BORH)	
○	BORH ID
○	TEST ID
	BORH TYPE
	BORH RIG
	BORH DIA
	BORH CREW
	BORH MECH
	BORH METH
	BORH STAR
	BORH ENDD
	BORH REM

Samples (SAMP)	
○	SAMP ID
○	TEST ID
	SAMP NAME
	SAMP TYPE
	SAMP TOP
	SAMP BASE
	SAMP SDIA
	SAMP DATE
	SAMP REC
	SAMP DESC
	SAMP REM

Stratigraphy (STRA)	
○	STRA ID
○	TEST ID
	STRA TOP
	STRA BASE
	STRA USCS
	STRA COL
	STRA DESC

Water Table (WATR)	
○	WATR ID
○	TEST ID
	WATR DPTH
	WATR DATE
	WATR REM

Sample Files (SAMF)	
○	SAMF ID
○	SAMP ID
○	FILE ID
	SAMF DESC

Specimens (SPEC)	
○	SPEC ID
○	SAMP ID
	SPEC REF
	SPEC TOP
	SPEC BASE
	SPEC CREW
	SPEC REM

SPT Data (ISPT)	
○	ISPT ID
○	SAMP ID
	ISPT TOP
	ISPT RODL
	ISPT TPEN
	ISPT NVAL
	ISPT ERAT
	ISPT REM

Index Tests (INDX)	
○	INDX ID
○	SPEC ID
	INDX BDEN
	INDX DDEN
	INDX GS
	INDX WC
	INDX FINE
	INDX METH
	INDX REM

Particle-Size Dist. (GRAG)	
○	GRAG ID
○	SPEC ID
	GRAG METH
	GRAG REM

Atterberg Limits (PLAS)	
○	PLAS ID
○	SPEC ID
	PLAS LL
	PLAS PL
	PLAS METH
	PLAS REM

Relative Density (RDEN)	
○	RDEN ID
○	SPEC ID
	RDEN EMIN
	RDEN EMAX
	RDEN METH
	RDEN REM

Other Lab. Tests (OTHR)	
○	OTHR ID
○	SPEC ID
○	FILE ID
	OTHR NAME
	OTHR TYPE
	OTHR DESC

Part.-Size Dist. data (GRAT)	
○	GRAT ID
○	GRAG ID
	GRAT SIZE
	GRAT PERP

CPT (SCPG)	
○	SCPG ID
○	TEST ID
	SCPG CSA
	SCPG RATE
	SCPG CREW
	SCPG METH
	SCPG STAR
	SCPG ENDD
	SCPG PWP
	SCPG REM

Invasive Geophysical (GINV)	
○	GINV ID
○	TEST ID
	GINV TYPE
	GINV CONF
	GINV CREW
	GINV STAR
	GINV ENDD

Surface Wave (GSWG)	
○	GSWG ID
○	GSWD ID
	GSWD TOP
	GSWD BTM
	GSWD VS
	GSWD VP
	GSWD RHO

Within-Layer info (DETL)	
○	DETL ID
○	TEST ID
	DETL DPTH
	DETL DESC

Test Pits (TEPT)	
○	TEPT ID
○	TEST ID
	TEPT BASE
	TEPT METH
	TEPT CREW
	TEPT STAR
	TEPT ENDD
	TEPT REM

CPT Data (SCPT)	
○	SCPT ID
○	SCPG ID
	SCPT DPTH
	SCPT RES
	SCPT FRES
	SCPT PWP

Vel.Prof. from Invasive (GIND)	
○	GIND ID
○	GINV ID
	GIND DPTH
	GIND VS
	GIND VP

SW disp. curves (GSWD)	
○	GSWD ID
○	GSWG ID
	GSWD FREQ
	GSWD PHVL

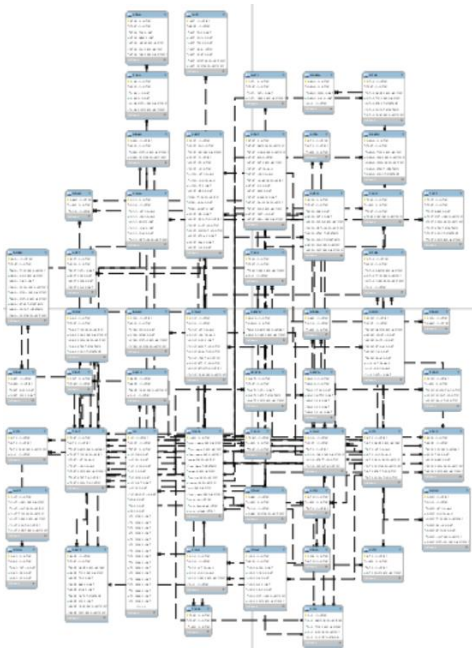
Other Field Tests (OTHF)	
○	OTHF ID
○	TEST ID
	OTHF NAME
	OTHF TYPE
	OTHF DESC
	OTHF STAR
	OTHF ENDD

V _s -V _p profiles info (SWVG)	
○	SWVG ID
○	GSWG ID
	SWVG NAME
	SWVG DESC

Vel. profiles from SW (SWVD)	
○	SWVD ID
○	SWVG ID
	SWVD TOP
	SWVD BTM
	SWVD VS
	SWVD VP
	SWVD RHO

NGL Database Schema

Observation Tables



Observations (FLDO)	
🔑	FLDO ID
🔑	EVNT ID
🔑	SITE ID
	FLDO DESC
	FLDO STAT
	FLDO REVW

🔑	Primary key
🔑	Foreign key

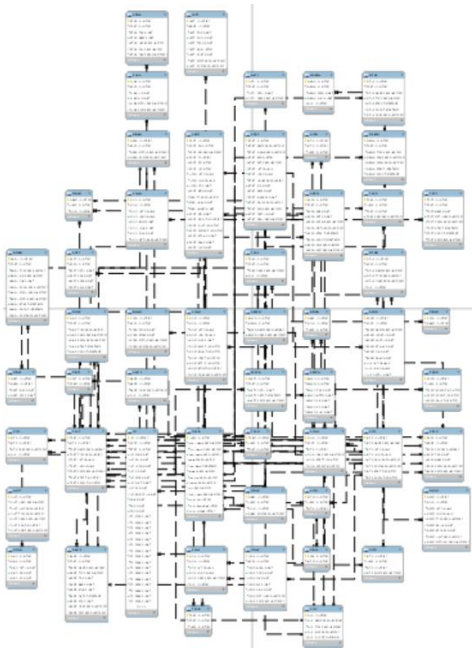
Ground Motion at site (GMIM)	
🔑	GMIM ID
🔑	FLDO ID
	GMIM LAT
	GMIM LON
	GMIM TYPE
	GMIM VALUE
	GMIM STDDEV
	GMIM UNIT
	GMIM METHOD

Observation Files (FLDF)	
🔑	FLDF ID
🔑	FLDO ID
🔑	FILE ID
	FLDF LAT
	FLDF LON
	FLDF DESC


Liquefaction Manifestations (FLDM)	
🔑	FLDM ID
🔑	FLDO ID
	FLDM LAT
	FLDM LON
	FLDM ELEV
	FLDM SFEV
	FLDM SNBL
	FLDM LTSP
	FLDM STTL
	FLDM STDN
	FLDM DESC


Disp. Vectors (FLDD)	
🔑	FLDD ID
🔑	FLDO ID
	FLDD LAT
	FLDD LON
	FLDD AZIM
	FLDD HDIS
	FLDD VDIS
	FLDD METH



NGL Database Schema






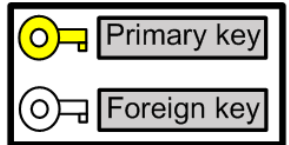
Event Tables

Earthquake Event (EVNT)	
	EVNT_ID
	EVNT_ID
	EVNT_EQID
	EVNT_NM
	EVNT_YR
	EVNT_MD
	EVNT_HM
	HYPO_LAT
	HYPO_LON
	HYPO_DT
	EVNT_MAG
	MAG_TY
	MAG_UNCK
	MAG_UNCST
	EVNT_MO
	EVNT_MECH
	EVNT_RUP
	EVNT_FFMOD
	EVNT_STRIKE
	EVNT_RAKE
	EVNT_DIP

Recording Station (STAT)	
	STAT_ID
	STAT_NAME
	STAT_SEQN
	STAT_NET
	STAT_LAT
	STAT_LON
	STAT_HOUSE
	STAT_ELE
	STAT_VS30
	STAT_SIGVS30
	STAT_NEHRP
	STAT_REG
	STAT_DEPTH
	STAT_GEOL

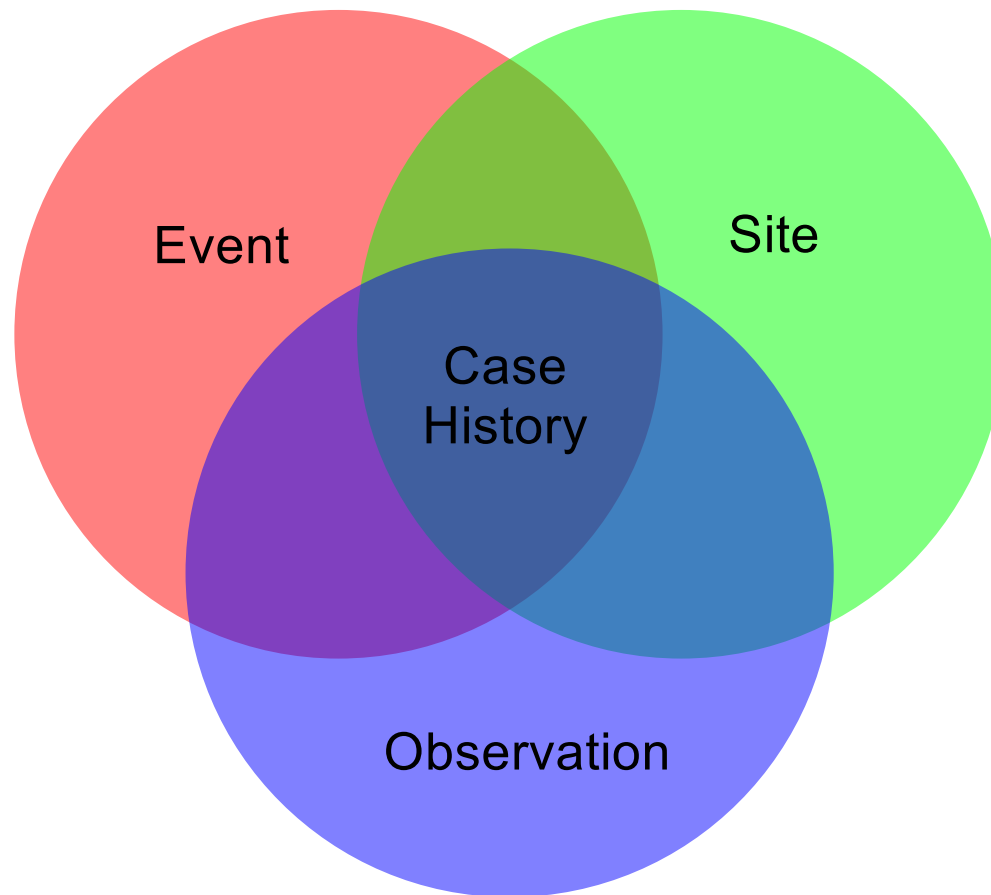
Fault Segment (SEGM)	
	SEGM_ID
	EVNT_ID
	SEGM_NAME
	SEGM_LENGTH
	SEGM_WIDTH
	SEGM_STRIKE
	SEGM_DIP
	SEGM_RAKE
	ULC_LAT
	ULC_LON
	ULC_DEPTH

Recorded IMs (RCIM)	
	RCIM_ID
	EVNT_ID
	STAT_ID
	IM_RJB
	IM_EPI
	IM_HYPO
	IM_R_DIST
	IM_RMS
	IM_CLST
	IM_RX
	IM_AZIMUTH
	PGA
	PGV
	PGD
	T0.010S
	T0.020S
	T...S
	T20.000S



**NGL includes all NGA West-2 events
...soon NGA Sub**

NGL Case History Definition



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.

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

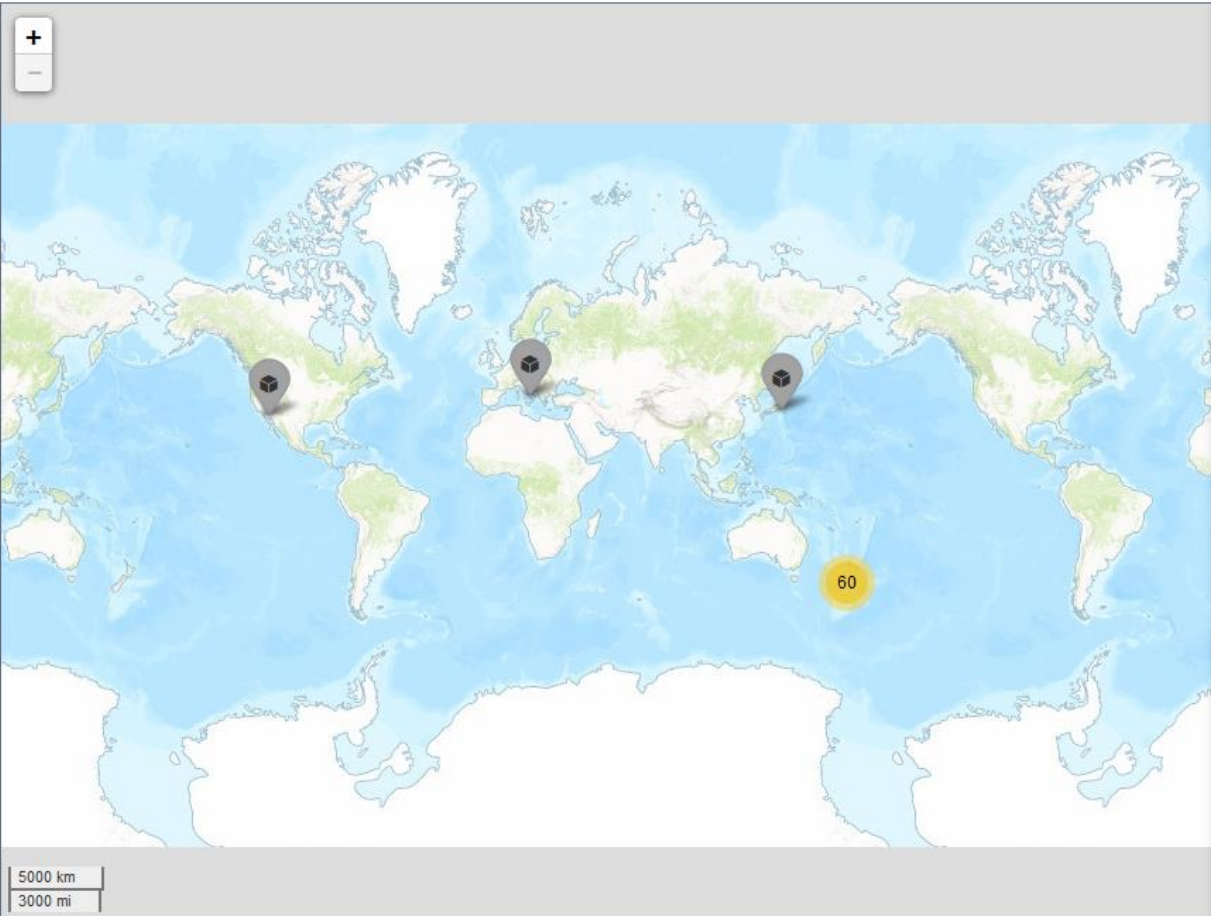
Earthquake

Event Name Magnitude -

Ground Motion

Measured Ground Motion

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



Topographic Map
 Terrain Map
 Imagery Map

General description

Site

Geotechnical / Geophysical tests info

Borehole
 CPT
 Geophysical test (Vs)

Event Information

Event

Field Observation

Observation

Developed as Structured Query Language (SQL) database management system

KPHP platform, GIS-based mapping tool

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

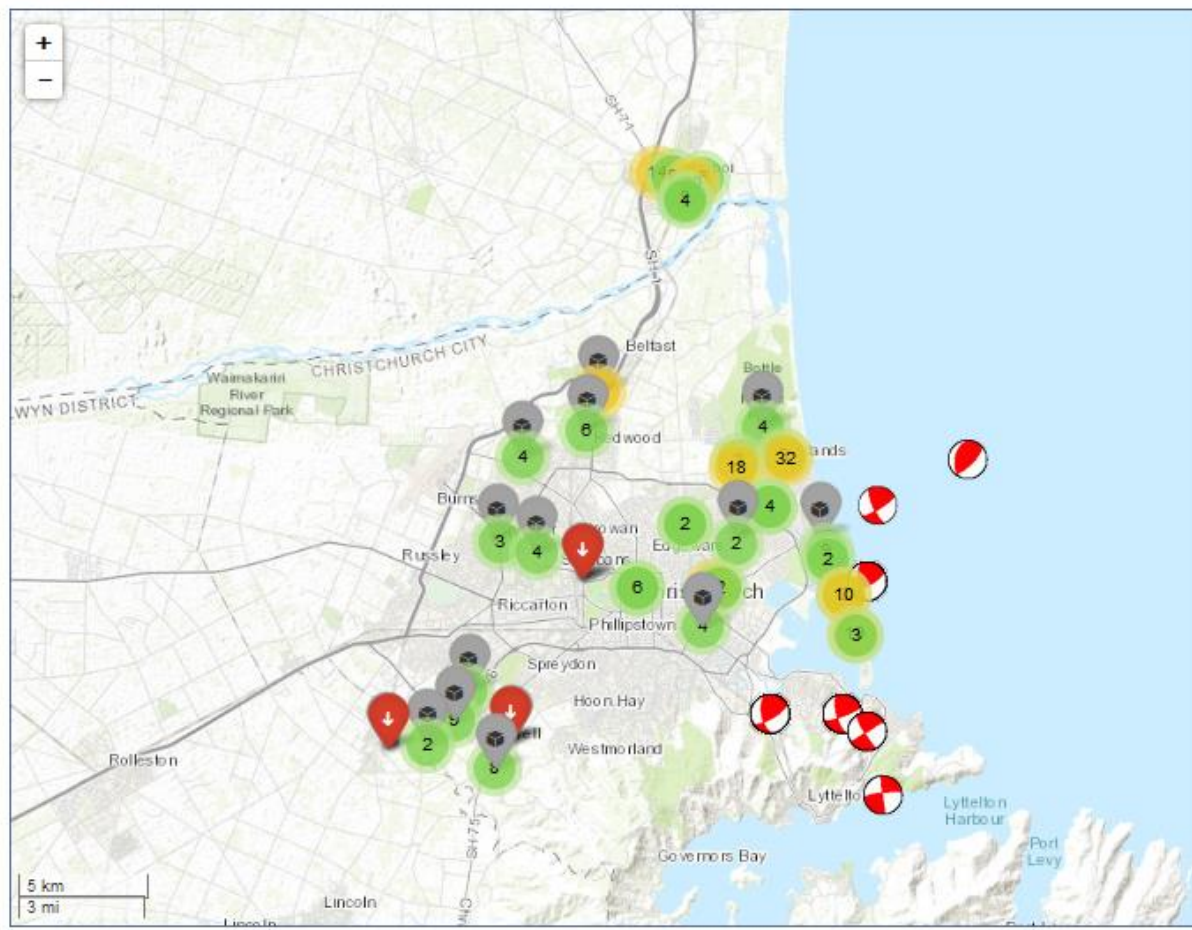
Event Name Magnitude -

Ground Motion

Measured Ground Motion

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

RESET **SUBMIT**



Topographic Map
 Terrain Map
 Imagery Map

General description
 Site

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

Event Information
 Event

Field Observation
 Observation



Field Performance

Measured Lateral Def.
 Disp. Sand Boil

Settlement Post-event def.

Observation Type

Field Note Field Mapping
 Recon. Photo Satel. Image
 Repair Report Other

Earthquake

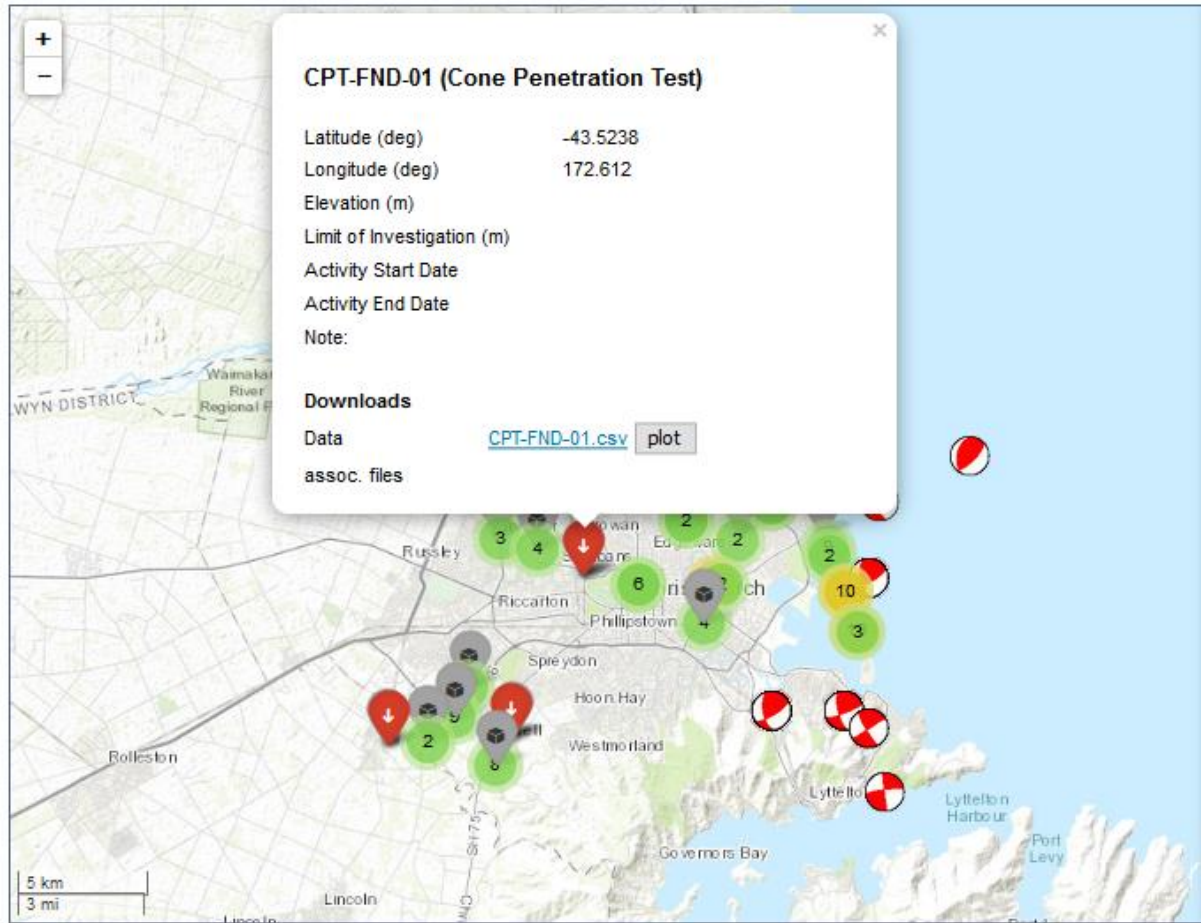
Event Name Magnitude
 -

Ground Motion

Measured Ground Motion

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

RESET **SUBMIT**



CPT-FND-01 (Cone Penetration Test)

Latitude (deg) -43.5238
 Longitude (deg) 172.612
 Elevation (m)
 Limit of Investigation (m)
 Activity Start Date
 Activity End Date
 Note:

Downloads

Data [CPT-FND-01.csv](#) **plot**

assoc. files

Topographic Map
 Terrain Map
 Imagery Map

General description

Site

Geotechnical / Geophysical tests info

Borehole
 CPT
 Geophysical test (Vs)

Event Information

Event

Field Observation

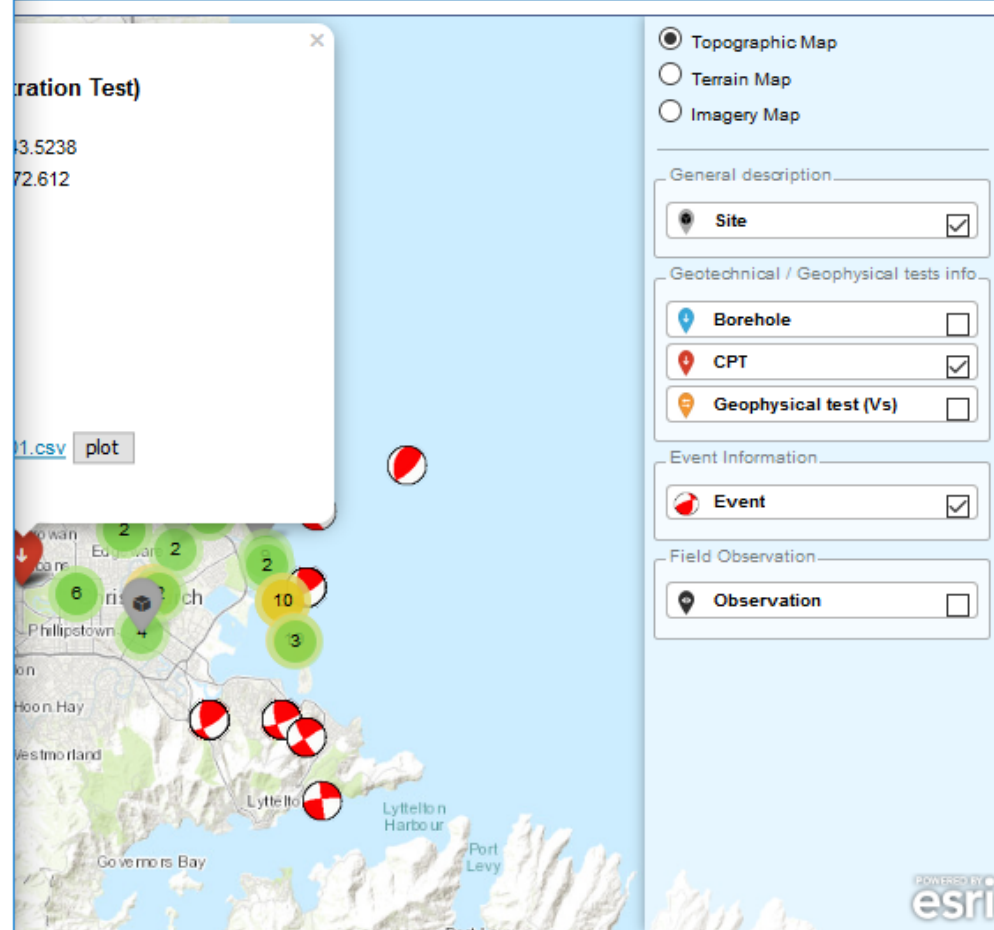
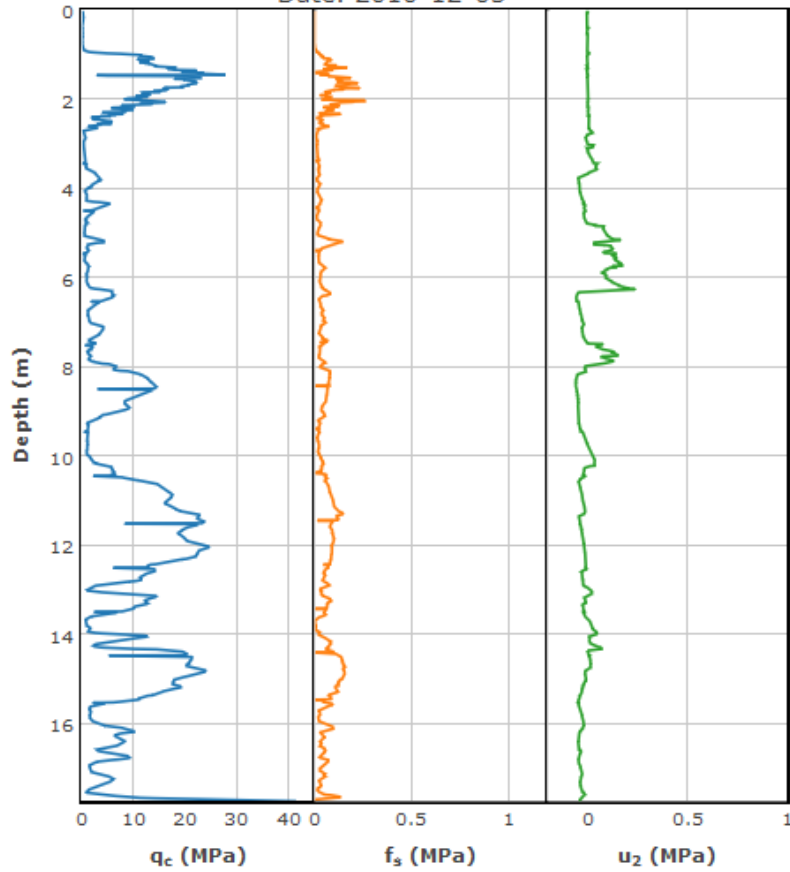
Observation



CPT-FND-01

Lat/Long: -43.52377 / 172.61232

Date: 2010-12-03



Field Performance

Measured Disp.
 Settlement
 Post-event def.

Lateral Def.
 Sand Boil

Observation Type

Field Note
 Recon. Photo
 Repair Report

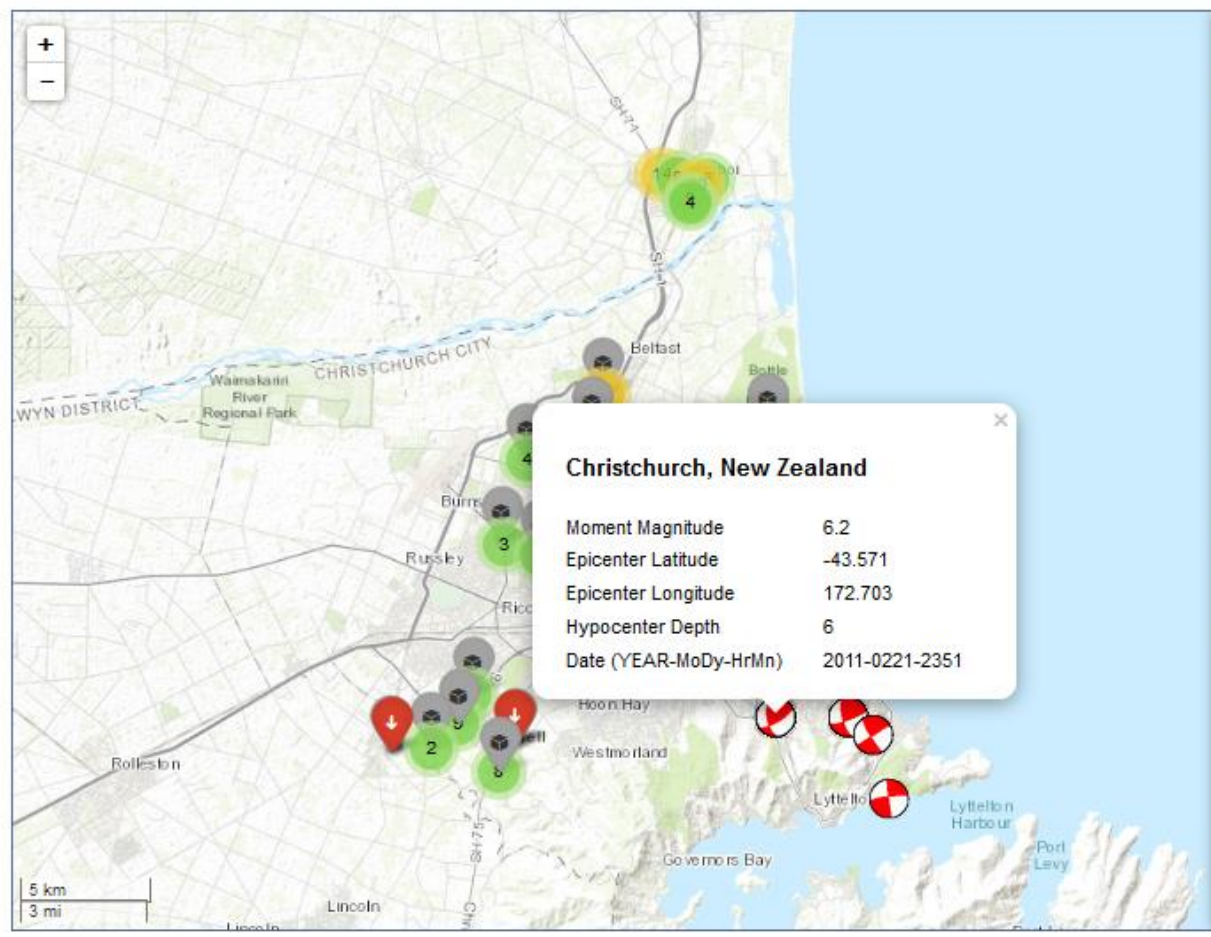
Field Mapping
 Satel. Image
 Other

Earthquake

Event Name Magnitude -

Ground Motion

Measured Ground Motion
 PGA (g) - 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

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**

The map shows a topographic view of a coastal area with a road and a body of water. A location marker is placed on the road, and a pop-up window displays the following information:

by M9 Tohoku

Latitude: 35.6379
 Longitude: 139.933
 Observation type: Reconnaissance photo
 Observations: Measured displacement / Lateral deformation / Settlement / Sand boil
 Note: Recon. photo by GEER team

Downloads

Data **assoc. files**
[Tohoku-731.csv](#)

A scale bar at the bottom left indicates 20 m and 50 ft. A scale indicator on the map shows a green circle with the number '2'.

Topographic Map
 Terrain Map
 Imagery Map

General description

Site

Geotechnical / Geophysical tests info

Borehole
 CPT
 Geophysical test (Vs)

Event Information

Event

Field Observation

Observation



Benefits of the NGL Database

Old case-histories

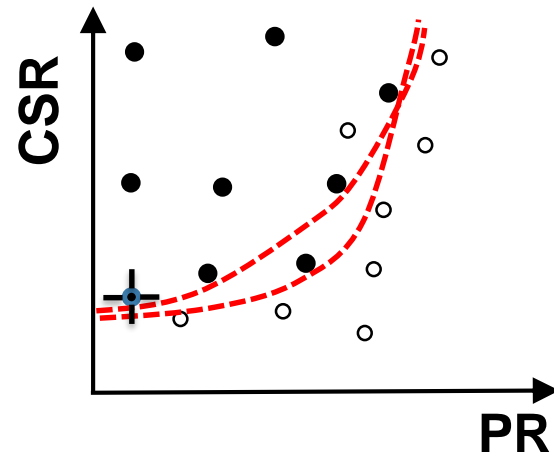
face clay silt layer. Following the 1977 earthquake, signs of liquefaction such as ejection of fine sand through the fissures or cracks were observed here and there in this area. Photo.2 shows typical sand ejection



Bucarest (1977, **M**7.2 Vrancea event)
From Ishihara and Perlea (1984)

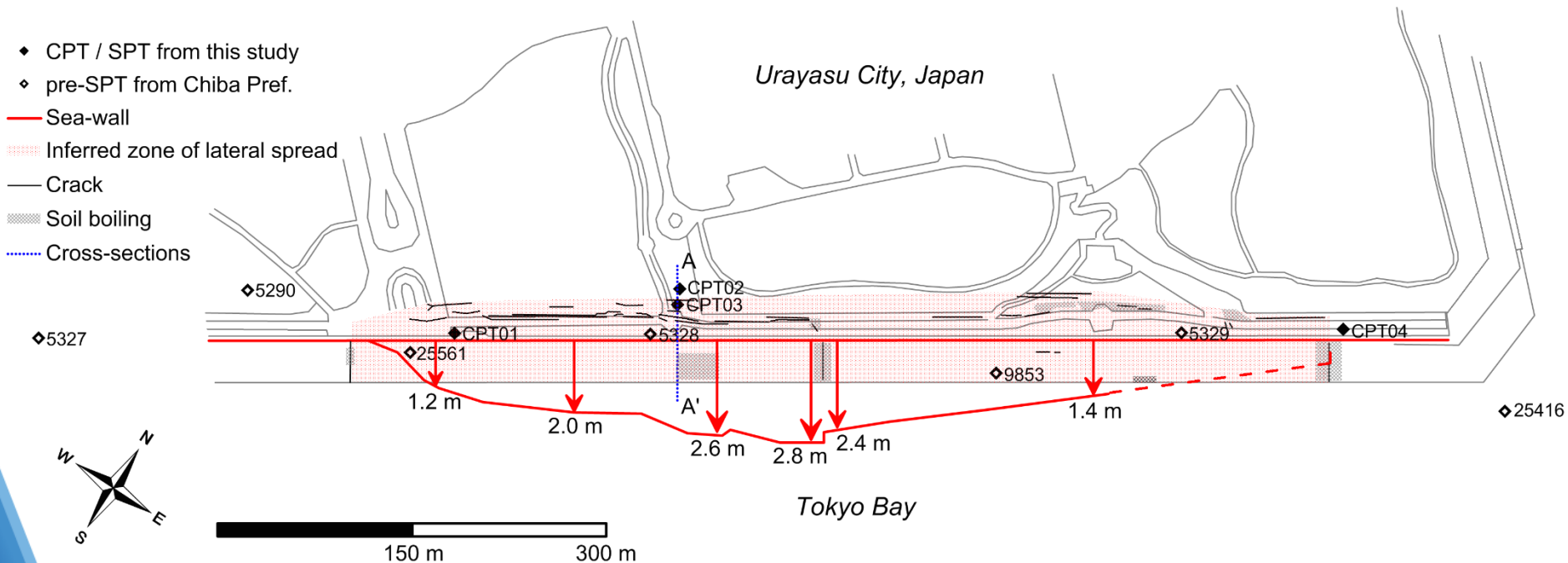
Earthquake	M_w
1977 Vrancea, Romania	7.20 ± 0.11
Site	Liquefied?
Site 2	No

- Liquefaction
- No Ground Failure



Benefits of the NGL Database

Recent case-histories



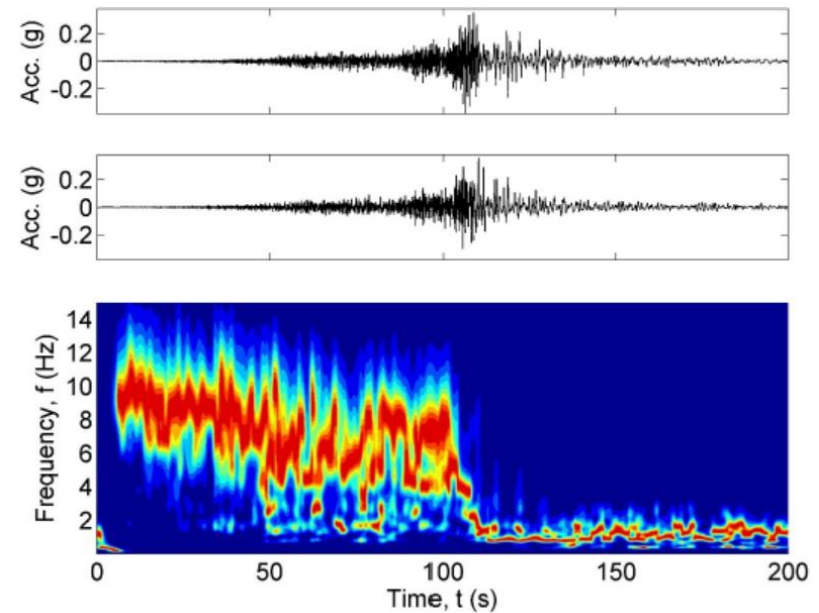
Urayasu, Japan (2011 – **M9.0** Tohoku-Oki event)
From Stewart et al. (2016)

Benefits of the NGL Database

Recent case-histories



Motion-based data



Ibaraki, Japan (2011 – **M**9.0 Tohoku-Oki)
From Kramer et al. (2016)
and M. Greenfield pers. comm.

Benefits of the NGL Database

Recent case-histories



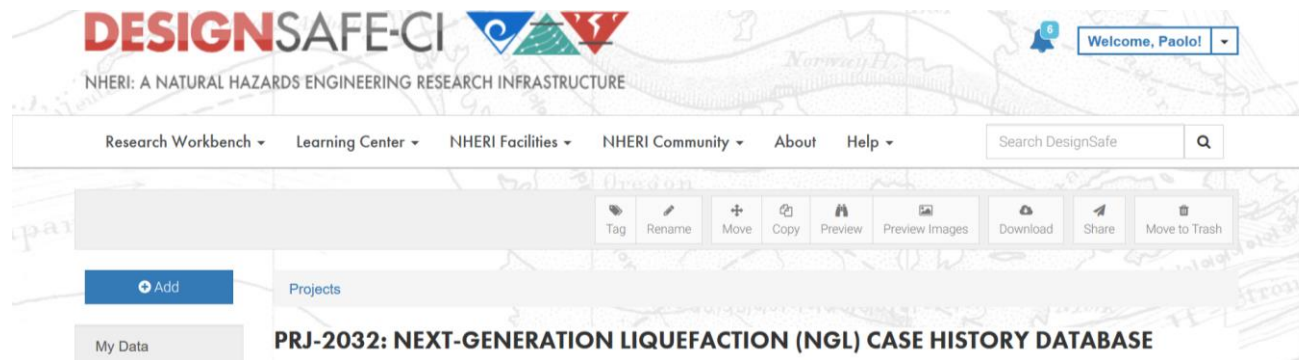
Emilia, Italy (2012 – **M**5.9 Emilia event)
(Crespellani et al., 2012 and M.G. Durante pers. comm.)

Current Status and Review Process

- 63 sites (~200 case histories) in current version of NGL website.
- Additional case histories (~25) created using a CSV template that can easily be uploaded to the new website.
- Legacy case-histories will be added.
- The **database working group** will review all of the uploaded data. 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.
- **Beta version of new website** under development. Official release: soon...stay tuned!

Vision for Community Access (*to cloud or not to cloud?*)

- Due to **large amount of data**, downloading data and processing them on a laptop is inefficient and undesirable (though still possible).
- We are **mirroring the database to DesignSafe** (www.designsafe-ci.org). Users will be able to process data on the cloud using SQL queries in Jupyter notebook Python scripts (*off-the-shelf* libraries).



Sites

Field Performance

Field Investigation

Earthquake

Type event name

Magnitude

min

max

Reset

Submit

Statistics



- Topographic Map (high res.)
- Imagery Map (middle res.)
- Terrain Map (low res.)

General description

Site

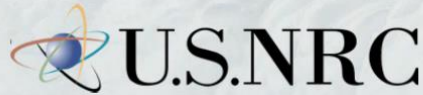
Event Information

Event

Field Performance

Observation (Note)

Observation (File)



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.



Project homepage:

<https://uclageo.com/NGL/>

Database (beta):

<http://uclageo.com/NGL/database/index.php>