

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER
2019 ANNUAL MEETING
JANUARY 17-18, 2019 LOS ANGELES, CA



SEISMIC RESILIENCE **25** YEARS AFTER NORTHRIDGE:
ACCOMPLISHMENTS AND CHALLENGES

UCLA Samueli
School of Engineering

NGL: An Open-Source Database for Next-Generation of Liquefaction Assessment Procedures and its Impact on Global Community Resilience

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January 18, 2019



Engineer Change.

Outline

Introduction and project needs

The Next-Generation Liquefaction database

Current status of the NGL database

Vision for community access and final remarks

NGL Database Contributors

- ***NGL leadership:*** Jonathan Stewart, Steven Kramer, Yosef Bozorgnia
- ***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



U.S.NRC



NGL Database Contributors

- **U. of Utah:** Steve Bartlett, Masoud Hosseinali
- **Virginia Tech:** Russell Green, Kristin Ulmer
- **UC Berkeley:** Jonathan Bray, Christine Beyzaei
- **Tonkin & Taylor:** Sjoerd Van Ballegooey, Mike Liu
- **BYU:** Heidi Dacayanan, Lila Lasson
- **METU:** Gizem Can, Makbule Ilgac
- **UCLA:** Omar Issa, Chris Nicas, Trini Inouye, Arielle Sanghvi, Tristan Buckreis, Naoto Inagaki, Wyatt Iwanaga, Michael Winders, Bryan Ong, Siddhant Jain, Allison Lee, Honor Fisher
- **Others:** Mike Greenfield, Teruo Nakai, Hideo Sekiguchi, ...

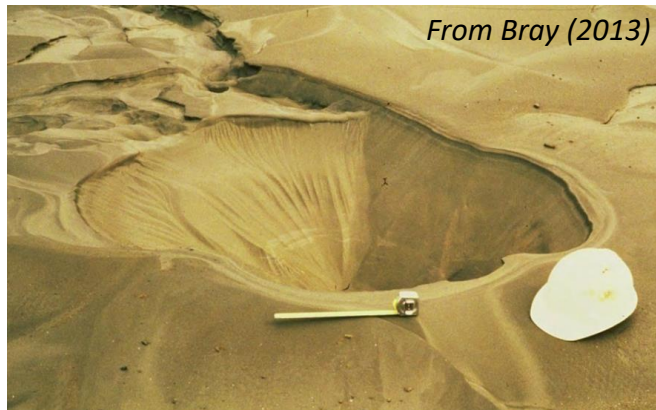


U.S.NRC



Current challenges: Liquefaction and its effects

Liquefaction manifestations (Loma Prieta, 1989)



and its effects (Kocaeli, 1999)



Effects on infrastructure (Northridge, 1994)

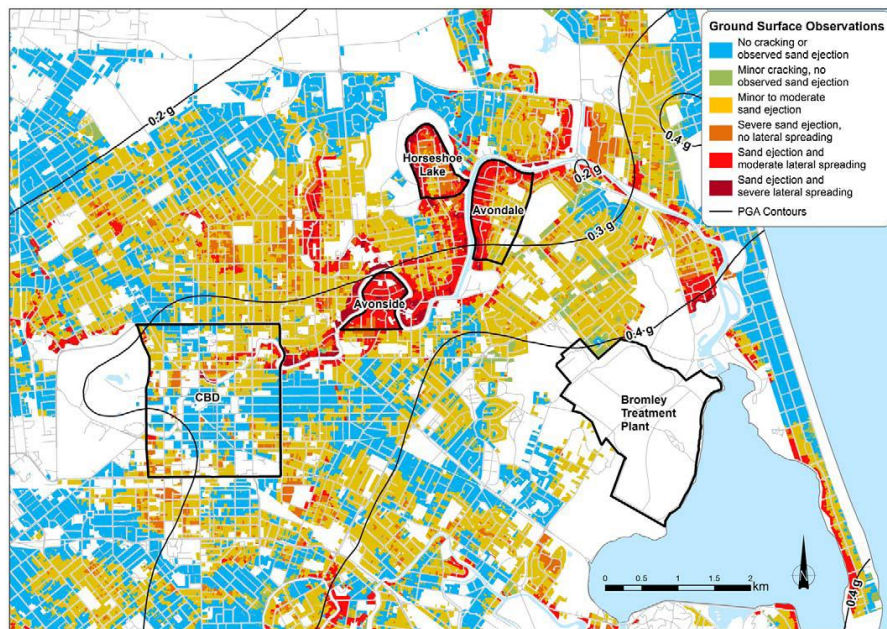


and distributed systems (levees, Tohoku, 2011)

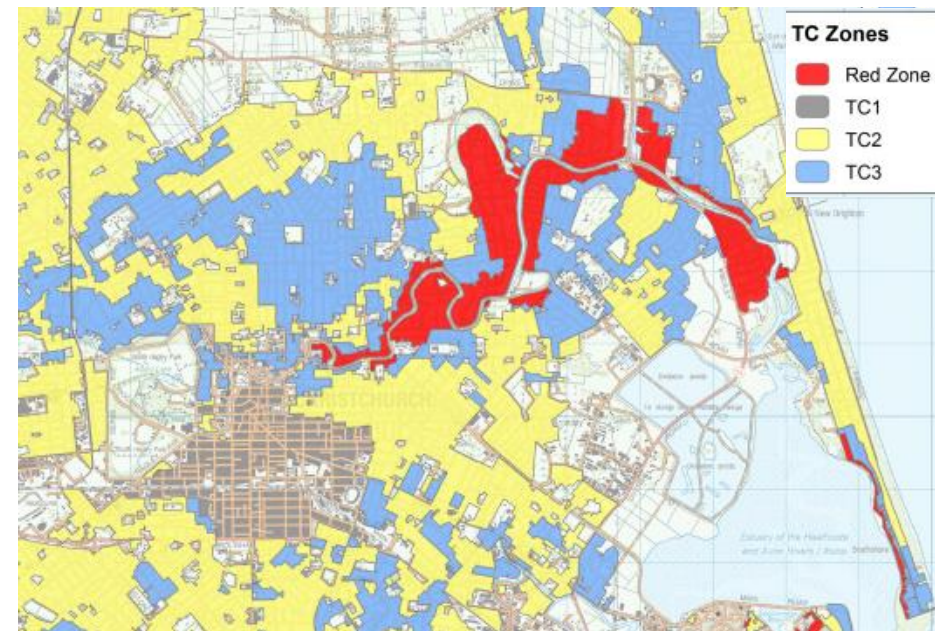


Current challenges: regional-scale analysis

Community resilience – The example of Christchurch Post-earthquake damage assessment (2011 event)



***Liquefaction-induced damages
(from van Ballegooy et al., 2014)***



***Future land planning of Christchurch
(from Saunders and Becker, 2015)***

Project needs

Liquefaction triggering assessment: current status

Small data sets

A few sites are especially consequential

Alternate liquefaction models provide different outcomes

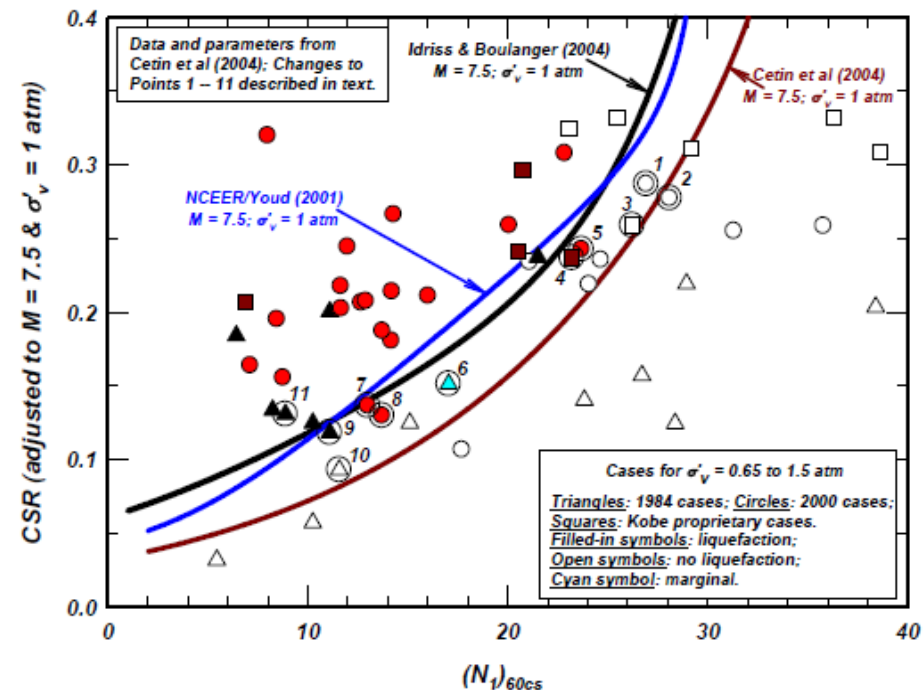
Existing data sets are necessarily incomplete, especially:

Depth > 10 m

$M > 7.5$ and $M < 6.0$

$FC > 30\%$

$CSR > 0.4$



From Idriss and Boulanger (2010)

Data quality: Legacy vs new case-histories

Legacy case histories:

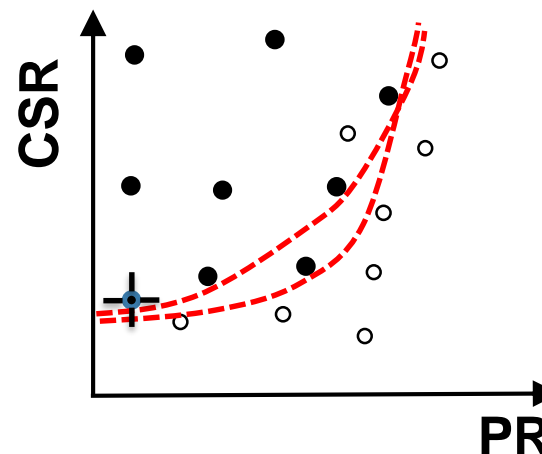
face clay silt layer. Following the 1977 earthquake, signs of liquefaction such as ejection of fine sand through the fissures or cracks were observed here and there in this area. Photo.2 shows typical sand ejection



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

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

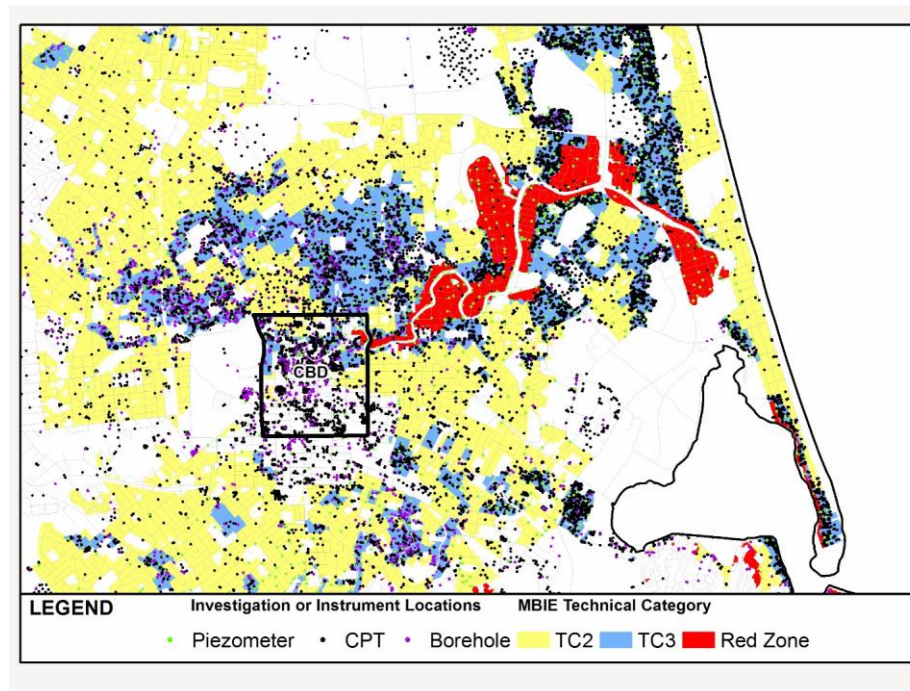
- Liquefaction
- No Ground Failure



Data quality: Legacy vs new case-histories

Recent case histories:

- High-quality characterization



The Canterbury Geotechnical Database
From: www.tonkintaylor.co.nz

Data quality: Legacy vs new case-histories

Recent case histories:

- High quality magnitude estimation
- Large digital networks (good ground motion characterization)

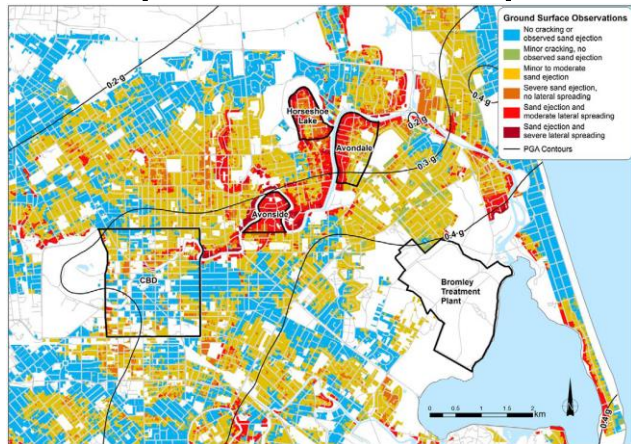
The screenshot shows the USGS Earthquake Hazards Program website for the 2016 Kaikoura earthquake. The header features the USGS logo and a seismic waveform. The main title is "M 7.8 - 54km NNE of Amberley, New Zealand" with coordinates 2016-11-13 11:02:56 UTC, 42.737°S, 173.054°E, and a depth of 15.1 km. A left sidebar lists navigation options: Overview, Interactive Map, Regional Information, Impact, Felt Report - Tell Us!, Did You Feel It?, ShakeMap, and PAGER. The main content area includes: "Interactive Map" (Contributed by USGS), "Regional Information" (Contributed by USGS), "Felt Report - Tell Us!" (Citizen Scientist Contributions) with a response counter of 000710, "Did You Feel It?" (Contributed by USGS) with a red "IX" indicator, and "ShakeMap" (Contributed by ATLAS2) with a red "IX" indicator.

Event page for the 2016 Kaikoura earthquake (New Zealand)
From earthquake.usgs.gov

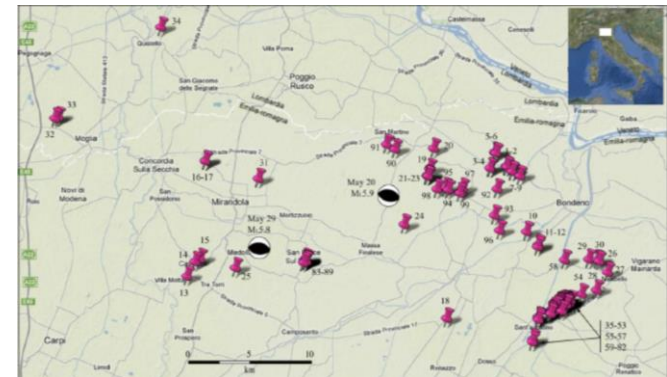
Data quality: Legacy vs new case-histories

Recent case histories:

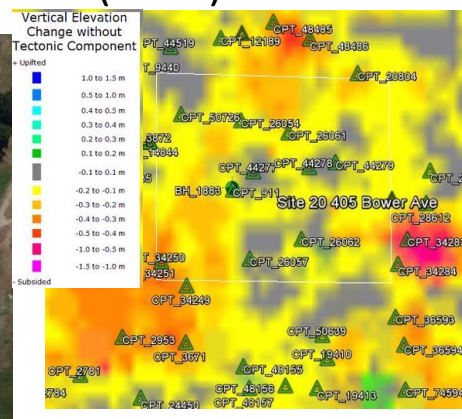
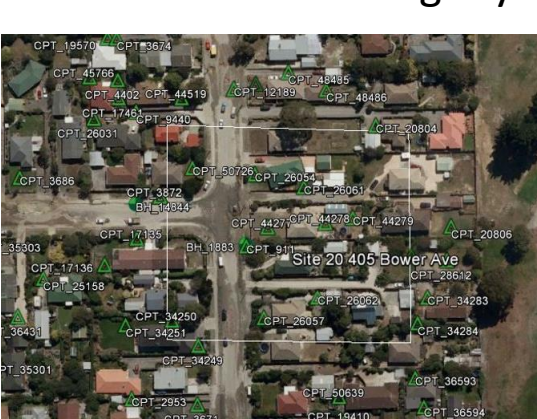
- Unprecedented quantity/quality of observations



From Van Ballegooy et al. (2014)



From Emergeo (2012)



NGL Vision

- Community field **case history database**
- **Fully-vetted** database
- **Formal relational database**
- Large amount of **high-quality** data
- **Supporting studies** of critical effects poorly constrained by data
- **Model development:** team meetings, common resources, required parameter space

Traditional vs Next-Generation Databases

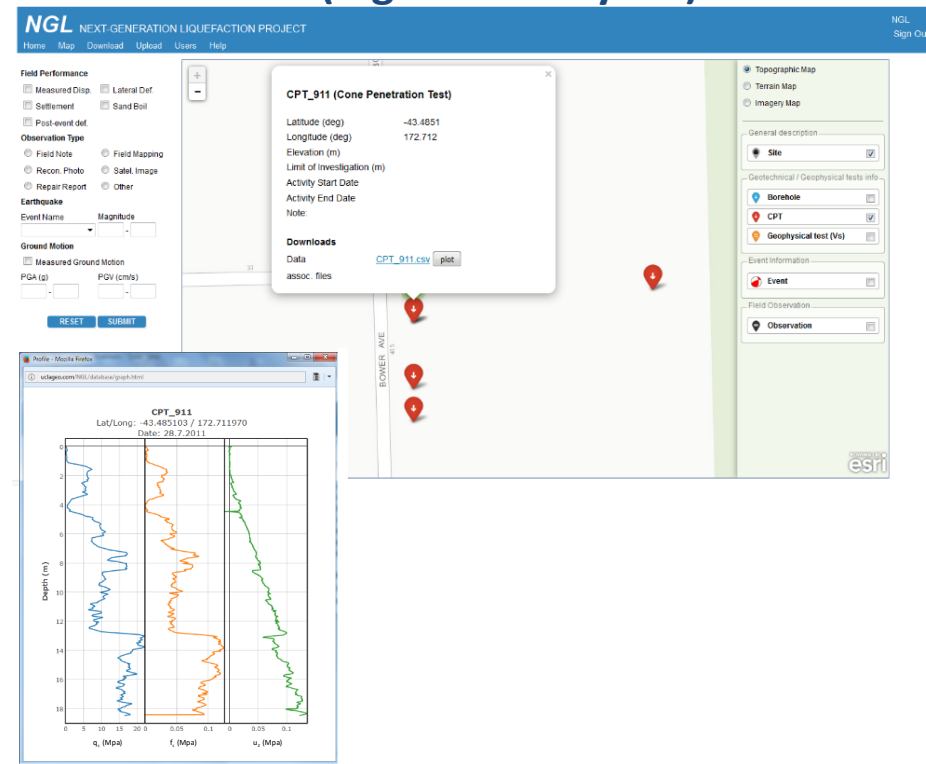
From *spreadsheet*
(Traditional data analysis)



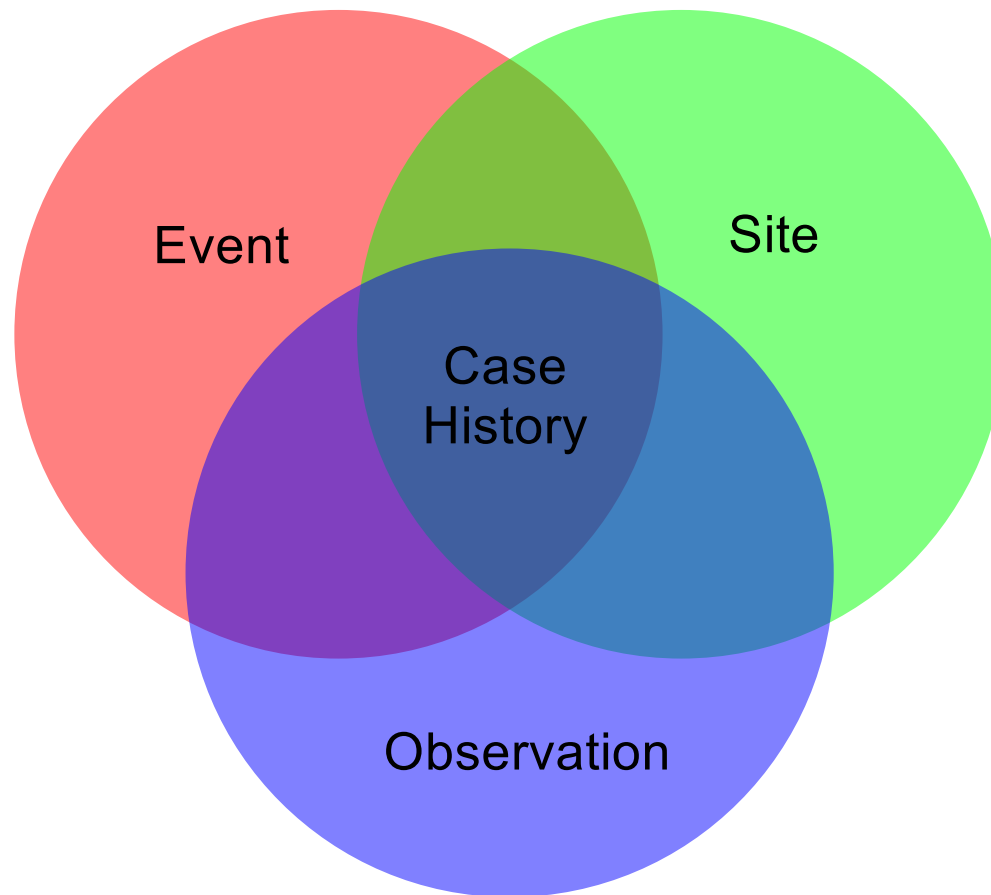
To **relational database**
(big-data analytics)

	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	Humbolt 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
16	16	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
8165	0.004065	0.005418



NGL case-history definition



NGL Database GUI development

Several beta-versions incorporating community inputs

Next-Generation Liquefaction Database

Number of Sites



NGL NEXT-GENERATION LIQUEFACTION PROJECT

Home Map Download Upload Users Help

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

min max

RESET SUBMIT

Ground Motion

Measured Ground Motion

PGA (g) PGV (cm/s)

RESET SUBMIT

Data Statistics	NGL liquef. project
Sites	68
Penetration/Geophysical tests	
Borehole (Boring, SPT)	70
CPT	419
Test pit	0
Geophysical test (Vs)	84
Lab tests	
Sieve	52
Atterberg limit	52
Consolidation	0
Triaxial (monotonic)	0
Triaxial (cyclic)	0
Others	0



The screenshot displays the NGL Database GUI interface. It features a world map with several red and green markers indicating site locations. A search form is visible on the left, and a sidebar on the right contains various filters and options. The interface includes a navigation menu at the top and a footer with logos for SwRI, PEER, Caltrans, U.S. NRC, MPC, and LT DOT.

Ver. Beta_1
(csv + SQL)



Ver. Beta_2
(full SQL)



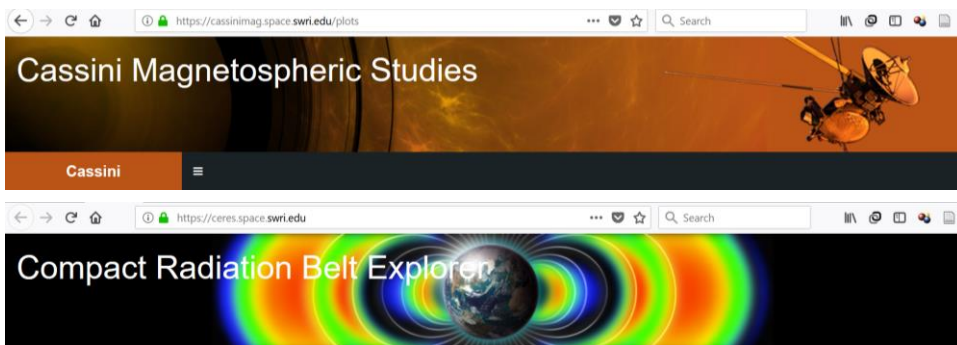
Official release (ver. 2.04)
(full SQL + Review)

NGL Database GUI development



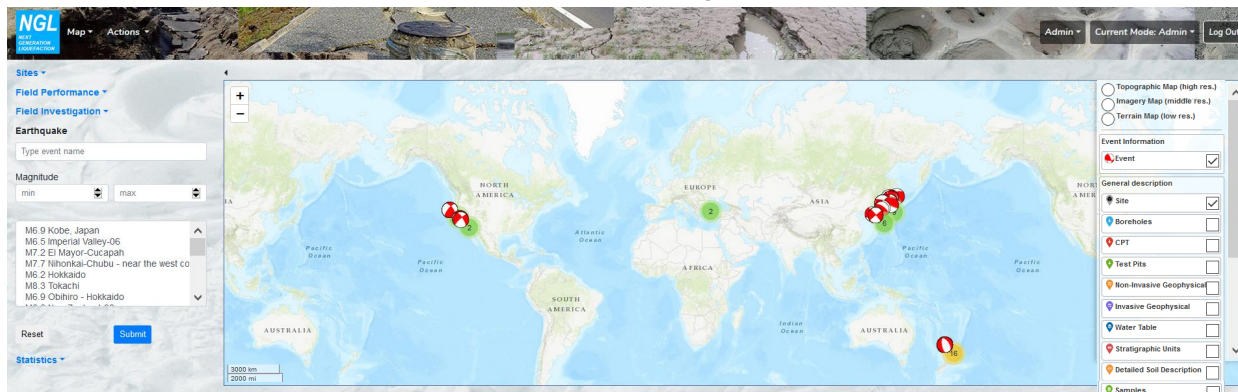
Samueli
School of Engineering

UCLA-SwRI Collaboration



www.nextgenerationliquefaction.org

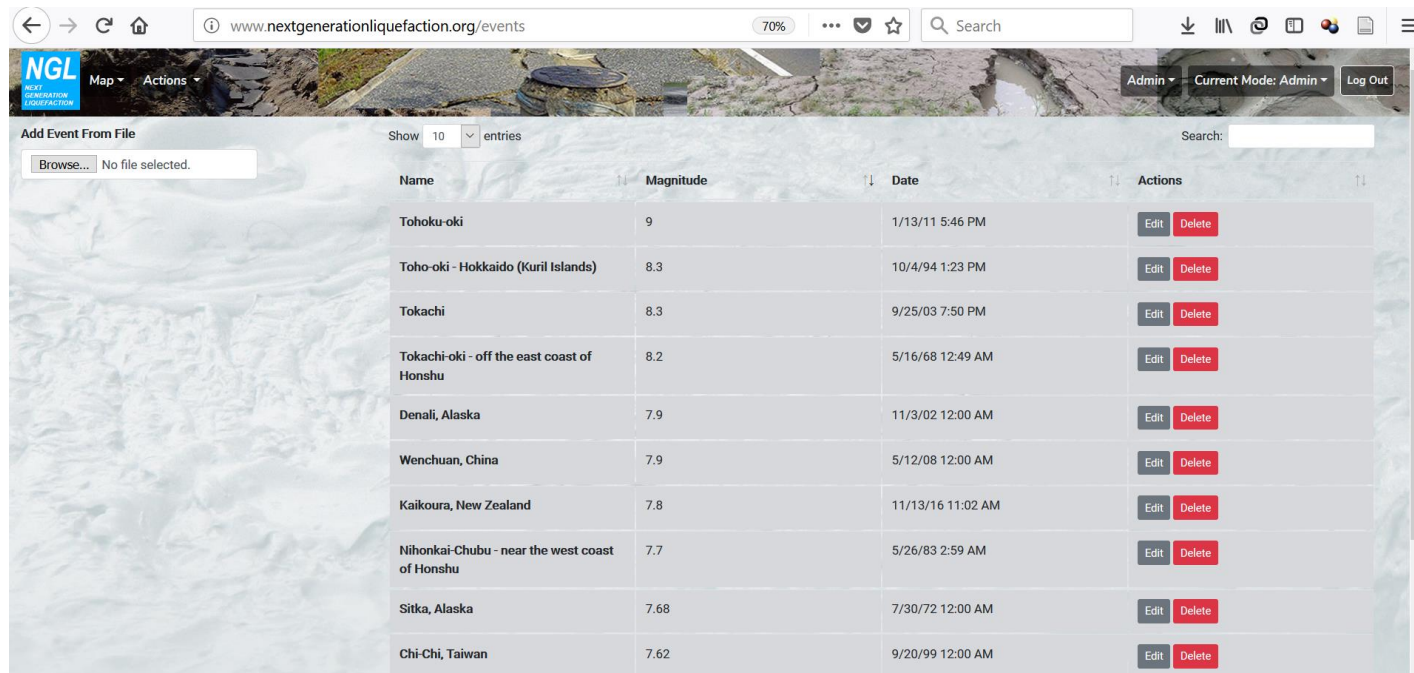
DOI: 10.21222/C2J040



U.S. NRC



NGL Database GUI Earthquake Events



www.nextgenerationliquefaction.org/events

70% Search

Admin Current Mode: Admin Log Out

Add Event From File

Show 10 entries

Browse... No file selected.

Name	Magnitude	Date	Actions
Tohoku-oki	9	1/13/11 5:46 PM	Edit Delete
Toho-oki - Hokkaido (Kuril Islands)	8.3	10/4/94 1:23 PM	Edit Delete
Tokachi	8.3	9/25/03 7:50 PM	Edit Delete
Tokachi-oki - off the east coast of Honshu	8.2	5/16/68 12:49 AM	Edit Delete
Denali, Alaska	7.9	11/3/02 12:00 AM	Edit Delete
Wenchuan, China	7.9	5/12/08 12:00 AM	Edit Delete
Kaikoura, New Zealand	7.8	11/13/16 11:02 AM	Edit Delete
Nihonkai-Chubu - near the west coast of Honshu	7.7	5/26/83 2:59 AM	Edit Delete
Sitka, Alaska	7.68	7/30/72 12:00 AM	Edit Delete
Chi-Chi, Taiwan	7.62	9/20/99 12:00 AM	Edit Delete



PEER Ground Motion Database
Pacific Earthquake Engineering Research Center

NGA West 2 Database
NGA Subduction (soon...)

NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

The screenshot displays the NGL Database GUI in its map view. At the top, there is a navigation bar with 'Map' and 'Actions' menus, and user controls for 'Admin', 'Current Mode: Admin', and 'Log Out'. The main area features a world map with several colored markers (green, blue, red, yellow) indicating site locations. On the left, there is a sidebar with filters for 'Sites', 'Field Performance', 'Field Investigation', and 'Earthquake', including a search box and a list of earthquake events. On the right, a legend panel is visible with a red border, listing various data types such as 'Event', 'Site', 'Boreholes', 'CPT', 'Test Pits', 'Non-Invasive Geophysical', 'Invasive Geophysical', 'Water Table', 'Stratigraphic Units', 'Detailed Soil Description', 'Samples', and 'Other', each with a checkbox.



Site – Geotechnical characterization

NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

The screenshot displays the NGL Database GUI in map view. At the top, navigation links include 'Introduction', 'NGL Database GUI', 'NGL Database Current status', and 'Final remarks'. The main title is 'NGL Database GUI (Map view)' with the URL 'www.nextgenerationliquefaction.org' below it.

The interface features a world map with several earthquake event markers. On the left, a search filter for 'Earthquake' is highlighted with a red box. It includes a text input for 'Type event name', a 'Magnitude' range selector (min to max), and a dropdown menu listing various earthquake events such as 'M6.9 Kobe, Japan', 'M6.5 Imperial Valley-06', 'M7.2 El Mayor-Cucapah', 'M7.7 Nihonkai-Chubu - near the west co', 'M6.2 Hokkaido', 'M8.3 Tokachi', and 'M6.9 Obihiro - Hokkaido'. A 'Submit' button is located below the dropdown.

On the right side, a 'Filter' panel is visible, also with a red box around the 'Event Information' section. It includes options for map styles (Topographic, Imagery, Terrain) and checkboxes for 'Event', 'Site', 'Boreholes', 'CPT', 'Test Pits', 'Non-Invasive Geophysical', 'Invasive Geophysical', 'Water Table', 'Stratigraphic Units', 'Detailed Soil Description', 'Samples', and 'Other'. The 'Event' checkbox is checked.

At the bottom of the map view, there are logos for SwRI, PEER, Caltrans, U.S.NRC, MPC (Mountain Plains Consortium), and LTDOT (Keeping Utah Moving).

Earthquake events (that produced observations)

NGL Database GUI (Map view)

www.nextgenerationliquefaction.org



NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

The screenshot displays the NGL Database GUI in its map view. At the top left, there is a navigation bar with 'View Data' and 'Actions' dropdowns. Below this is a 'Sites' dropdown menu. The main map area shows a street map of Nantou City with numerous data points represented by colored circles and icons. A legend on the right side of the map allows users to filter the data points by type, including Boreholes, CPT, Test Pits, Non-Invasive Geophysical, Invasive Geophysical, Water Table, Stratigraphic Units, Detailed Soil Description, Samples, and Other. Below the legend, there are checkboxes for 'Field Performance' options: 'Observation (Note)' and 'Observation (File)'. On the left side of the map, there is an 'Earthquake' filter section with a text input for 'Type event name', a 'Magnitude' range selector (min to max), and a list of recent earthquakes: M6.6 New Zealand-02, M7 Darfield, New Zealand, M6.2 Christchurch, New Zealand, M5.8 Emilia, Italy, M9.1 Tohoku-oki, M7 Haicheng (Liaoning), China, and M7.6 Chi-Chi, Taiwan. There are 'Reset' and 'Submit' buttons below the earthquake list. A scale bar at the bottom left of the map indicates 200 meters and 500 feet.



NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

View Data **Actions** **Current Mode: User** **Log Out**

Sites
Field Performance
Field Investigation
Earthquake

Type event name

Magnitude
 min max

M6.6 New Zealand-02
 M7 Darfield, New Zealand
 M6.2 Christchurch, New Zealand
 M5.8 Emilia, Italy
 M9.1 Tohoku-oki
 M7 Haicheng (Liaoning), China
 M7.6 Chi-Chi, Taiwan

Reset **Submit**

Statistics

Latitude: 23.9096
 Longitude: 120.6878
 Observations:
 Note: Building Settlement observed. No surface evidence. "Sites A and B were chosen to investigate the soil conditions in the downtown area where there are numerous mapped locations of building subsidence and other areas where there was no apparent ground failure," Chu et al. (2004). Note: Photographs from site provide limited evidence. This description was extracted directly from PEER's Taiwan Ground Failure Database: https://apps.peer.berkeley.edu/lifelines/research_projects/3A02/nantou-site-b.html

Legend:
 Boreholes
 CPT
 Test Pits
 Non-Invasive Geophysical
 Invasive Geophysical
 Water Table
 Stratigraphic Units
 Detailed Soil Description
 Samples
 Other
Field Performance
 Observation (Note)
 Observation (File)

200 m / 500 ft



NGL Database GUI (List view and functionalities)

www.nextgenerationliquefaction.org

The screenshot shows a web browser at the URL www.nextgenerationliquefaction.org/sites. The page features a navigation bar with a logo, a search bar, and user controls. Below the navigation bar, there are two main sections: 'Add Site From File' and 'Search and select a site'. The 'Add Site From File' section includes a 'Browse...' button and a 'No file selected.' message. The 'Search and select a site' section has a search input field. Below these sections is a table listing various sites, each with a set of action buttons.

Site Name	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Amagasaki	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Bonds Corner	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Hachirogata	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Higashi-Kobe Bridge	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Hanshin Expressway	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
HKD086	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Brady Farm4	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Edgumbe Pipe Breakages	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Gordon Farm1	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
Gordon Farm2	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments
James Street Loop	Edit	Delete	Add Member	Field Tests	Field Observations	Submit for review	Add Comment	View Member Comments

NGL Database GUI

(How to upload a case history?) metadictionary

<http://nextgenerationliquefaction.org/schema/index.html>

NGL Database Home Schema index Tables Columns Constraints Relationships Orphan Tables Anomalies Routines

Tables

SchemaSpy Analysis of NGL_11_19_2018

Generated on Tue Nov 27 12:08 PST 2018

XML Representation
Insertion Order Deletion Order



Database Properties

Database Type: MySQL - 5.6.34-log

Tables

All Tables Views Comments

Search:

Table / View	Children	Parents	Columns	Rows	Type	Comments
BORH	0	1	11	0	Table	General information for boreholes

Database Current Status

- Legacy case-histories (used in the past for model development) are in the process of being added (~300 case histories)
- Case histories with co-located recording stations
- Recent case histories
 - Christchurch 2010-2011 sequence (New Zealand)
 - Tohoku 2011 **M**9.1 earthquake (Japan)
 - Emilia 2012 **M**5.9 (Italy)
- Stable database GUI officially released on 09/24/2018

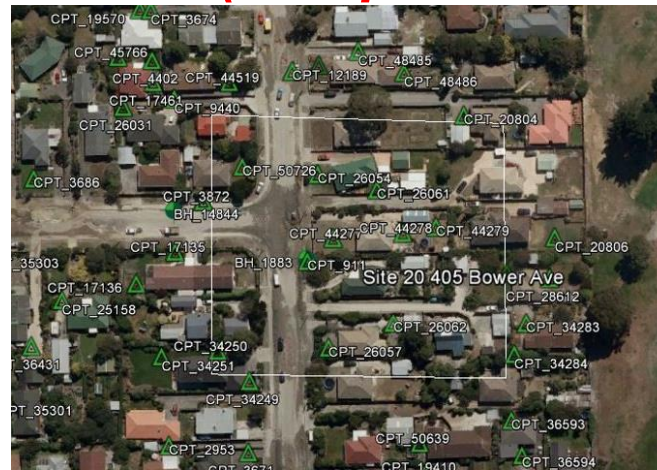
Database Current Status

- Christchurch (New Zealand) 2010-2011 sequence:

Green et al. (2014) case histories (VTech Green and Ulmer)
25 sites, 50 case histories (Complete - under review)

Tonkin + Taylor case histories (Van Ballegooy and Liu)
37 sites, 135 case histories (Complete – will be under review soon)

UC Berkeley sites (Bray and Beyzaei)
10 sites, 20 case histories (Complete - under review)



Database Current Status

- Tohoku (Japan) 2011 **M**9.1 event – Unpublished

Urayasu + Mihama - UCLA

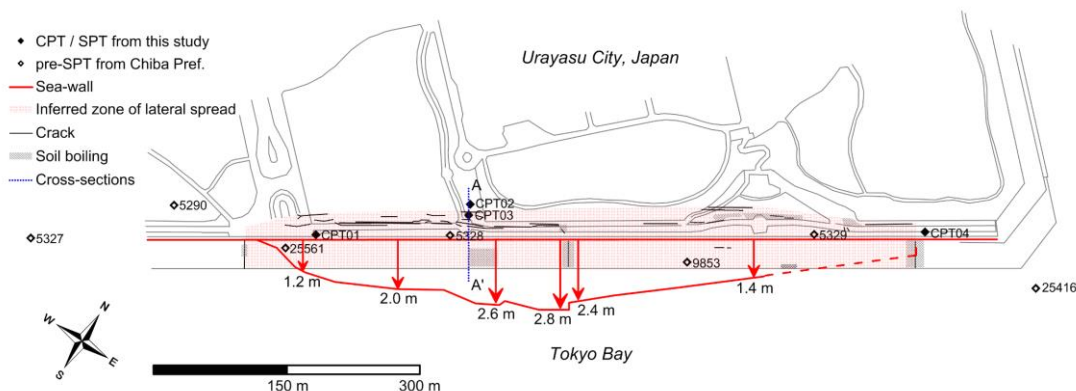
2 sites/case histories (Complete – under review)

Instrumented levee arrays - UCLA

3 sites/case histories (Complete –under review)

Additional lateral spread sites – UCLA-BYU

3 sites/case histories (work in progress)



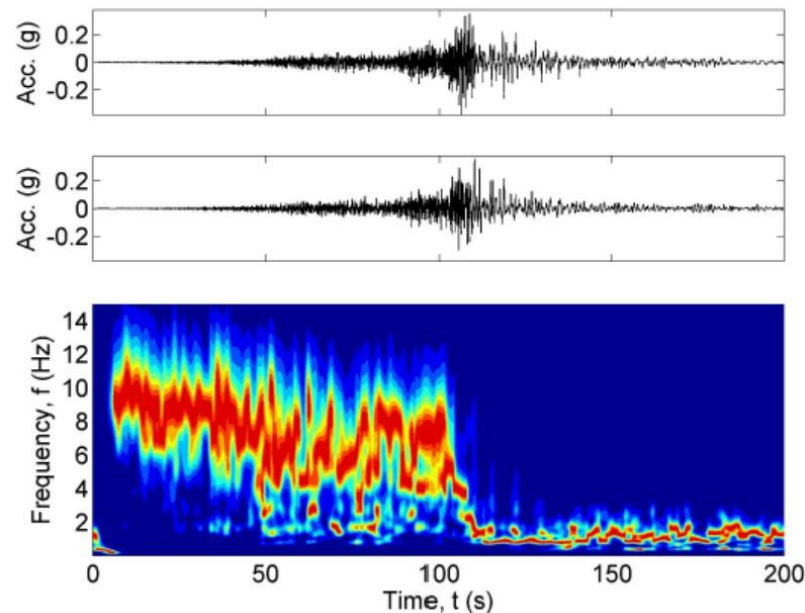
Database Current Status

- Case histories with co-located recording stations (Kramer and Greenfield (U. Washington))

16 sites, 22 case histories (Complete - under review)



Ibaraki, Japan (2011 – Tohoku):
from Kramer et al. (2016) and
M. Greenfield pers. comm.



- Emilia (Italy) 2012 **M5.8** earthquake – UCLA

4 sites/4 case histories (Complete - will be under review soon)

Review/Vetting Process

NGL Database working group

Purpose: to verify that required fields are present and the inputs match source materials.

Bi-weekly meetings.


Standardized procedure to look at data.

Review performed via **NGL graphical interface** – easy process!












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



- Large amount of data, processing them on a laptop is inefficient (but still possible).
- The database is mirrored onto DesignSafe (www.designsafe-ci.org).
Cloud-based tools (i.e. Jupyter notebooks)

Jupyter Interactive Plots_modified-pymysql Last Checkpoint: Yesterday at 12:43 AM (autosaved)  Logout Control Panel

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3 C












 Markdown



This post-processing tool generates CPT/SPT/VS profile for each case history in the NGL database. Queries are produced for earthquake events that produced observations and sites for which geotechnical data are available.

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



- **Large amount of data**, processing them on a laptop is inefficient (but still possible).
- The database is mirrored onto **DesignSafe** (www.designsafe-ci.org).
Cloud-based tools (i.e. Jupyter notebooks)

Select the event.

EVENT

Select the site.

SITE

Remarks: Industrial site near Yomoga River. Coordinates inferred from Abe site plan

Select the test.

TEST

Select the Ground Water Depth or select "Other" and enter the depth.

GWD Other:

Select the Peak Ground Acceleration or select "Other" and enter a value.

PGA 0.316 -- Calculated from recorded ground motion

Other:

Click button to plot soil data.

Final Remarks

- Release of stable database GUI: ***nextgenerationliquefaction.org***
- The NGL relational database (being populated): capabilities for big data analytics
- Vetted database (NGL working group)
- NGL-NGA interaction – earthquake events
- The NGL database is mirrored onto DesignSafe – Cloud-based analytics

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.

The logo for the Next-Generation Liquefaction (NGL) project, featuring the letters 'NGL' in a large, bold, white font on a blue square background.

NEXT
GENERATION
LIQUEFACTION

Project homepage:

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

Database:

DOI: 10.21222/C2J040

<http://nextgenerationliquefaction.org>

Engineer Change.